OpenML V1.0 Specification
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SECTION

I

INTRODUCTION AND OVERVIEW OF OPENML™

OpenML is a standard, cross-platform interface that supports the creation and playback of digital media (including audio, video and graphics). This specification is not intended to be a programmer's guide. The specification instead strives to accomplish two objectives: provide guidance to developers regarding the functionalities that are important to digital media applications, and define a set of application programming interfaces that are guaranteed to exist in an OpenML environment. Stated more succinctly, the goal of the specification is to provide for developers an interface to which applications should be written.

CHAPTER 1

INTRODUCTION

Motivation

The development of media authoring and playback systems has evolved from early, highly customized, monolithic approaches. Today's systems are assembled from a diverse set of standard components. However while the burden of hardware development has been eased, system-level software problems have been compounded, especially when the system is required to interoperate with other media devices.

There are numerous examples of how the establishment of an industry standard has helped to accelerate market growth and acceptance of new technology. Industry standards exist for many technologies, such as 3D graphics programming APIs, web page programming APIs, network protocols, and high speed bus interfaces.

Standards are defined to establish a common ground for developers looking at a problem from two or more directions. For instance, a standard for 3D graphics programming benefits both 3D graphics application developers and 3D graphics hardware developers by defining a common interface to which both sides can implement. When completed, a 3D graphics application written to this interface will run on any hardware that supports the interface. Conversely, hardware developed to support the interface can support any application written to the standard interface. In a similar manner, both computer manufacturers and peripheral manufacturers benefit from having a common interconnection standard and bus protocol. Finally, end users benefit from standards as the market grows and costs decline.

The members of the Khronos Group SIG believe that a standard is necessary to accelerate the development of both digital media hardware and application software.

Objective of the Specification

This document defines Version 1.0 of the OpenML (Open Media Library) programming environment. An architectural overview is included in order to present a broad overview of the entire OpenML environment and describe how various OpenML components are interrelated and interact with one another. This document also precisely specifies the various programming interfaces that comprise the OpenML programming environment, and it enumerates and defines each of the function calls that comprise those interfaces. It is assumed that implementors will use the API definition sections to properly develop a conforming OpenML implementation, and application programmers will use these sections to determine how to develop OpenML-based multimedia application programs. Some of the intent of the OpenML design team is also communicated through a "recommended practices" section. This section includes topics that are not reflected directly in the design of the APIs themselves, but are presented to provide additional guidance to OpenML implementors and application programmers.

The specification is also intended to be forward looking. No hardware that exists at this moment incorporates all of the functionality contained in Version 1.0 of this specification. However, the specification attempts to provide guidance to hardware developers regarding the design of future generations of multimedia hardware.

The overall goal of this specification is to enable digital media devices to interoperate in an open architecture. In the future it is expected that the specification will be implemented on a wide range of device types from high end workstations for professional content authoring through portable PCs to dedicated playback appliances such as set-top boxes and game devices, as well as on servers dedicated to serving streaming media content.

Scope of the Document

This document is targeted at both programmers and implementors, although, as stated in the overview, it is not meant to serve as a programmer's guide. To the programmer, the API describes a set of commands for creation and playback of complex digital media streams. To the implementor, OpenML describes a conceptual machine which creates, manages, and consumes streams of digital content. OpenML defines only the semantic nature of the conceptual machine, allowing for a wide range of implementations.

Document Organization

The basic layout for this document is as follow:

- Section I provides an overview for all readers.
- Section II contains detailed technical information defining the ML Digital Media I/O API.
- Section III addresses the specifics of OpenGL as they pertain to the OpenML environment.
- Section IV defines the MLdc API for the control of video display devices
- Section V contains the appendix for this document.

CHAPTER

2

BACKGROUND

Goals of the Khronos Group

The goal of the Khronos Group is to develop and manage OpenML, a standard set of open application programming interfaces (APIs) for media content creation and playback.

It is the intent of the Khronos Group to:

- Foster a cross-platform, cross-OS development environment. The group will drive open standards between platform, hardware, and application vendors to enable a seamless interoperability to customers for transparent migration of content creation and playback across a variety of platforms and devices.
- Enable integration and synchronization of video, audio and 2D/3D graphics to deliver compelling content through media-rich interactive applications.
- Enable hardware and software providers to produce a larger number of standardized, transportable, and compelling media products to be brought to market in a more timely fashion. This in turn will foster user acceptance and market growth with customers benefiting from a larger selection of systems, applications, and peripherals to choose from.
- Establish synergy to multi-purpose and re-purpose content for a variety of distribution mediums such as broadcast and the Internet.
- Build on the strengths of OpenGL® and work with the OpenGL Architecture Review Board to strengthen OpenGL.

The Application Space

In developing a cross-platform programming environment for capturing, transporting, processing, displaying and synchronizing digital media, there are certain technical goals to be considered:

- The standard must provide support for audio, video, 2D graphics and 3D graphics at the lowest level that provides the desired functionality and unification (i.e., the thinnest possible layer on top of the hardware).
- The standard must support a range of operating environments, from embedded systems to high-end workstations.
- Existing standards should be utilized wherever possible.

- At a minimum, comparable functionality must exist across operating environments, but the desirable case is to support the exact same API across multiple environments.
- Conformance and performance tests need to be developed to not only certify implementations, but to allow for comparison as well.

Although there are certainly many target application spaces for OpenML, it is expected that the first implementations will be in the desktop and workstation environments.

Feature List

The OpenML environment provides many powerful features to the programmer, among them:

- support for asynchronous communication between an application and media devices such as video input, audio output, and graphics
- synchronization primitives that give applications the ability to correlate multiple digital media streams and coordinate their presentation to an end user
- processing capabilities (transcoders) for digital media streams
- device control and device capability queries
- buffering mechanisms that support the smooth delivery of digital media and obtain the best possible performance on a given system
- reading and writing of interlaced video images
- control of video back-end features
- direct OpenGL support for video pixel formats such as CbYCr
- extended texturing functionality in support of compositing

OS Invariance

OpenML is intended to be a cross-platform standard environment for the creation and display of digital content. However, due to the often substantial differences between various OS environments, it is inevitable that OpenML implementations will vary from one OS environment to another.

It is intended that, to the extent possible, the OpenML programming environment is syntactically and semantically identical between various OS environments. Where it is not possible to make the environment identical, OpenML defines APIs that are semantically identical. Thus, applications can count on the same functionality being present in all OS environments, even though some function calls may not have the exact same syntax.

OpenML is not meant to be a pixel-exact specification. Thus, there is no guarantee of an exact match between images that are produced by different OpenML implementations. Aside from external events, a conforming OpenML implementation shall produce the same results on the same machine each time a specific set of commands is given from the same initial conditions.

Operating Environment	Window System	Window System 'Glue'	2D Graphics	3D Graphics	Audio, Video I/O	Digital Media Transcoding	Display Control
Windows	Windows	wgl	OpenGL/Win32	OpenGL	ML	ML	MLdc
Linux/Unix	X11	GLX	OpenGL/X11	OpenGL	ML	ML	MLdc

Table 2.1 The Current OpenML Programming Environment

As a programmer or implementor surveys the landscape of the target OS and system, there are various segmentations within the system itself to consider. For instance, are there separate 2D and 3D APIs? What are the given capabilities of those systems? And in the ultimate goal of producing an OpenML compliant application, what API is used to influence those separate pieces of the system? Table 2.1 represents our answers to this question based on implementations of OpenML that we expect to become available. It strives to show a clear picture of which APIs are utilized in specific portions of the target environment. It is expected that in the future the OpenML programming environment will be available on additional target operating systems.

CHAPTER

3

ARCHITECTURAL OVERVIEW

The OpenML programming environment provides standard APIs for dealing with video, graphics, and audio and it is expected that the standard OpenML APIs will be supported on major operating environments, including Microsoft Windows*, Linux*, and UNIX*.

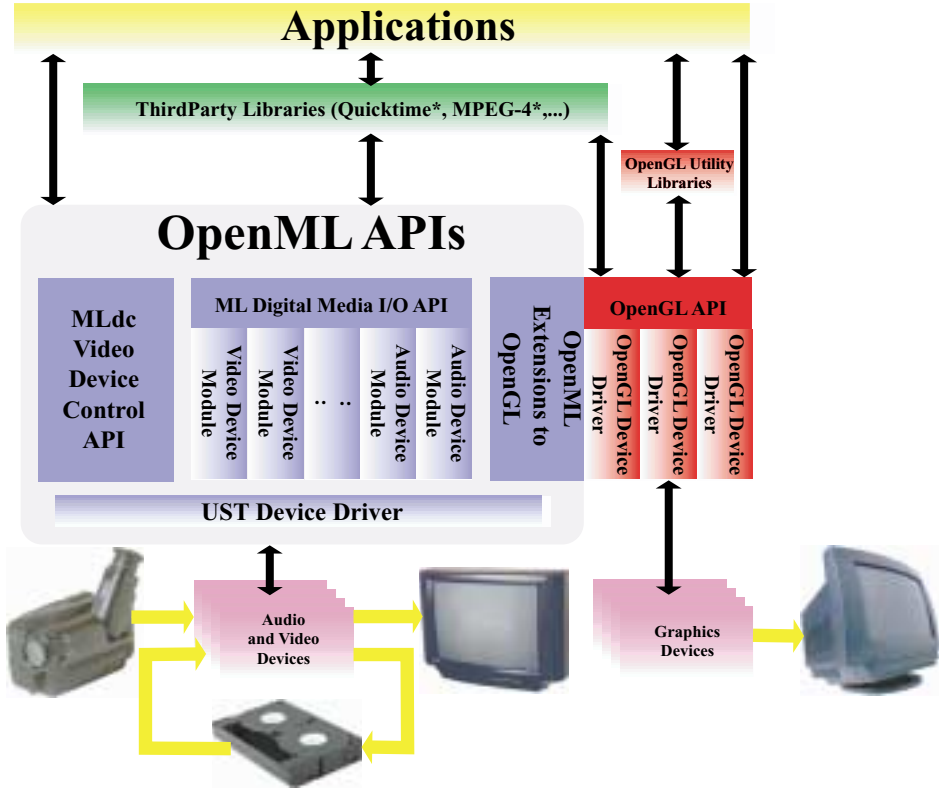


Figure 3.1 The OpenML Programming Environment

Figure 3.1 is a pictorial representation of the OpenML environment from a programmer's perspective. It identifies the major components of the OpenML environment.

The three main APIs available in the OpenML environment are OpenGL, ML, and MLdc. OpenGL is the natural choice for a cross-platform standard for 3D graphics because it is a mature API that is supported on every major operating system.

ML is an API that fills the need for a cross-platform standard dealing with media input, output, and device control. ML and OpenGL communicate with each other through shared buffers in system memory. It is the intention of the Khronos Group that future versions of OpenML will support communication between ML and OpenGL at the device control level in order to efficiently utilize system resources, and to achieve maximum performance and throughput, particularly for devices which integrate video and graphics.

MLdc is an application programming interface meant to control the display of video streams in a system. It provides application developers with a portable and powerful API to control system display devices that may not be available through the native windowing environment. The display may be a desktop screen or another device such as a special studio monitor. The native windowing system may or may not possess knowledge of the display device controlled by MLdc. Parameters controlled through MLdc include refresh rate, pixel resolution, external synchronization (genlock), and gamma correction lookup tables.

Synchronizing Audio, Video and Graphics

OpenML also defines facilities that provide precise timing and synchronization information. The Unadjusted System Time or UST is a high-resolution, 64-bit, monotonically increasing counter that is available throughout the system. In addition, each media channel in the OpenML environment maintains a Media Stream Counter or MSC that is incremented at the sampling rate of the channel. Thus the MSC of a video channel is incremented at the frame rate of the corresponding device. The MSC of a graphics accelerator is incremented for each vertical retrace on the device. By using UST/MSC pairs, an application can accurately control and synchronize media streams between different devices in the system.

In addition, each OpenGL device maintains a per-window Swap Buffer Counter (SBC) that is incremented at each buffer swap on the corresponding window. UST, MSC and SBC values are available to applications through the ML API and through extensions to OpenGL.

ML Features

ML is a new API based on dmSDK* 2.0 from SGI. It represents the culmination of several generations of API development aimed at supporting digital media in a hardware and OS-independent fashion. ML is a low-level API in the same sense that OpenGL is considered a low-level API; it exposes the capabilities of the underlying hardware in a way that imposes little policy. Policy decisions can be made by higher-level software such as utility libraries or toolkits, or left up to the application itself.

The primary functions of ML are to:

- Support asynchronous communication between an application and media devices such as video input, audio output, and graphics.
- Provide synchronization primitives that give applications the ability to correlate multiple digital media streams and coordinate their presentation to an end user.
- Provide processing capabilities (transcoders) for digital media streams.
- Provide device control and device capability queries.
- Provide buffering mechanisms that support the smooth delivery of digital media and obtain the best possible performance on a given system.

An underlying paradigm of ML is the concept of a path, which is a directed connection between a device and a buffer, or between two (2) devices. A path may operate on data as it is moved from the source to destination.

In OpenML 1.0, a buffer is a user-allocated and managed region of system memory. It is the intent of the Khronos Group that, in future versions of OpenML, such buffers may be located in the local memory of a video/graphics combination device. This will allow video frames to be streamed directly to or from OpenGL where they can be used as textures or otherwise operated on (for example to perform transcoding operations). Using video images as texture images in OpenGL is the basis for the implementation of the compositing operations common to digital content creation and playback.

Figure 3.2 is a simplified representation of the possible data flow paths in the OpenML environment.

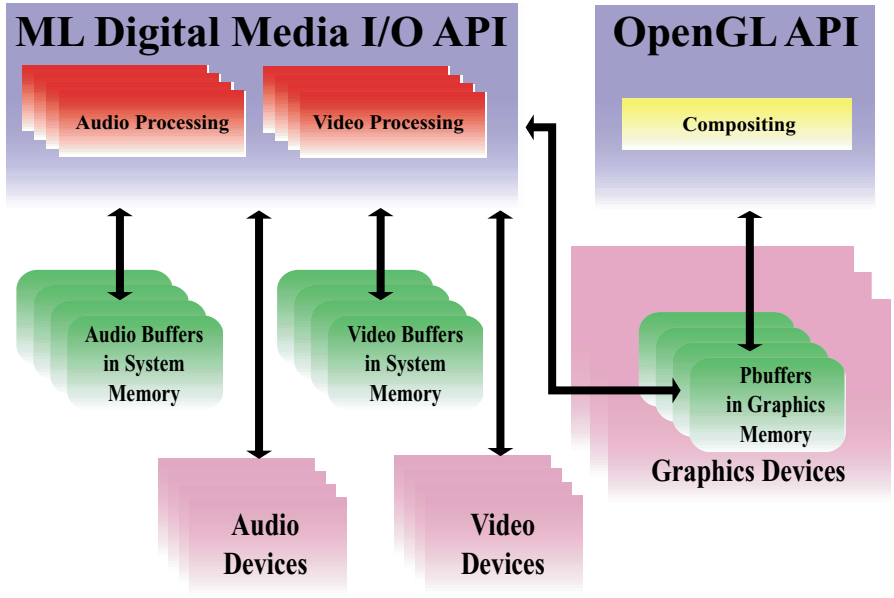


Figure 3.2 Data Flow in the OpenML Environment

OpenGL Features

OpenGL is known as an API with a rich and robust set of features for 3D graphics programming. OpenGL also has an extensive set of capabilities for dealing with pixel data (images), both on their way into and out of the frame buffer and textures. OpenGL has achieved a level of standardization and popularity that no other 3D graphics API has ever achieved. This makes it a natural choice as the API that provides graphics and access to the frame buffer. OpenML compliance requires support of OpenGL 1.2. OpenML compliance also requires the OpenGL 1.2 Imaging Subset.

OpenGL has a well-defined extension mechanism that has led to the definition of more than 200 unique extensions. Some of these extensions were developed to address the needs of multimedia application developers. The existing OpenGL extensions that address the needs of digital media creation have been evaluated for their applicability to the OpenML environment. Certain of these extensions are a required part of an OpenML-compliant environment. In addition, as part of OpenML V1.0, the Khronos Group has developed new OpenGL extensions to strengthen OpenGL's rendering and video integration capabilities. This set of extensions is an integral part of OpenML and is required as part of an OpenML compliant content authoring implementation.

The list of OpenGL extensions required for OpenML V1.0 content authoring provides:

- synchronization using UST/MSC/SBC information
- reading and writing of interlaced video images
- direct support for video pixel formats such as CbYCr
- asynchronous behavior for certain OpenGL operations

Video Back-end Device Control

MLdc is an API that allows applications to control the video back-end of graphics devices. It is based on Xdc, an extension to the X Window System designed by SGI. MLdc is a platform-independent API that can be used to obtain information about the monitor, set gamma correction tables, provide genlock notification, load video formats, set video output gain, set pedestal, and change H-phase (horizontal genlock phase).

The Future

OpenML is intended for use in a range of application scenarios, from professional content authoring through playback on desktops, in set-top boxes, and even in such devices as PDAs. We believe that all of these domains require similar functionality but with different performance profiles. For example, professional content authoring typically requires substantial bandwidth, the ability to composite several layers in real time, and hardware support for full scene anti-aliasing, among other requirements. Playback usually involves only modest bandwidth utilization, compositing of just one or two layers and simple rendering primitives but may require sophisticated full scene anti-aliasing so that the image will look acceptable on a very small display.

The Khronos Group is looking at ways to create small-footprint APIs to bring dynamic media capabilities to a wide variety of appliances and embedded devices. Efforts will focus on producing API profiles to meet the requirements of a range of market segments such as safety-critical automotive and avionics displays, handheld and line-powered appliances and rich-media devices such as advanced digital TVs, set top boxes and game consoles. Embedded applications typically have strong requirements for a few key graphics capabilities. For instance, the smaller screens that will be typical of handheld devices demand high-quality anti-aliasing for text and graphics.

Finally, the Khronos Group intends to develop both conformance tests and performance benchmarks. Conformance tests will allow implementors to demonstrate compliance with the OpenML specification. The benchmarks will be designed to provide performance information for a variety of application profiles.

SECTION

II

DIGITAL MEDIA INPUT/OUTPUT PROGRAMMING

Description

This section provides an overview of the OpenML Media Library (ML) as well as detailed descriptions of its structure, components and capabilities. The Application Programming Interface (API) is also presented. The section is composed of the following chapters:

- Chapter 4: “Overview of ML.”

A global look at ML and how its various parts fit together. The concepts pertaining to Systems, Devices, Jacks, Paths and Transcoders (Xcoders) are discussed, as well as key components of ML, including the message and buffer queue model.

- Chapter 5: “ML Parameters.”

How parameters are constructed and the various types of parameters are described.

- Chapter 6: “ML Capabilities.”

An important concept of ML is the ability of an application to discover the capabilities of the system, its devices, and those jacks, paths and transcoders attached to the devices (as well as software only transcoders).

- Chapter 7: “ML Video Parameters.”

Video parameters are those that refer to the video signal as it enters or exits via a jack. Video parameters are common to Video Jacks and Video Paths.

- Chapter 8: “ML Image Parameters.”

Image parameters describe how the various parts of an image are represented while in memory. Aspects such as size, color space, and pixel packing are discussed. Image parameters are common to both Video Paths and Video Transcoders.

- Chapter 9: “ML Audio Parameters.”

Audio parameters describe various aspects and components of an audio stream as it exists as a set of audio samples. These include the layout of an Audio Buffer as well as the precision, format, sample rate, etc. Audio parameters are common to Audio Jacks, Audio Paths, and Audio Xcodes.

- Chapter 10: “ML Processing.”

The API functions needed to interact with ML are presented.

- Chapter 11: “Synchronization in ML.”

Another powerful concept in ML is the ability to synchronize simultaneous streams of digital media such as a video and audio stream. This chapter describes the ML synchronization methods.

CHAPTER

4

OVERVIEW OF ML

The OpenML Media Library (ML) provides an application programming interface to the digital media I/O, digital media data conversion, and digital media synchronization facilities in an OpenML programming environment.

Components of ML

ML is based on the following components

- A capability tree of the system's media devices, their parameters, and methods of transforming data.
- Messages, passed between the application and media devices.
- A queuing system for buffering messages, both to and from devices.
- Synchronization for media streams.

An overview of each of these components is given in the sections below, along with some simple examples for controlling and buffering media data.

Capability Tree

A capability tree is a hierarchy of all ML devices in the system, and contains information about each ML device (see Figure 4.1). An application may search a capability tree to find suitable media devices for operations it wishes to perform. Capability trees always have a computer system as their root. The root's descendents are the system's physical media devices. Under the physical devices are logical devices, which are ML's abstraction of media devices: *jacks* as sources and destinations of media data, plus *paths, pipes,* and *transcoders* to move and operate on the data between jacks. Finally, each logical device has a set of parameters that can be used to query and set the device's controls.

Access to a capability tree is via two functions:

mlGetCapabilities returns the capabilities of a particular ML object.

mlPvGetCapabilities returns the capabilities for a parameter on a given device.

The root of the tree for the local system can be found using the name **ML_SYSTEM_LOCALHOST.**

See Chapter 6, ”ML Capabilities” for details on traversing and using the capability tree. The objects in the tree are described in more detail below.

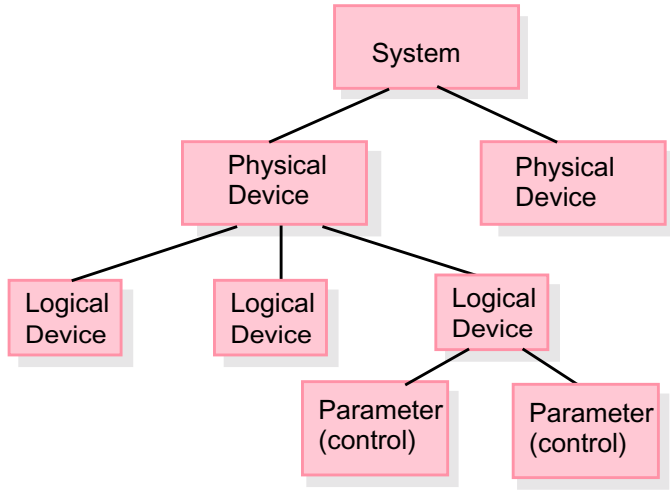


Figure 4.1 Capability Tree Overview

Physical Devices

ML physical devices are exposed by the device-dependent modules provided for the devices in a system. Typically, each device-dependent module supports a set of software transcoders, or a single piece of hardware. Examples of devices are audio cards on a PCI bus, DV camcorders on an IEEE 1394 bus, or software Digital Video (DV) transcoder modules.

It is possible for a single ML physical device to be built from multiple devices as seen by the hardware or operating system. For example, a single graphical display shown on two monitors through two graphics cards could be presented to ML as a single physical device by using an appropriate device-dependent module.

Logical Devices

Logical devices are created by software layered on top of the physical devices. These are the key devices that applications will use to manipulate media data. Typically, a single physical device will be used to expose multiple logical devices. The ML abstractions of jacks, paths, transcoders, and pipes are all logical devices.

Buffers

A buffer is a block of host memory, described by a single virtual address and a length. ML applications do not manipulate media data as a continuous stream, but instead as discrete segments stored in buffers. Buffers don’t appear in the ML capability tree, as they are allocated and managed by the application.

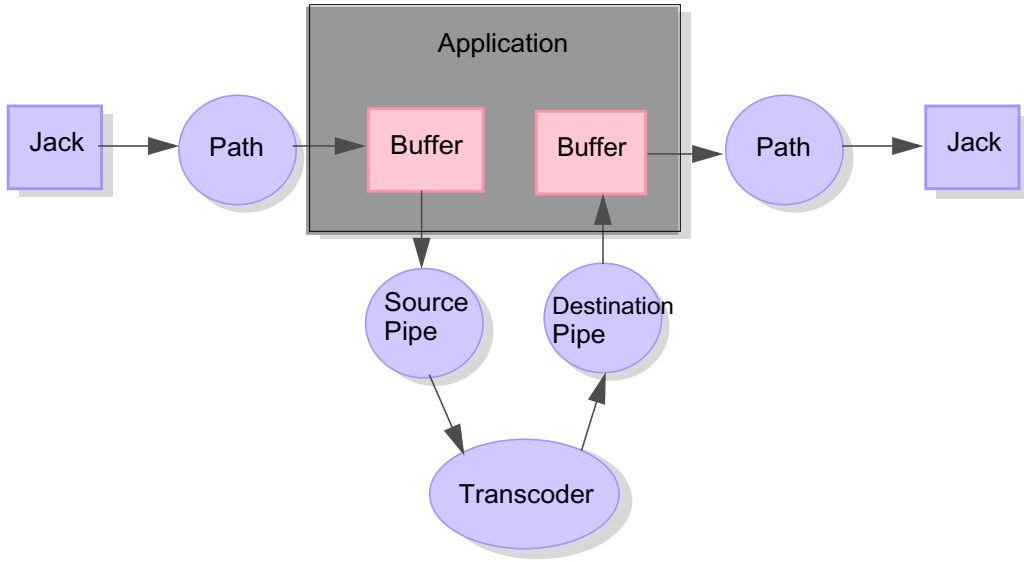


Figure 4.2 Logical Flow of Media Data.

Jacks

A jack is a logical device that represents an input or output interface to the system. Examples of jacks are composite video connectors and microphone jacks. Jacks often, but not always, correspond to a physical connector, and it is possible for a single ML jack to refer to several such connectors. It is also possible for a single physical connector to appear as several logical devices. Jacks have associated controls that are used to filter or otherwise manipulate the signal. Such controls might include contrast, brightness, volume, etc.

Paths

A path is a logical device that provides logical connections between buffers and jacks. For example, a video output path transports data from buffers to a video output jack. A single path can have more than one instance. Depending on the device, it is possible for several instances of a path to be open and in use concurrently. Controls for a path deal with data formats and image quality, including any compression if available.

Transcoders

A transcoder is a logical device that performs an operation on a stream of data. Example transcoders are DV compression, or JPEG decompression. Pipes, described next, are used to provide the input data to the transcoder and deliver the output data from the transcoder.

Pipes

A pipe is a logical device that connects a transcoder to buffers. A source pipe connects a buffer to the input of a transcoder. A destination pipe connects the output of a transcoder to a buffer. Jacks, paths and transcoders are all explicitly opened for use. Pipes, on the other hand, are opened for use as a side effect of opening the transcoder with which they are associated.

Parameters

All devices have a set of parameters that the application can read and possibly modify. These parameters include any controls the device may have. All parameters for all devices are described in the API with the same format. As we'll see in the section on messages, arrays of parameters are built up to form messages.

Messages and Communication

The fundamental unit of communication between application and device is the message. Messages are composed of arrays of parameters, where the last parameter is always **ML_END**. The term “parameter” is used in ML to refer to both the components of a message and the device controls which these components may affect. Parameters may define control values (e.g. the frame rate, or the size of an image) or they may describe the location of data (perhaps a single video frame, or some Vertical Interval Time Code data).

Some simple examples will be used to show how to construct and send a message.

Opening a Jack

Messages can be used to set the controls of a jack. Before sending messages to a jack, a connection must be opened. This is done by calling **mlOpen**. The ID of the object to open is passed in, and an openId is returned as a handle to use when referring to the jack in later calls.

Applications will use **mlSetControls** or **mlGetControls** calls to send messages that manipulate the jack’s controls.

Constructing a Message

A message is an array of parameters. All parameters (or digital media parameters, or MLpv’s) have an identical structure, containing four items:

param

A unique numeric tag identifying the parameter. An example is **ML_IMAGE_WIDTH_INT32**. Bits within the name indicate the type and size of the parameter (including which member of the **value** union to use).

value

The value of the named parameter. This is a union of several basic types, including 64-bit integers, 32-bit integers and pointers to basic types.

length

The number of valid elements in the value array. It is ignored when the value is a scalar (single basic type). If length is set to -1, after a **mlSetControls** or **mlSendControls** call, it indicates the array parameter encountered an error.

maxLength

The maximum number of elements in the value array. It is ignored for scalars. If maxLength is set to 0 on a **mlGetControls** or **mlGetCapabilities** call then the size of the array is returned.

Every piece of information in the ML API is represented in the same, consistent manner. Every message is constructed from MLpv's, every video buffer is described using MLpv's, every control parameter is an MLpv.

Messages are arrays of parameters, where the last parameter is always **ML_END**. For example, the flicker and notch filters can be adjusted with a message such as the following:

```
MLpv message[3];

message[0].param = ML_VIDEO_FLICKER_FILTER_INT32;
message[0].value.int32 = 1;
message[1].param = ML_VIDEO_NOTCH_FILTER_INT32;
message[1].value.int32 = 1;
message[2].param = ML_END;
```

Sending a Message

Here is an example of how the genlock vertical and horizontal phase can be obtained:

```
MLpv message[3];

message[0].param = ML_VIDEO_H_PHASE_INT32;
message[1].param = ML_VIDEO_V_PHASE_INT32;
message[2].param = ML_END;

if (!mlGetControls(aJackConnection, message) )
    handleError();
else
    printf("Horizontal offset is %d, Vertical offset is %d\n",
            message[0].value.int32, message[1].value.int32);
```

mlSetControls and **mlGetControls** are blocking calls: when the call returns, the message has been processed. Note that not all controls may be set via **mlSetControls**. The access privilege in the param capabilities can be used to verify when and how controls can be modified.

Receiving Reply Messages

Some jacks support sending asynchronous messages such as sync lost or acquired. To receive a reply message from a device, use **mlReceiveMessage**. This routine returns back to the application with the oldest unread message sent from the device. More detail about managing the flow of the messages from a device is given in the Queue Model section.

Closing a Jack

When an application has finished using a jack it may close it with **mlClose.** All controls previously set by this application normally remain in effect though they may be modified by other applications.

Out-of-Band and In-Band Messages

ML supports two types of communication between application and device. The simpler mechanism is based on *out-of-band* delivery and receipt of messages. The term “out-of-band” is borrowed from communications. These messages are sent using **mlSetControls** and **mlGetControls** as in the example above. Calls to send out-of-band messages block until the message has been processed. Out-of-band messages are only used for setting and inquiring the control state of a device, as in the above example.

In-band messages are queued and non-blocking. Thus, calls to send them typically return before the message has been processed. In-band messages are mostly used to send buffers to logical devices, using **mlSendBuffers**. Such buffers may contain data to be output to the device or may serve as a repository for data that the device receives. Like out-of-band messages, in-band messages can also be used to set the control state of a device using **mlSendControls**. Messages sent from a device to the application will be received by calling **mlReceiveMessage**.

Out-of-band messages are not buffered or enqueued and are treated as higher priority than messages that have been buffered or queued up.

Queue Model

Because a typical system has unpredictable latencies due to interrupts and context switches for multi-tasking, a buffering mechanism is needed to ensure the continuous flow of data through a jack. In ML, queues of messages serve this purpose. Queues provide delivery of in-band, buffered messages between an application and a logical device. The queue model is designed to minimize the effects of latency as well as provide an abstraction between the producer and consumer of buffers. Care is taken to ensure that the ownership of messages and buffers is well defined.

Two queues are used to connect an application with a logical device. The *send queue* is used for messages going from the application to the device, and the *receive queue* is used for messages going from the device to the application.

Queuing Messages

Four areas of memory are allocated and managed by ML to handle queued messages. The *payload* area keeps copies of messages sent by the application, two queues of *headers* point to the messages, and an *exception* area stores exceptional event messages sent asynchronously from a device. The application has control over the sizes of these areas, but otherwise they are maintained by ML.

When an in-band message is sent to a logical device, a copy of the message is placed in the payload area and a small header is placed on the send header queue for eventual processing by a device.

The bulk of media data itself is not contained within a message, but within buffers, which messages can point to. Buffers are not copied to the payload when a message is sent.

Sending an in-band message eventually results in the logical device sending a reply back to the application, using the receive header queue.

All of the messages sent to a queue observe a strictly ordered relationship. All messages on a send queue are processed by the associated device in the order in which they are enqueued. Each message is completely processed before the processing of the next message begins, and if message A is sent before message B, then the reply to A must arrive before the reply to B.

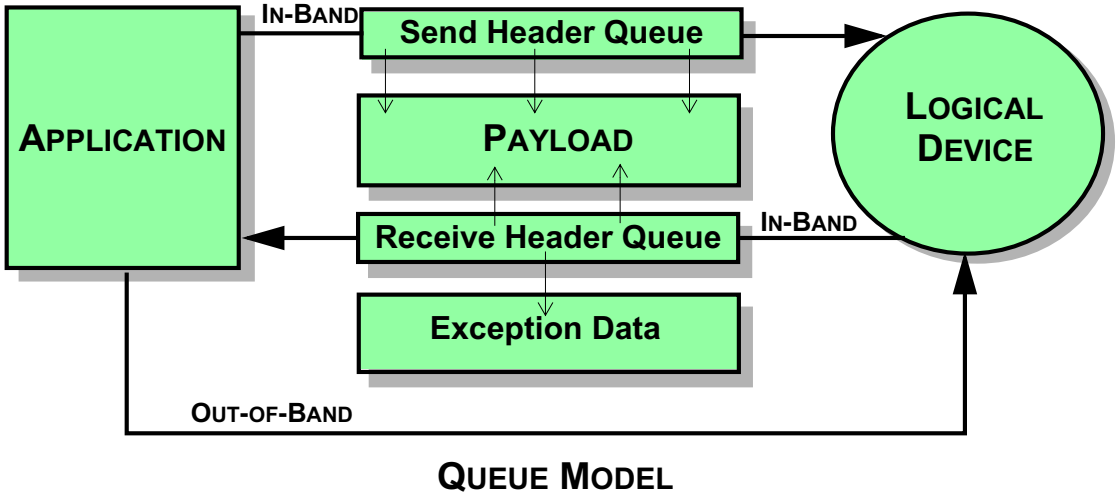


Figure 4.3 Queue Model

Path Example

ML is concerned with three types of interfaces: Jacks for control of external adjustments, Paths for audio and video through jacks in or out of the machine, and Pipes to or from transcoders. All share common control, buffer, and queuing mechanisms. In this section these mechanisms are described in the context of operating on a jack and its associated path. In subsequent sections, the application of these mechanisms to transcoders and pipes is discussed.

Paths for audio and video through jacks in or out of the machine deal with the transfer of data; usually accompanied by some processing. For example, extensive controls are available to adjust the size of images as well as the packing, colorspace, and encoding of the individual pixels. Images may be inverted to accommodate special hardware or placed inside of other images.

Opening a Logical Path

Before sending messages to a device, a connection to some processing path through the device must be opened. This is done by calling **mlOpen,** which will return an openId for future use. A path is a logical device; a physical device (e.g. a PCI card) may simultaneously support several such paths. A side effect of opening a path is that space is allocated for the send and receive header queues for messages between the application and the path.

Sending In-Band Messages

Out-of-band messages are appropriate for simple control changes, but they provide no buffering between the application and the device. For most applications, processing real-time data will require using a queuing communication model. ML supports this with the **mlSendControls**, **mlSendBuffers** and **mlReceiveMessage** calls.

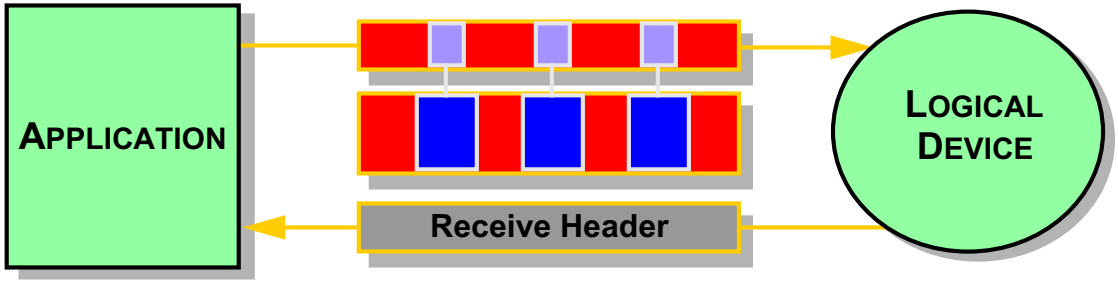


Figure 4.4 Sending In-Band Messages

For example, a controls message is sent to a device send queue using **mlSendControls**:

MLstatus **mlSendControls**(MLopenid *openId*, MLpv* *message*);

Devices interpret messages in the order in which they are enqueued. Because of this, the time relationship is explicit between, for example, video buffers and changes in video modes. Note that the **Send** calls, **mlSendControls** and **mlSendBuffers**, do not wait for a device to process the message. Rather, they copy the message to the device send queue and then return. A primary difference between **mlSendControls** and **mlSendBuffers** is that control processing may be deferred until a buffer is enqueued. This allows a device driver to optimize its access to the send queue, and to also collapse differing control settings to single values. For this reason, reply messages might not be generated for a set of **mlSendControls** until the next **mlSendBuffers** is enqueued. On start-up the application should avoid completely filling the send queue with controls such that a buffer can not be enqueued.

When an application successfully sends a message, it is copied into the payload area and a small header is placed on the send header queue.

Sometimes there is not enough space in the payload or send queue for a new message. In that case, the return code indicates that the message was not enqueued. As a rule, a full send queue is not a problem -- it simply indicates that the application is generating messages faster than the device can process them.

Processing In-Band Messages

A device processes a message as follows:

1. remove the message header from the send header queue,
2. process the message and write any response into the payload area,
3. place a reply header on the receive header queue.

The application must allow space in the message for any reply that it expects the device to return. Notice that the device performs no memory allocation, but rather uses the memory allocated when the application enqueued the message. This is important because it guarantees there will never be any need for the device to block because it didn't have enough space for the reply.

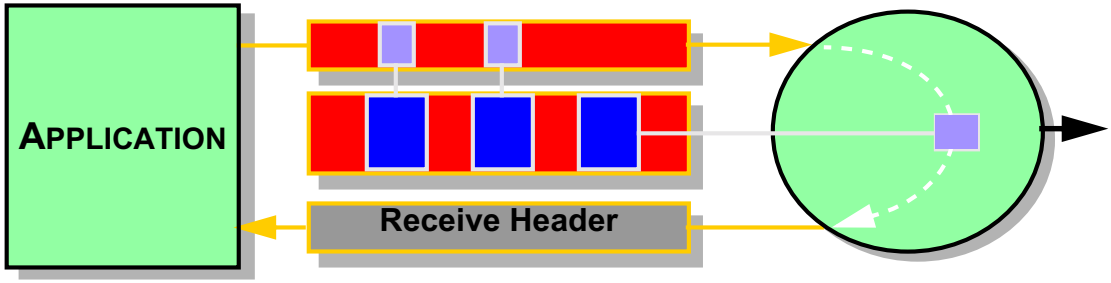


Figure 4.5 Processing In-Band Messages

Receiving In-Band Reply Messages

Each message sent successfully is guaranteed to result in at least one reply message from the device. The reply messages can be used to determine when the sent message was interpreted and what the result was.

- The reply message for an **mlSendControls** indicates the success of the control, and should be checked by the application to ensure that the control executed correctly.
- The reply message for an **mlSendBuffers** call indicates that the device has completed the request. The application is then free to reuse the buffer.

In addition to these reply messages, some devices can send messages to advise the application of important events (for example some video devices can notify the application of every vertical retrace). However, it is guaranteed that no such notification messages will be generated until the application explicitly asks for them.

To receive a reply message from a device, an application calls **mlReceiveMessage**:

MLstatus mlReceiveMessage(MLopenid *openId***, MLint32*** *messageType***, MLpv**** *reply***);**

This routine returns the oldest unread message sent from the device back to an application. The *messageType* parameter indicates why this reply was generated. It could result from a call to **mlSendControls** or **mlSendBuffers**, or it could have been generated spontaneously by the device as the result of an event. The reply pointer is guaranteed to remain valid until an application attempts to receive a subsequent message. This allows the application to overwrite a value in a reply message and then send that as a new message.

The application must read its receive queue frequently enough to prevent the device from running out of space for messages which it was asked to enqueue.

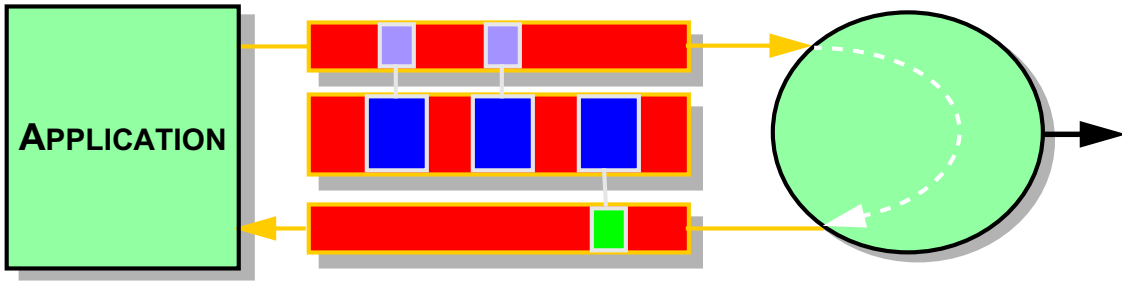


Figure 4.6 Receiving Reply Messages

Processing Exceptional Events

In some cases an exceptional event occurs which requires that the device pass a message back to the application. Examples of such events include **ML_EVENT_VIDEO_SYNC_LOST** or **ML_EVENT_VIDEO_VERTICAL_RETRACE**. The application must explicitly ask for such events.

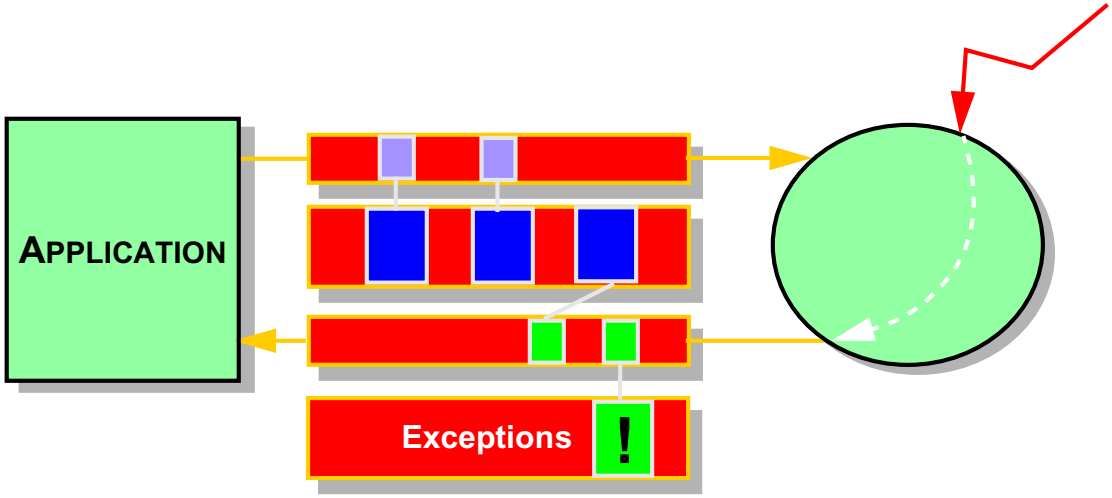


Figure 4.7 Processing Exceptional Events

Here's an example of how to request video sequence loss and vertical retrace events in a message:

```
MLpv message[2];
MLint32 myEvents[2];

myEvents[0] = ML_EVENT_VIDEO_SEQUENCE_LOST;
myEvents[1] = ML_EVENT_VIDEO_VERTICAL_RETRACE;
message[0].param = ML_DEVICE_EVENTS_INT32_ARRAY;
message[0].value.pInt32 = myEvents;
message[0].length = sizeof(myEvents)/sizeof(MLint32);
message[0].maxLength=sizeof(myEvents)/sizeof(MLint32);
message[1].param = ML_END;

mlSetControls( someOpenPath, message);
```

If the application does ask for exceptional events, it must read its receive queue frequently enough to prevent the device from running out of space for messages which it is asked to enqueue. If the queue starts to fill up, then the device will enqueue an event message advising that it is stopping notification of exceptional events.

The device never needs to allocate space in the payload area for reply messages. It will automatically stop sending notifications of events if the receive queue starts to fill up. Space is reserved in the receive queue for a reply to every message the application enqueues. If there is insufficient payload space, then any attempt by the application to send new messages will fail.

Beginning Transfers

On both paths and pipes, messages containing buffers are treated in a special way. The very first call to **mlSendBuffers** will cause the device send queue to stall. That message, and subsequent messages, will not be processed until an application issues an **mlBeginTransfer** call.

MLstatus mlBeginTransfer(MLopenid *openId***);**

This call frees the device to begin processing messages containing buffers. It also commands the device to begin generating exceptional events. Typically, an application will open a device, enqueue several buffers (priming the send queue) and then call **mlBeginTransfe**r. In this way, the application avoids the underflow which could otherwise occur if the application were swapped out immediately after enqueuing the first buffer to the device.

Closing a Logical Path

When an application has finished using a device it may close it with **mlClose**.

MLstatus mlClose(MLopenid *openId***);**

This causes an implicit **mlEndTransfer** on the specified device. It then frees any resources consumed by the device. To process all pending messages prior to closing a device, an application may uniquely identify a message, perhaps by adding a piece of userdata (See "User Parameters" on page 35.) or remembering its MSC number (See "Synchronization in ML" on page 93.) as the last message that it expects to enqueue. When that message appears on the receive queue, all messages have been processed and the application may close the device.

Pipes and Transcoders

An ML transcoder device is composed of:

- a transcoder *engine* that performs the actual processing
- a number of source pipes and destination pipes

The engine takes data from buffers in the source pipes, processes the data, and stores the results in buffers in the destination pipes. Each pipe acts much like a path: source pipes provide a way for the application to send buffers containing data to be processed, and destination pipes provide a way to send empty buffers to hold the results of the processing.

Finding a Suitable Transcoder

mlGetCapabilities is used to obtain details of all transcoders on the system. The selected transcoder ID is then used as the *objectid* parameter to **mlOpen**. A side effect of opening a transcoder is that it creates any required source and destination pipes. The opened transcoder *openId* is a logical entity. A single physical device may support several transcoders simultaneously.

Controlling the Transcoder

The transcoder engine is controlled indirectly by using controls on the source and destination pipes:

- controls on the source pipe describe what an application will be sending the transcoder for input.
- controls on the destination pipe describe the desired output format.

The difference between the source and destination controls dictates what operations the transcoder should perform.

For example, if the **ML_IMAGE_CODING_INT32** is **ML_CODING_UNCOMPRESSED** on the source and **ML_CODING_DVCPRO_50** on the destination, then an application is requesting the transcoder to**:**

- take uncompressed data from the source pipe
- apply a DVCPRO_50 compression
- write the results to the destination pipe.

To set controls on a transcoder, a controls message is constructed just as for a path. The only difference is that an application must explicitly direct controls to a particular pipe. This is achieved using the **ML_SELECT_ID_INT64** parameter, which directs all following controls to a particular ID (in this case, the ID of a pipe on the transcoder).

For example, here is a code fragment to set image width and height on both the source and destinations pipes:

```
MLpv msg[7];

msg[0].param = ML_SELECT_ID_INT64;
msg[0].value.int64 = ML_XCODE_SRC_PIPE;
msg[1].param = ML_IMAGE_WIDTH_INT32;
msg[1].value.int32 = 1920;
msg[2].param = ML_IMAGE_HEIGHT_INT32;
msg[2].value.int32 = 1080;
msg[3].param = ML_SELECT_ID_INT64;
msg[3].value.int64 = ML_XCODE_DST_PIPE;
msg[4].param = ML_IMAGE_WIDTH_INT32;
msg[4].value.int32 = 1920;
```

```
msg[5].param = ML_IMAGE_HEIGHT_INT32;
msg[5].value.int32 = 1280;
msg[6].param = ML_END;

mlSetControls(someOpenXcode, msg);
```

Sending Buffers

Once the controls on a pipe have been set, an application may begin to send buffers to it for processing. Do this with the **mlSendBuffers** call.

MLstatus mlSendBuffers(MLopenid *openId*, **MLpv*** *buffers*);

Call **mlSendBuffers** once for all the buffers corresponding to a single instant in time. For example, if the transcoder expects both an image buffer and an audio buffer, an application must send both in a single **mlSendBuffers** call.

For example, here is a code fragment to send a source buffer to the source pipe, and a destination buffer to the destination pipe:

```
MLpv msg[5];

msg[0].param = ML_SELECT_ID_INT64;
msg[0].value.int64 = ML_XCODE_SRC_PIPE;
msg[1].param = ML_IMAGE_BUFFER_POINTER;
msg[1].value.pByte = srcBuffer;
msg[1].length = srcImageSize;
msg[2].param = ML_SELECT_ID_INT64;
msg[2].value.int64 = ML_XCODE_DST_PIPE;
msg[3].param = ML_IMAGE_BUFFER_POINTER;
msg[3].value.pByte = dstBuffer;
msg[3].maxLength = dstImageSize;
msg[4].param = ML_END;

mlSendBuffer(someOpenXcode, msg);
```

Starting a Transfer

The **mlSendBuffers** call places buffer messages on a pipe queue to the device. An application must then call **mlBeginTransfer** to tell the transcoder engine to start processing messages. The **mlBeginTransfer** call may fail if the source and destination pipe settings are inconsistent.

Changing Controls During a Transfer

During a transfer, an application could attempt to change controls by using **mlSetControls**, but this is often undesirable since the effect of the control change on buffers currently being processed is undefined. A better method is to send control changes in the same queue as the buffer messages. This is performed with the same **mlSendControls** call as on a path, again using **ML_SELECT_ID** to direct particular controls to a particular pipe.

Note that parameter changes sent with **mlSendControls** are guaranteed to only affect buffers sent with subsequent send calls.

Note also that some hardware transcoders may be unable to accommodate control changes during a transfer. If in doubt, examine the capabilities of a particular parameter to determine if it may be changed while a transfer is in progress.

Receiving a Reply Message

Whenever an application passes buffer pointers to the transcoder (by calling **mlSendBuffers**) the application gives up all rights to that memory until the transcoder has finished using it. As the transcoder finishes processing each buffer's message, it will enqueue a reply message back to the application. An application may read these reply messages in exactly the same way as on a path by calling **mlReceiveMessage**.

The transcoder queue maintains a strict first-in, first-out ordering. If buffer A is sent before buffer B, then the reply to A will come before the reply to B. This is guaranteed even on transcoders which parallelize across multiple physical processors.

By examining the reply to each message, an application can determine whether or not it was successfully processed.

Transcoder Work Functions

In most cases, the difference between hardware and software transcoders is transparent to an application. Software transcoders may have more options and may run more slowly, but for many applications these differences are not significant.

One notable difference between hardware and software transcoders is that software transcoders will attempt to use as much of the available processor time as possible. This may be undesirable for some applications. To counter this, an application has the option to do the work of the transcoder itself, in its own thread. This is achieved with the **mlXcodeWork** function.

MLstatus mlXcodeWork(MLopenid *openId***);**

If a software transcoder is opened with the **ML_XCODE_MODE_SYNCHRONOUS** option, the transcoder will not spawn any threads and will not do any processing on its own. To perform a unit of transcoding work, the application must now call the **mlXcodeWork** function.

Multi-Stream Transcoders

This chapter has described the operation of a single-stream transcoder (one in which all controls/buffers can be sent to the transcoder engine using the **ML_SELECT_ID** parameter). Some transcoders, however, particularly those which need to consume source and destination buffers at different rates, will not work efficiently with this programming model. For those cases, it is possible to access each transcoder pipe individually, sending/receiving buffers on the source pipe at a different rate than on the destination pipe. It is expected that this capability will be supported in a future revision of OpenML.

Ending Transfers

To stop a transfer, call **mlEndTransfer**.

MLstatus mlEndTransfer(MLopenid *openId***);**

This causes the device to flush its send queue, to stop processing messages containing buffers, and to stop notification of exceptional events.

It is also acceptable to call **mlEndTransfer** before **mlBeginTransfer** has been called. In that case any messages in the queue are aborted and returned to the application. If an application is not interested in the

result of any pending buffers, the application can simply close the transcoder without bothering to first end the transfer.

Closing a Transcoder

An application calls **mlClose** when it has finished using a transcoder. This causes an implicit call to **mlEndTransfer**. **mlClose** then frees any resources used by the device.

Synchronization

Normal operating system methods of synchronization fail when multiple streams of media must stay “in sync” with each other. Each stream, as has been described in this chapter, is broken into a set of buffers and put into a queue to avoid the large (and unpredictable) processing delays that frequently occur on non-real time operating systems. However, a new problem is introduced by now having multiple independent queues of buffers that need to be synchronized.

To solve this problem, ML provides feedback to the application about when each buffer actually started passing through its jack. By looking at the returned time-stamps, the application can see how much two streams of buffers are drifting from each other, relative to how far apart they should be. It can then make any corrections, for example skipping a video frame, to reduce the drift.

ML models this time-stamp feedback after the existing media industry practice of using a global *UST*, or Unadjusted System Time, and a per-device *MSC*, or Media Stream Count.

See Chapter 11, ”Synchronization in ML” for the specification of the ML UST and MSC architecture.

CHAPTER

5

ML PARAMETERS

This chapter describes the semantics of ML parameters. These parameters may define control values (the frame rate, or the width of an image) or they may describe the location of data (perhaps a single video field). Applications communicate with digital media devices by passing arrays of param/value pairs.

Param/Value Pairs

The fundamental building block of ML is the *param*/*value* pair, also referred to as a *parameter*. The *param* of the param/value pair is a unique identifier that determines the usage of the parameter and is used by ML to interpret the *value* component. The C-language binding of the param/value pair is the **MLpv** structure:

```
typedef struct __MLpv{
    MLint64     param;
    typedef union {
        MLbyte      byte;           /* 8-bit unsigned byte value */
        MLint32     int32;          /* 32-bit signed integer value */
        MLint64     int64;          /* 64-bit signed integer value */
        MLreal32    real32          /* 32-bit floating point value */
        MLreal64    real64;         /* 64-bit floating point value */
        MLbyte*     pByte;          /* pointer to an array of bytes */
        MLint32*    pInt32;         /* pointer to an array of 32-bit signed integer values */
        MLint64*    pInt64;         /* pointer to an array of 64-bit signed integer values */
        MLreal32*   pReal32;        /* pointer to an array of 32-bit floating point values */
        MLreal64*   pReal64;        /* pointer to an array of 64-bit floating point values */
        struct __MLpv*  pPv;        /* pointer to a message of param/value pairs */
        struct __MLpv** ppPv;       /* pointer to an array of messages */
    }   MLvalue     value;
    MLint32     length;
    MLint32     maxLength;
} MLpv;
```

The **param** of **MLpv** is a unique 64-bit numeric tag. The **value**, **length** and **maxLength** components comprise the remainder of the param/value pair. The **value** is a union of several possible types.

Every **param** has a type that determines how ML will interpret the **value** of a param/value pair. Bits within the name indicate the type and size of the parameter (including which member of the **value** union to use).

The following table shows the correspondence between **param** type and **value** interpretation:

param type	**value** interpretation
ML_TYPE_BYTE	**byte**
ML_TYPE_INT32	**int32**
ML_TYPE_INT64	**int64**
ML_TYPE_REAL32	**real32**
ML_TYPE_REAL64	**real64**
ML_TYPE_BYTE_POINTER **ML_TYPE_BYTE_ARRAY**	**pByte**
ML_TYPE_INT32_POINTER **ML_TYPE_INT32_ARRAY**	**pInt32**
ML_TYPE_INT64_POINTER **ML_TYPE_INT64_ARRAY**	**pInt64**
ML_TYPE_REAL32_POINTER **ML_TYPE_REAL32_ARRAY**	**pReal32**
ML_TYPE_REAL64_POINTER **ML_TYPE_REAL64_ARRAY**	**pReal64**
ML_TYPE_MSG	**pPv**
ML_TYPE_MSG_ARRAY	**ppPv**

Table 5.1 Correspondence Between **param** Type and **value** Interpretation

Similarly, each parameter has an ID of the form ML_*parameterID_type* where the *type* suffix is one of **INT32, INT64, REAL32, REAL64, BYTE_POINTER, BYTE_ARRAY, INT32_POINTER, INT32_ARRAY, INT64_POINTER, INT64_ARRAY, REAL32_POINTER, REAL32_ARRAY, REAL64_POINTER, REAL64_ARRAY, MSG** and **MSG_ARRAY.** These suffixes indicate the same **value** interpretation as shown in the preceding table.

ML is described in terms of *capabilities* (sometimes referred to as *capability lists*) and *messages*. Capabilities and messages have different uses but each is realized as a list of param/value pairs, terminated with an **ML_END** param/value pair. The C-language implementation of such a list is as an array of param/value pairs.

Applications obtain the *capabilities* of an ML object by querying the capabilities tree (discussed in the next chapter).

Applications communicate with ML devices by sending *messages*. Such messages contain param/value pairs that are used to set or query the state of a device. Messages can also be used to deliver buffers of data to a device.

For example, the image width can be set to 720 and the image height to 486 using a message such as the following:

```
MLpv message[3];

message[0].param = ML_IMAGE_WIDTH_INT32;
message[0].value.int32 = 720;
message[1].param = ML_IMAGE_HEIGHT_INT32;
message[1].value.int32 = 486;
```

```
message[2].param = ML_END;
```

Scalar Parameters

Some parameters take only a scalar value, for example a single integer or floating point number. Such scalar values are placed directly in the **value** component of **MLpv**. For such parameters, the **length** and **maxLength** components are ignored except that on return (**mlReceiveMessage**) a length parameter that equals -1 indicates that this parameter was in error. For example, the following code fragment shows how a parameter might be initialized for use in setting video timing:

```
MLpv message[2];

message[0].param = ML_VIDEO_TIMING_INT32;
message[0].value.int32 = ML_TIMING_525;
message[1].param = ML_END;
```

If in the message returned, message[0].length == -1, it indicates that the device does not support a timing of 525 for that jack, path, or xcode.

To obtain the value of a scalar parameter, the application needs only to initialize the **param** component. The following code fragment shows how a parameter might be initialized for use in querying video timing:

```
MLpv message[2];

message[0].param = ML_VIDEO_TIMING_INT32;
message[1].param = ML_END;
```

Array Parameters

Some ML parameters have a value that is an array. In such a case, the **value** component of the MLpv is a pointer to the first element of the array, the **length** component is the number of valid elements in the array, and the **maxLength** component is the total length of the array. In general, an application sets the **length** component when setting an array parameter, and specifies the **maxLength** component when getting an array parameter. In this latter case, ML sets the **length** component to the number of valid elements returned.

To set the value of an array parameter, the application fills out the **param**, **value**, **maxLength** and **length** fields. The returned **length** will be unaltered if the values are valid. An error status will be returned and **length** will be set to -1 if the values are invalid or if the parameter is not recognized at all by the device.

During the execution of a routine that passes an array parameter to ML (e.g. **mlSetControl, mlSendControl)**, ML makes a copy of the contents of the parameter including the array data. Thus the application is free to modify or delete an array except during the execution of such a routine.

The following code fragment shows how a parameter might be initialized for use in setting a look-up table:

```
MLreal64 data[] = { 0, 0.2, 0.4, 0.6, 1.0};
MLpv message[2];

message[0].param = ML_PATH_LUT_REAL64_ARRAY;
message[0].value.pReal64 = data;
message[0].length = sizeof(data)/sizeof(MLreal64);
message[1].param = ML_END;
```

The following code fragment shows how a parameter might be initialized for use in getting a look-up table:

```
MLint32 data[10];
MLpv message[2];

message[0].param = ML_PATH_LUT_INT32_ARRAY;
message[0].value.pInt32 = data;
message[0].length = 0;
message[0].maxLength = 10;
message[1].param = ML_END;
```

ML will return at most **maxLength** array elements and will set **length** to the number of elements returned. In this same case, if the application sets **maxLength** to 0, ML will change **maxLength** to the minimal array length needed to contain the array parameter. No data is transferred in this case.

Pointer Parameters

A pointer parameter is a special type of array parameter that is used to send and receive data buffers (as arrays of bytes). The application sends a buffer by calling **mlSendBuffer**. **mlSendBuffer** places the controls and buffer pointer in the data payload area and inserts a header on the send queue for the device. After the device processes the buffer, it places the reply on the receive queue. Because a data buffer can be arbitrarily large, ML does not copy the buffer contents to the payload area.

This method of enqueuing buffers imposes an additional restriction on pointer parameters: after giving a pointer parameter to a device, the application may not touch the memory pointed to until the device has finished processing it.

The following code fragment shows how a pointer parameter might be initialized to send a buffer to a video input path for receiving data:

```
MLpv message[2];

message[0].param = ML_IMAGE_BUFFER_POINTER;
message[0].value.pByte = someBuffer;
message[0].length = 0;
message[0].maxLength = sizeof(someBuffer);
message[1].param = ML_END;
```

Similarly, the following code fragment shows how a pointer parameter might be initialized to send an image buffer to a video output path:

```
MLpv message[2];

message[0].param = ML_IMAGE_BUFFER_POINTER;
message[0].value.pByte = someBuffer;
message[0].length = sizeof(someBuffer);
message[1].param = ML_END;
```

User Parameters

The user parameter is a facility to allow the definition of unique user parameters. These parameters may be useful for example in communicating information in a message from one thread to another. A user parameter might also be used by an application to mark a location in a sequence of messages submitted to some send queue. The parameter **ML_VIDEO_ASC_INT64** is an example of a pre-defined user parameter. The **ML_USERDATA_DEFINED** macro is provided to construct a parameter name from the type specification and an index value. The following code fragment shows how unique user parameters might be defined for a special set of module controls:

```
enum UniqueControls {
    UNIQUE_CONTROL_1 = ML_USERDATA_DEFINED(ML_TYPE_INT32, 1);
    UNIQUE_CONTROL_2 = ML_USERDATA_DEFINED(ML_TYPE_INT64, 2);
};
```

The **ML_USERDATA_DEFINED** macro defines the parameter with the type and index value supplied (“1” and “2” in the above example), but it adds a “base value” to prevent conflicts with internally defined USER parameters.

CHAPTER

6

ML CAPABILITIES

This chapter describes the ML capabilities tree, the repository of information on all installed ML devices. The capabilities tree forms a hierarchy that describes the installed ML devices in the following order from top to bottom:

1. physical system
2. physical devices
3. logical devices
4. supported parameters on the logical devices

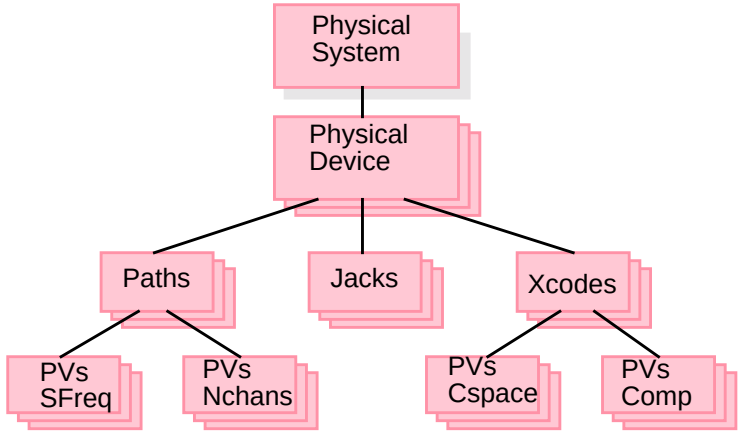


Figure 6.1 The Capabilities Tree

All ML objects and parameter types have identification numbers (IDs). There are three types of ID numbers in ML.

Constant IDs have defined names and may be hard-coded in an application. They are system-independent. Examples of constant IDs are **ML_SYSTEM_LOCALHOST**, and **ML_IMAGE_WIDTH_INT32.**

Static IDs are allocated by the ML system as new hardware is added. They are machine-dependent and may change after reboot.The static ID of a device may change if it is removed from the system and then reconnected

Examples of static IDs are the physical and logical device IDs returned in calls to **mlGetCapabilities**. If an application needs to share such information between machines, the application should use the text names (system-independent) that correspond to the static IDs.

Open IDs are allocated when logical devices are opened. They are machine-dependent, and have a limited lifetime -- from when **mlOpen** is called until **mlClose** is called.

Accessing Capabilities

Each ML object has an associated set of capabilities. These capabilities are represented as a list of param/value pairs. The set of capabilities is object dependent and device dependent. The order of param/value pairs within a list of capabilities is undefined, but a list is always terminated by an **ML_END** entry.

Access to ML capabilities is via several functions:

Function Call	Description
mlGetCapabilities	returns the capabilities for an ML object
mlPvFind	finds a parameter in a capabilities list
mlPvGetCapabilities	returns the capabilities for a parameter on a given device
mlFreeCapabilities	releases a set of capability descriptions

All objects in ML are referred to via 64-bit identifying numbers. For example, the 64-bit ID number for the system on which the application is running is **ML_SYSTEM_LOCALHOST .**

The capabilities of all ML objects are obtained using:

MLstatus mlGetCapabilities(MLint64 *objectId***, MLpv**** *capabilities***);**

objectId is the 64-bit identifier for the object whose capabilities are being queried. The status **ML_STATUS_INVALID_ID** is returned if *objectId* is invalid. On return, *capabilities* is the pointer to the head of the resulting capabilities list. This list should be treated as read-only by the application. The status **ML_STATUS_INVALID_ARGUMENT** is returned if the capabilities pointer *capabilities* is invalid. If the call was successful, then **ML_STATUS_NO_ERROR** is returned.

Capabilities are queried in a hierarchical fashion. The capabilities of a physical system are queried using an ID to identify the system. The resulting capabilities list will include ID numbers for all physical devices on the system. **mlGetCapabilities** is called with a physical device ID to obtain the ID's for all its logical devices. Logical devices include paths, jacks and transcoders. **mlGetCapabilities** is called with a logical device ID to obtain its capabilities.

mlGetCapabilities may be called with either a static object identifier, obtained from a previous call to **mlGetCapabilities**, or an open ID, obtained from a call to **mlOpen**. Querying the capabilities of an opened object is identical to querying the capabilities of the corresponding static object.

The following sections describe the capabilities of each type of ML object. The capabilities are not necessarily in the order shown. In these tables, the string in the Parameter column is a shortened form of the full parameter name. The full parameter name is of the form **ML**_*parameter_type*, where *parameter* and *type* are the strings listed in the Parameter and Type columns respectively. For example, the full name of **ID** is **ML_ID_INT64**.

System Capabilities

Currently, the only defined physical system ID is **ML_SYSTEM_LOCALHOST**. When a system ID is queried, the resulting capabilities list contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this system
NAME	**BYTE_ARRAY**	NULL-terminated ASCII string containing the hostname for this system.
SYSTEM_DEVICE_IDS	**INT64_ARRAY**	Array of physical device IDs (these need not be sorted or sequential). For more details on a particular device ID call mlGetCapabilities. This array could be of length zero.

Table 6.1 System Capabilities

Physical Device Capabilities

The capabilities list for a physical device contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this physical device.
NAME	**BYTE_ARRAY**	NULL-terminated ASCII description of this physical device (e.g. “HD Video I/O” or "AVC/1394").
PARENT_ID	**INT64**	Resource ID for the system to which this physical device is attached.
DEVICE_VERSION	**INT32**	Version number for this particular physical device.
DEVICE_INDEX	**BYTE_ARRAY**	Index string for this physical device. This is used to distinguish multiple identical physical devices - indexes are generated with a consistent algorithm - identical machine configurations will have identical indexes - e.g. plugging a particular card into the first 64-bit, 66MHz PCI slot in any system will give the same index number. Uniquely identifying a device in a system-independent way requires using both the name and index.
DEVICE_LOCATION	**BYTE_ARRAY**	Physical hardware location of this physical device (on most platforms this is the hardware graph entry). Makes it possible to distinguish between two devices on the same i/o bus, and two devices each with its own i/o bus.
DEVICE_JACK_IDS	**INT64_ARRAY**	Array of jack IDs. For more details on a particular jack ID call **mlGetCapabilities**. This array could be of length zero.
DEVICE_PATH_IDS	**INT64_ARRAY**	Array of path IDs. For more details on a particular path ID call **mlGetCapabilities**. This array could be of length zero.

Table 6.2 Physical Device Capabilities

Parameter	Type	Description
DEVICE_XCODE_IDS	**INT64_ARRAY**	Array of transcoder device IDs. For more details on a particular transcoder ID call **mlGetCapabilities**. This array could be of length zero.

Table 6.2 Physical Device Capabilities

Jack Logical Device Capabilities

The capabilities list for a jack logical device contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this jack
NAME	**BYTE_ARRAY**	NULL-terminated ASCII description of this jack (e.g. “Purple S-video").
PARENT_ID	**INT64**	Resource ID for the physical device to which this jack is attached.
JACK_TYPE	**INT32**	Type of logical jack. Possible values are: **ML_JACK_TYPE_AUDIO** **ML_JACK_TYPE_VIDEO** **ML_JACK_TYPE_COMPOSITE** **ML_JACK_TYPE_SVIDEO** **ML_JACK_TYPE_SDI** **ML_JACK_TYPE_DUALLINK** **ML_JACK_TYPE_GENLOCK** **ML_JACK_TYPE_GPI** **ML_JACK_TYPE_SERIAL** **ML_JACK_TYPE_ANALOG_AUDIO** **ML_JACK_TYPE_AES** **ML_JACK_TYPE_GFX** **ML_JACK_TYPE_AUX** **ML_JACK_TYPE_ADAT** Where: AUDIO is a generic audio jack, VIDEO is a generic video jack, COMPOSITE is a composite video jack, SVIDEO is an S-video jack, SDI is a Serial Digital Interface jack, DUALLINK is an SDI dual link jack, GENLOCK is a genlock jack, GPI is a General Purpose Interface jack, SERIAL is a generic serial control jack, ANALOG_AUDIO is an analog audio jack, AES is a digital AES standard jack, GFX is a digital graphics jack, AUX is a generic auxiliary jack, and ADAT is a digital ADAT standard jack.

Table 6.3 Jack Logical Device Capabilities

Parameter	Type	Description
JACK_DIRECTION	**INT32**	Direction of data flow through this jack. May be: **ML_JACK_DIRECTION_IN** **ML_JACK_DIRECTION_OUT** Where: IN is an input jack with data for memory and OUT is an output jack with data from memory.
JACK_COMPONENT_SIZE	**INT32**	Maximum number of bits of resolution per component for the signal through this jack. Stored as an integer, so 8 means 8 bits of resolution.
JACK_PATH_IDS	**INT64_ARRAY**	Array of path IDs which may use this jack. For more details on a particular path ID call **mlGetCapabilities**. This array could be of length zero.
PARAM_IDS	**INT64_ARRAY**	List of resource IDs for parameters which may be set and/or queried on this jack.
OPEN_OPTION_IDS	**INT64_ARRAY**	List of resource IDs for option parameters which may be used when this jack is opened.
JACK_FEATURES	**BYTE_ARRAY**	Double-NULL terminated list of ASCII feature strings. Each string represents a specific feature supported by this jack. Entries are separated by NULL characters (there are 2 NULLs after the last string).

Table 6.3 Jack Logical Device Capabilities

Path Logical Device Capabilities

The capabilities list for a path logical device contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this path.
NAME	**BYTE_ARRAY**	NULL-terminated ASCII description of this path (e.g., "Memory to S-video Out").
PARENT_ID	**INT64**	Resource ID for the physical device on which this path resides.
PARAM_IDS	**INT64_ARRAY**	List of resource IDs for parameters which may be set and/or queried on this path.
OPEN_OPTION_IDS	**INT64_ARRAY**	List of resource IDs for option parameters which may be used when this path is opened.
PRESET	**MSG_ARRAY**	Each entry in the array is a message pointer (a pointer to the head of an MLpv list, where the last entry in the list is **ML_END**). Each message provides a single valid combination of all setable parameters on this path. In particular, it should be possible to call **mlSetControls** using any of the entries in this array as the control's message. Each path is required to provide at least one preset.

Table 6.4 Path Logical Device Capabilities

Parameter	Type	Description
PATH_TYPE	**INT32**	Type of this path: **ML_PATH_TYPE_MEM_TO_DEV** **ML_PATH_TYPE_DEV_TO_MEM** **ML_PATH_TYPE_DEV_TO_DEV** Where: MEM_TO_DEV is a path from memory to a device, DEV_TO_MEM is a path from device to memory and DEV_TO_DEV is a path from device to another device.
PATH_COMPONENT_ALIGNMENT	**INT32**	The location in memory of the first byte of a component (either an audio sample or a video line), must meet this alignment. Stored as an integer in units of bytes.
PATH_BUFFER_ALIGNMENT	**INT32**	The location in memory of the first byte of an audio or video buffer must meet this alignment. Stored as an integer in units of bytes.
PATH_SRC_JACK_ID	**INT64**	Resource ID for the jack which is the source of data for this path (unused if path is of type **ML_PATH_TYPE_MEM_TO_DEV**). For details on the jack ID call **mlGetCapabilities**.
PATH_DST_JACK_ID	**INT64**	Resource ID for the jack which is the destination for data from this path (unused if path is of type **ML_PATH_TYPE_DEV_TO_MEM**). For details on the jack ID call **mlGetCapabilities**.
PATH_FEATURES	**BYTE_ARRAY**	Double-NULL terminated list of ASCII features strings. Each string represents a specific feature supported by this path. Entries are separated by NULL characters (there are 2 NULLs after the last string).

Table 6.4 Path Logical Device Capabilities

Transcoder Logical Device Capabilities

The capabilities list for a transcoder logical device contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this transcoder.
NAME	**BYTE_ARRAY**	NULL-terminated ASCII description of this transcoder (e.g. "Software DV and DV25").
PARENT_ID	**INT64**	Resource ID for the physical device on which this transcoder resides.
PARAM_IDS	**INT64_ARRAY**	List of resource IDs for parameters which may be set and/or queried on this transcoder (May be of length 0).
OPEN_OPTION_IDS	**INT64_ARRAY**	List of resource IDs for option parameters which may be used when this transcoder is opened.

Table 6.5 Transcoder Logical Device Capabilities

Parameter	Type	Description
PRESET	**MSG_ARRAY**	Each entry in the array is a message pointer (a pointer to the head of a MLpv list, where the last entry in the list is **ML_END**). Each message provides a single valid combination of all setable parameters on a transcoder. In particular, it should be possible to call **mlSetControls** using any of the entries in this array as the controls message. Each transcoder is required to provide at least one preset for each transcoder.
XCODE_ENGINE_TYPE	**INT32**	Type of the engine in this transcoder. At this time the only defined engine type is: **ML_XCODE_ENGINE_TYPE_NULL.**
XCODE_IMPLEMENTATION_TYPE	**INT32**	How this transcoder is implemented: **ML_XCODE_IMPLEMENTATION_TYPE_SW** **ML_XCODE_IMPLEMENTATION_TYPE_HW** The implementation of the transcoder could be in either software (SW) or hardware (HW).
XCODE_COMPONENT_ALIGNMENT	**INT32**	The location in memory of the first byte of a component (either an audio sample or a video line), must meet this alignment. Stored as an integer in units of bytes.
XCODE_BUFFER_ALIGNMENT	**INT32**	The location in memory of the first byte of an audio or video buffer must meet this alignment. Stored as an integer in units of bytes.
XCODE_FEATURES	**BYTE_ARRAY**	Double-NULL terminated list of ASCII features strings. Each string represents a specific feature supported by this transcoder. Entries are separated by NULL characters (there are 2 NULLs after the last string).
XCODE_SRC_PIPE_IDS	**INT64_ARRAY**	List of pipe IDs from which the transcode engine may obtain buffers to be processed.
XCODE_DEST_PIPE_IDS	**INT64_ARRAY**	List of pipe IDs from which the transcode engine may obtain buffers to be filled with the result of its processing.

Table 6.5 Transcoder Logical Device Capabilities

Pipe Logical Device Capabilities

The capabilities list for a pipe logical device contains the following parameters:

Parameter	Type	Description
ID	**INT64**	Resource ID for this path.
NAME	**BYTE_ARRAY**	NULL-terminated ASCII description of this pipe (“DV Codec Input Pipe”).
PARENT_ID	**INT64**	Resource ID for the transcoder on which this pipe resides.
PARAM_IDS	**INT64_ARRAY**	List of resource IDs for parameters which may be set and/or queried on this transcoder (May be of length 0).
PIPE_TYPE	**INT32**	Type of this pipe: **ML_PIPE_TYPE_MEM_TO_ENGINE** **ML_PIPE_TYPE_ENGINE_TO_MEM** MEM_TO_ENGINE is the trancoder input pipe with data flow from memory to engine. ENGINE_TO_MEM is the trancoder output pipe with data flow from engine to memory.

Table 6.6 Pipe Logical Device Capabilities

Finding a Parameter in a Capabilities List

A parameter within a message or capabilities list may be found using:

MLpv* mlPvFind(MLpv* *msg*, **MLint64** *param*);

msg points to the first parameter in an **ML_END** terminated array of parameters and *param* is the 64-bit unique identifier of the parameter to be found. **mlPvFind** returns the address of the parameter if successful; otherwise it returns **NULL**.

Obtaining Parameter Capabilities

Details on the interpretation of a particular device dependent parameter are obtained using:

MLstatus mlPvGetCapabilities(MLint64 *objectId*, **MLint64** *parameterId*, **MLpv**** *capabilities*);

objectId is the 64-bit unique identifier for the object whose parameter is being queried. An example is the *openId* returned from a call to **mlOpen**. The status **ML_STATUS_INVALID_ID** is returned if the specified object ID was invalid. *parameterId* is the 64-bit unique identifier for the parameter whose capabilities are being queried. The status **ML_STATUS_INVALID_ARGUMENT** is returned if the capabilities pointer is invalid. *capabilities* is a pointer to the head of the resulting capabilities list. This list should be treated as read-only by the application. If the call was successful, then the status **ML_STATUS_NO_ERROR** is returned.

objectid may be either a static ID (obtained from a previous call to **mlGetCapabilities**) or an open ID (obtained by calling **mlOpen**). Querying the capabilities of an opened object is identical to querying the capabilities of the corresponding static object.

It is also possible to get the capabilities of the capabilities parameters themselves. Those parameters are not tied to any particular object and so the *objectId* should be 0.

The list returned in *capabilities* contains the following parameters, though not necessarily in this order. The string in the Parameter column is a shortened form of the full parameter name. The full parameter name is of the form **ML**_*parameter_type*, where *parameter* and *type* are the strings listed in the Parameter and Type columns respectively. For example, the full name of **ID** is **ML_ID_INT64**.

Parameter	Type	Description
ID	**INT64**	Resource ID for this parameter.
NAME	**BYTE_ARRAY**	NULL-terminated ASCII name of this parameter. This is identical to the enumerated value. For example, if the value is **ML_XXX**, then the name is "**ML_XXX**".
PARENT_ID	**INT64**	Resource ID for the logical device (video path or transcoder pipe) on which this parameter is used.
PARAM_TYPE	**INT32**	Type of this parameter: **ML_TYPE_INT32** **ML_TYPE_INT32_POINTER** **ML_TYPE_INT32_ARRAY** **ML_TYPE_INT64** **ML_TYPE_INT64_POINTER** **ML_TYPE_INT64_ARRAY** **ML_TYPE_REAL32** **ML_TYPE_REAL32_POINTER** **ML_TYPE_REAL32_ARRAY** **ML_TYPE_REAL64** **ML_TYPE_REAL64_POINTER** **ML_TYPE_REAL64_ARRAY** **ML_TYPE_BYTE_POINTER** **ML_TYPE_BYTE_ARRAY**
PARAM_ACCESS	**INT32**	Access control flags that describe when and how this parameter can be used. Bitwise "or" of the following flags: **ML_ACCESS_READ** **ML_ACCESS_WRITE** **ML_ACCESS_PASS_THROUGH** **ML_ACCESS_OPEN_OPTION** **ML_ACCESS_IMMEDIATE** **ML_ACCESS_QUEUED** **ML_ACCESS_SEND_BUFFER** **ML_ACCESS_DURING_TRANSFER** Refer to Chapter 10,"ML Processing" for details.
PARAM_DEFAULT	same type as param	Default value for this parameter, of type indicated by **ML_PARAM_TYPE**. (If the **length** component of this parameter is 0, there is no default).

Table 6.7 Parameters returned by **mlPvGetCapabilities**

Parameter	Type	Description
PARAM_MINS	array of same type as param	Array of minimum values for this parameter (may be missing if there are no specified minimum values). Each set of min/max values defines one allowable range of values. If min equals max then the allowable range is a single value. If the **length** component is one, there is only one legal range of values. The **length** component will be 0 if there are no specified minimum values.
PARAM_MAXS	array of same type as param	Array of maximum values for this parameter . There must be one entry in this array for each entry in the **PARAM_MINS** array.
PARAM_INCREMENT	same type as param	Legal param values go from min to max in steps of increment. The **length** will be 0 if there are no specified minimum values. Otherwise, **length** will be non-zero.
PARAM_ENUM_VALUES	array of same type as param	Array of enumerated values for this parameter. The **length** component will be 0 if there are no enumeration values.
PARAM_ENUM_NAMES	**BYTE_ARRAY**	Array of enumeration names for this parameter (must have the same **length** as the **PARAM_ENUM_VALUES** array). The array is a double-NULL terminated list of ASCII strings. Each string represents a specific enumeration name corresponding to the enumerated value in the same position in the **PARAM_ENUM_VALUES** array. Entries are separated by NULL characters (there are 2 NULLs after the last string).

Table 6.7 Parameters returned by **mlPvGetCapabilities**

Freeing Capabilities Lists

A capabilities list *capabilities* obtained from either **mlGetCapabilities** or **mlPvGetCapabilities** is returned to the system using

MLstatus mlFreeCapabilities(MLpv* *capabilities***);**

The status **ML_STATUS_INVALID_ARGUMENT** is returned if the capabilities pointer is invalid. The **ML_STATUS_NO_ERROR** is returned if the call was successful.

CHAPTER

7

ML VIDEO PARAMETERS

This chapter covers parameters for describing the source of a video input path, or the destination of a video output path.

The complete processing of a video path is described by three sets of parameters. For input or output paths: video parameters on jacks are generally used to adjust external hardware processing of the video signal, video parameters on paths describe how to interpret or generate the signal as it arrives or leaves, and image parameters describe how to write or read the resulting bits to or from memory. [1]

Each of the subsections in this chapter is devoted to a single video parameter. The subsection describes which aspect of the video jack or input or output path the parameter controls, as well as the accepted values of the parameter.

Not all parameters may be supported on a particular video jack or path. Note that some parameters may be adjusted on both a path and a jack, or may be adjustable on just one or the other. Use **mlGetCapabilities** to obtain a list of parameters supported by a jack or path. In addition, not all values may be supported on a particular parameter. Use **mlPvGetCapabilities** to obtain a list of the values supported by the parameter.

For information on image parameters see the chapter “ML Image Parameters”.

Video Jack and Path Control Parameters

The jack and path control parameters are set immediately in a call to **mlSetControls**, queried immediately using **mlGetControls**, or sent on a path (only) in a call to **mlSendControls**. Once set, video controls for a jack are persistent while those controls on a path that describe data transfer persist for at least the life of the path. Typically, an application will set several controls in a single message before beginning to process any buffers.

ML_VIDEO_TIMING_INT32

Sets or queries the timing on an input or output video path. Not all timings may be supported on all devices. On devices which can auto-detect, the timing may be read-only on input. In this case **ML_PARAM_ACCESS** is **ML_ACCESS_READ**. (Details of supported timings may be obtained by calling **mlPvGetCapabilites** on this parameter).

1.This chapter, as well as the chapter “ML Image Parameters” assumes a working knowledge of digital video concepts. For a more thorough explanation, readers may wish to consult a text devoted to this subject. A good resource is *A Technical Introduction to Digital Video*, by Charles Poynton, published by John Wiley & Sons, 1996 (ISBN 0-471-12253-X, hardcover).

Standard definition (SD) timings are:

ML_TIMING_525 (NTSC)

ML_TIMING_525_SQ_PIX

ML_TIMING_625 (PAL)

ML_TIMING_625_SQ_PIX

High definition (HD) timings are:

ML_TIMING_1125_1920x1080_60p

ML_TIMING_1125_1920x1080_5994p

ML_TIMING_1125_1920x1080_50p

ML_TIMING_1125_1920x1080_60i

ML_TIMING_1125_1920x1080_5994i

ML_TIMING_1125_1920x1080_50i

ML_TIMING_1125_1920x1080_30p

ML_TIMING_1125_1920x1080_2997p

ML_TIMING_1125_1920x1080_25p

ML_TIMING_1125_1920x1080_24p

ML_TIMING_1125_1920x1080_2398p

ML_TIMING_1250_1920x1080_50p

ML_TIMING_1250_1920x1080_50i

ML_TIMING_1125_1920x1035_60i

ML_TIMING_1125_1920x1035_5994i

ML_TIMING_750_1280x720_60p

ML_TIMING_750_1280x720_5994p

ML_TIMING_525_720x483_5994p

ML_TIMING_1125_1920x1080_24PsF

ML_TIMING_1125_1920x1080_2398PsF

ML_TIMING_1125_1920x1080_30PsF

ML_TIMING_1125_1920x1080_2997PsF

ML_TIMING_1125_1920x1080_25PsF

Details of the 601 standard timings are illustrated in Figure 7.1 and Figure 7.2. Details of high definition standard timings are illustrated in Figure 7.3 and Figure 7.4.

Note, all HD timing values follow the naming convention:

ML_TIMING_TotalRasterLines_ActivePixelsWidth**x**ActiveLinesHeight_FieldorFrameRate{**i** | **p** | **PsF**}

where:

i = interlaced frames

p = progressive frames

PsF = Progressive Segmented Frames

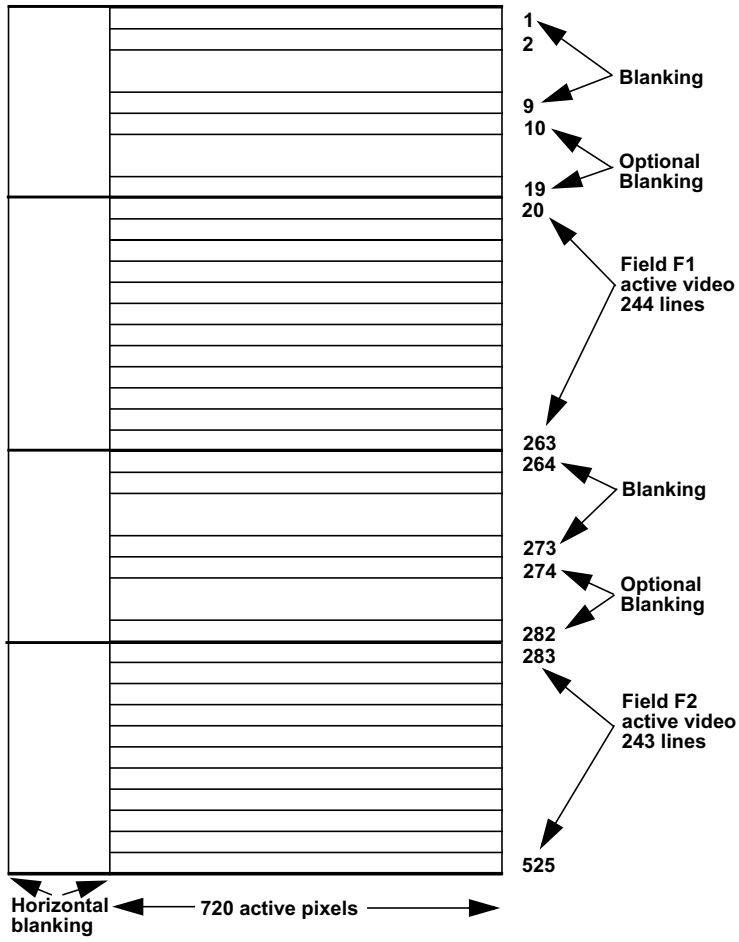


Figure 7.1 525/60 Timing (NTSC)

For more information on 525 and 625 timing systems, see SMPTE 259M Television - 10-Bit 4:2:2 Component and 4fsc Composite Digital Signals - Serial Digital Interface specification.

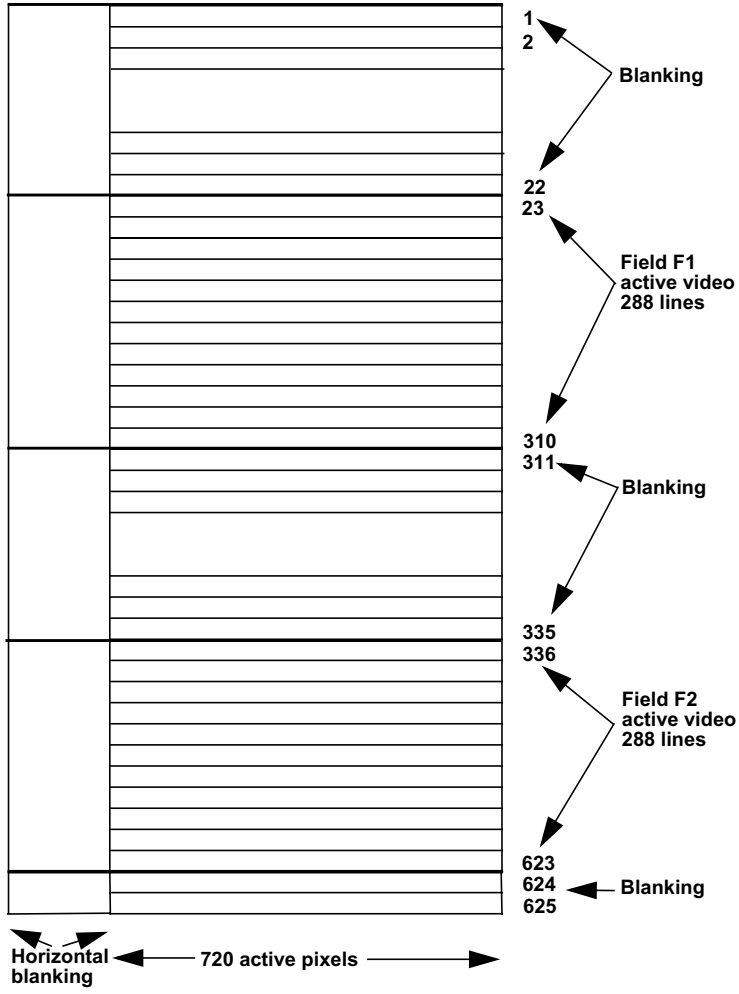


Figure 7.2 625/50 Timing (PAL)

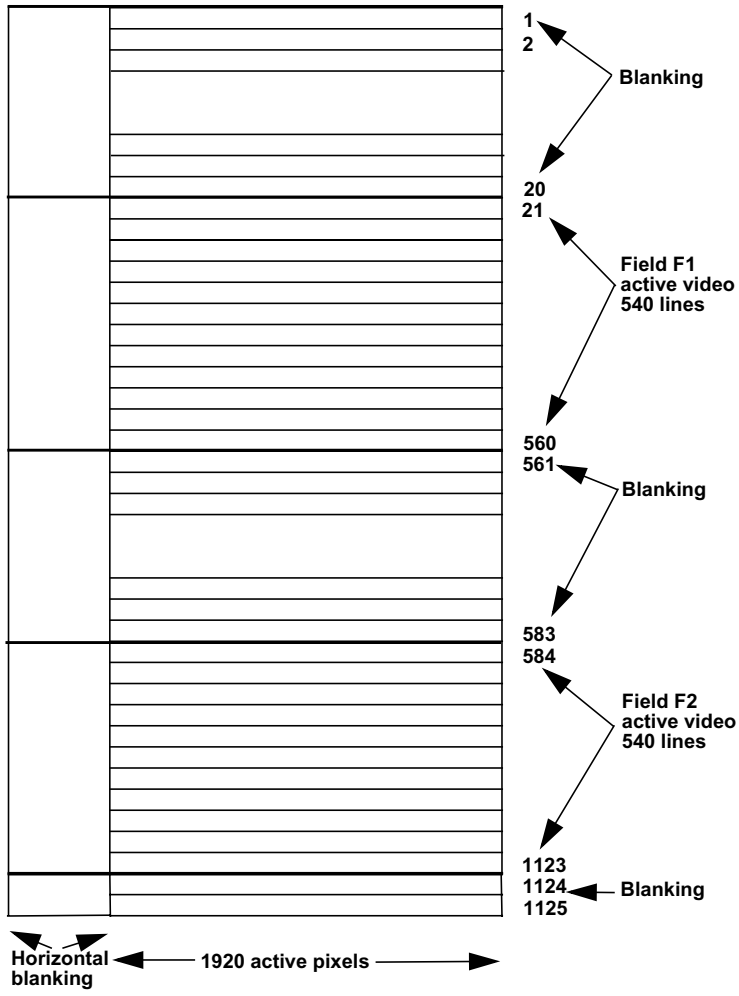


Figure 7.3 1080i Timing (High Definition)

For more information on 1080i timing systems, see SMPTE 274M Television - 1920 x 1080 Scanning and Interface specification.

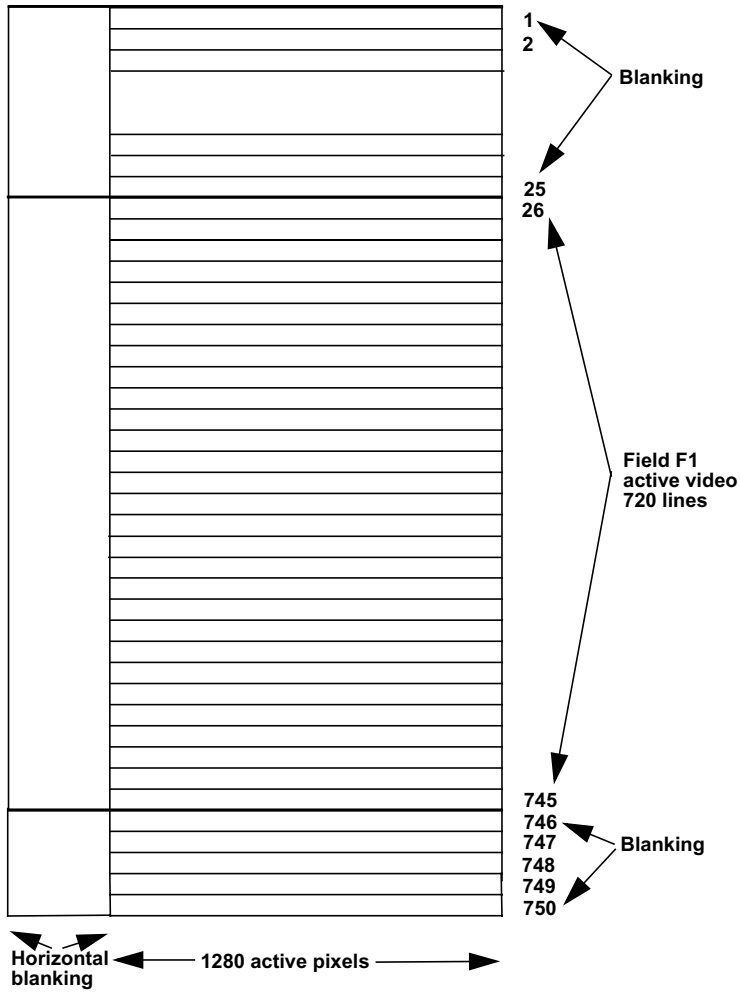


Figure 7.4 720p Timing (High Definition)

For more information on 720p systems, see SMPTE 296M Television - 1280 x 720 Scanning, Analog and Digital Representation and Analog Interface specification.

ML_VIDEO_SAMPLING_INT32

Sets the sampling at the video jack for RGB and CbYCr colorspaces.

For all RGB colorspaces, the legal samplings are:

- **ML_SAMPLING_444** indicates that the R, G and B components are each sampled once per pixel, and only the first 3 channels are used. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4444** indicates that the R, G, B and A components are sampled once per pixel.

For all CbYCr colorspaces, the legal samplings are:

- **ML_SAMPLING_444** indicates that the Cb, Y, and Cr components are each sampled once per pixel and only the first 3 channels are used. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4444** indicates that the Cb, Y, Cr and Alpha components are each sampled once per pixel.
- **ML_SAMPLING_422** indicates that the Y component is sampled once per pixel and the Cb and Cr components are sampled once per pair of pixels. In this case, Cb and Cr are interleaved on the 1st channel (Cb is first, Cr is second), and the Y component occupies the 2nd channel. If used with an image packing that provides space for a 3rd or 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4224** indicates that the Y and Alpha components are sampled once per pixel and the Cb and Cr components are sampled once per pair of pixels. In this case, Cb and Cr are interleaved on the 1st channel (Cb is first, Cr is second), Y is on the second channel, and Alpha is on the 3rd channel. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.

ML_VIDEO_COLORSPACE_INT32

Sets the colorspace at the video jack. For input paths, this is the expected colorspace of the input jack. For output paths, it is the desired colorspace at the output jack. Commonly supported values include:

ML_COLORSPACE_RGB_601_FULL,
ML_COLORSPACE_RGB_601_HEAD,
ML_COLORSPACE_CbYCr_601_FULL,
ML_COLORSPACE_CbYCr_601_HEAD,
ML_COLORSPACE_RGB_240M_FULL,
ML_COLORSPACE_RGB_240M_HEAD,
ML_COLORSPACE_CbYCr_240M_FULL,
ML_COLORSPACE_CbYCr_240M_HEAD,
ML_COLORSPACE_RGB_709_FULL,
ML_COLORSPACE_RGB_709_HEAD,
ML_COLORSPACE_CbYCr_709_FULL,
ML_COLORSPACE_CbYCr_709_HEAD.

For more information on the colorspace parameter see **ML_IMAGE_COLORSPACE_INT32** in the “ML Image Parameters” chapter.

ML_VIDEO_PRECISION_INT32

Sets the precision (number of bits of resolution) of the signal at the jack. A precision value of 10, means a 10-bit signal. A value of 8 means an 8-bit signal.

ML_VIDEO_SIGNAL_PRESENT_INT32

Used to query the incoming signal on an input path. Not all devices may be able to sense timing, but those which do will support this parameter. Common values match those for **ML_VIDEO_TIMING**, with two additions: **ML_TIMING_NONE** (there is no signal present) **ML_TIMING_UNKNOWN** (the timing of the input signal cannot be determined)

ML_VIDEO_GENLOCK_SOURCE_TIMING_INT32

Describes the genlock source timing. Only accepted on output paths. Each genlock source is specified as an output timing on the path and corresponds to the same timings as available with **ML_VIDEO_TIMING_INT32**.

ML_VIDEO_GENLOCK_TYPE _INT32

Describes the genlock signal type. Only accepted on output paths. Each genlock type is specified as either a 32-bit resource ID or **ML_VIDEO_GENLOCK_TYPE_INTERNAL**.

ML_VIDEO_GENLOCK_SIGNAL_PRESENT_INT32

Used to query the incoming genlock signal for an output path. Not all devices may be able to sense genlock timing, but those that do will support this parameter. Common values match those for **ML_VIDEO_TIMING**, with two additions: **ML_TIMING_NONE** (there is no signal present) and **ML_TIMING_UNKNOWN** (the timing of the genlock signal cannot be determined).

ML_VIDEO_BRIGHTNESS_INT32

Set or get the video signal brightness.

ML_VIDEO_CONTRAST_INT32

Set or get the video signal contrast.

ML_VIDEO_HUE_INT32

Set or get the video signal HUE.

ML_VIDEO_SATURATION_INT32

Set or get the video signal color saturation.

ML_VIDEO_RED_SETUP_INT32

Set or get the video signal RED channel setup.

ML_VIDEO_GREEN_SETUP_INT32

Set or get the video signal GREEN channel setup.

ML_VIDEO_BLUE_SETUP_INT32

Set or get the video signal BLUE channel setup.

ML_VIDEO_ALPHA_SETUP_INT32

Set or get the video signal ALPHA channel setup.

ML_VIDEO_H_PHASE_INT32

Set or get the video signal horizontal phase genlock offset.

ML_VIDEO_V_PHASE_INT32

Set or get the video signal vertical phase genlock offset.

ML_VIDEO_FLICKER_FILTER_INT32

Set or get the video signal flicker filter.

ML_VIDEO_DITHER_FILTER_INT32

Set or get the video signal dither filter.

ML_VIDEO_NOTCH_FILTER_INT32

Set or get the video signal notch filter.

ML_VIDEO_OUTPUT_DEFAULT_SIGNAL_INT64

Sets the default signal at the video jack when there is no active output. The only allowable values are:

- **ML_SIGNAL_NOTHING** indicates that output signal shall cease without generation of sync.
- **ML_SIGNAL_BLACK** indicates that output shall generate a black picture complete with legal sync values.
- **ML_SIGNAL_COLORBARS** indicates that output should use an internal colorbar generator.
- **ML_SIGNAL_INPUT_VIDEO** indicates that output should use the default input signal as a pass through.

Video Path Control Parameters

The following video path controls specify the clipping region (the region of the video signal to capture on input, or fill on output). For standard definition video, these numbers are in Rec601 coordinates. For interlaced signals, the two fields may have different heights. For progressive signals, only the values for field 1 are used.

ML_VIDEO_START_X_INT32

Sets the start horizontal location on each line of the video signal.

ML_VIDEO_START_Y_F1_INT32

Sets the start vertical location on F1 fields of the video signal. For progressive signals it specifies the start of every frame.

ML_VIDEO_START_Y_F2_INT32

Sets the start vertical location on F2 fields of the video signal. Ignored for progressive timing signals.

ML_VIDEO_WIDTH_INT32

Sets the horizontal width of the clipping region on each line of the video signal.

ML_VIDEO_HEIGHT_F1_INT32

Sets the vertical height for each F1 field of the video signal. For progressive signals it specifies the height of every frame.

ML_VIDEO_HEIGHT_F2_INT32

Sets the vertical height for each F2 field of the video signal. Ignored for progressive timing signals.

ML_VIDEO_OUTPUT_REPEAT_INT32

If the application is doing output and fails to provide buffers fast enough (the queue to the device underflows), this control determines the device behavior. Allowable options are:

- **ML_VIDEO_REPEAT_NONE** the device does nothing, usually resulting in black output.
- **ML_VIDEO_REPEAT_FIELD** the device repeats the last field. For progressive signals or interleaved formats, this is the same as **ML_VIDEO_REPEAT_FRAME**.
- **ML_VIDEO_REPEAT_FRAME** the device repeats the last two fields.

This output capability is device dependent and the allowable settings should be queried via the get capabilities of the **ML_VIDEO_OUTPUT_REPEAT_INT32** parameter.

On input, any signal outside the clipping region is simply ignored. On output, the following parameters control the generated signal:

ML_VIDEO_FILL_Y_REAL32

The luminance value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value (black), 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_Cr_REAL32

The Cr value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value, 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_Cb_REAL32

The Cb value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value, 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_RED_REAL32

The red value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value (black), 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_GREEN_REAL32

The green value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value, 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_BLUE_REAL32

The blue value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum legal value, 1.0 is the maximum legal value. Default is 0.

ML_VIDEO_FILL_ALPHA_REAL32

The alpha value for any pixel outside the clipping region. This is a real number: a value of 0.0 is the minimum (fully transparent), 1.0 is the maximum (fully opaque). Default is 1.0.

Examples

Here is an example that sets the video timing and colorspace for an HDTV signal:

```
MLpv message[3];

message[0].param = ML_VIDEO_TIMING_INT32;
message[0].value.int32 = ML_TIMING_1125_1920x1080_5994i;
message[1].param = ML_VIDEO_COLORSPACE_INT32;
message[1].value.int32 = ML_COLORSPACE_CbYCr_709_HEAD;
message[2].param = ML_END;

mlSetControls(device, message);
```

CHAPTER

8

ML IMAGE PARAMETERS

This chapter describes in detail the ML image parameters and gives examples of the resulting in-memory pixel formats.

Introduction

An *image buffer* is required for a frame or field of pixels. The memory for image buffers is allocated and managed by the application. Once a buffer has been created, a pointer to the buffer is passed to ML via the parameter **ML_IMAGE_BUFFER_POINTER**. The way ML maps memory bits into colored pixels is uniquely determined by the colorspace, packing, sampling and swap-bytes parameters. The colorspace describes what each component represents, the packing describes how the components are laid out in memory, and the sampling describes how often each component is stored.

Figure 8.1 illustrates a general image buffer layout with its associated image parameters. Figure 8.2 shows the more common simple image buffer layout.

.

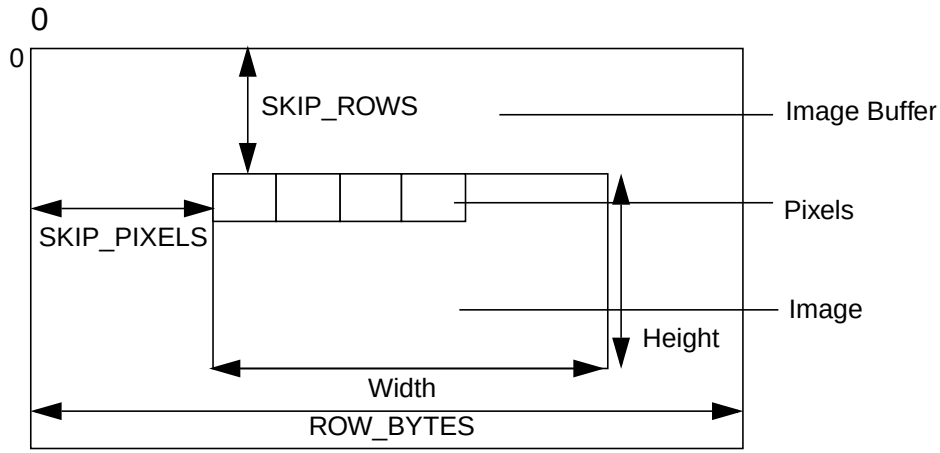


Figure 8.1 General Image Buffer Layout

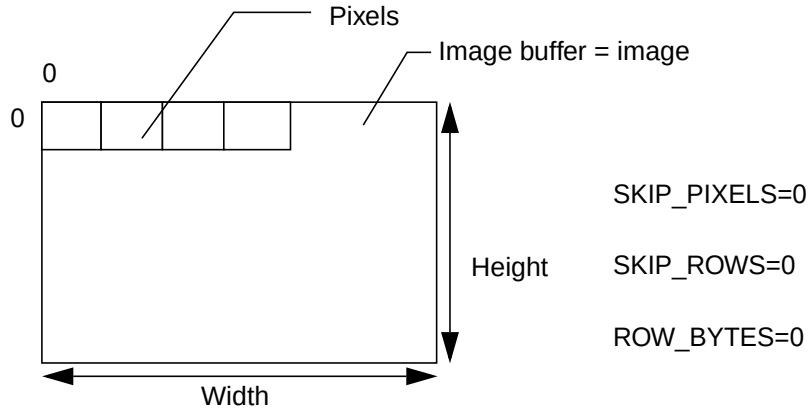


Figure 8.2 A Simple Image Buffer Layout

Image Buffer Parameters

ML_IMAGE_BUFFER_POINTER

Pointer to the first byte of an image buffer in memory. The buffer address must comply with the alignment constraints for buffers on the particular path or transcoder to which it is being sent. See **mlGetCapabilities** for details on determining alignment requirements with **ML_PATH_BUFFER_ALIGNMENT_INT32**. For example if **ML_PATH_BUFFER_ALIGNMENT_INT32** is 8, this means that the value of the buffer pointer must be a multiple of 8 bytes. The same applies to **ML_PATH_COMPONENT_ALIGNMENT_INT32** where the beginning of each line (the first pixel of each line) must be a multiple of the value of the **ML_PATH_COMPONENT_ALIGNMENT_INT32** parameter.

ML_IMAGE_WIDTH_INT32

The width of the image in pixels.

ML_IMAGE_HEIGHT_1_INT32

For progressive or interleaved buffers (depending on parameter **ML_IMAGE_INTERLEAVE_MODE_INT32**), this represents the height of each frame. For interlaced and non-interleaved signals, this represents the height of each F1 field. Measured in pixels.

ML_IMAGE_HEIGHT_2_INT32

The height of each F2 field in an interlaced non-interleaved signal. Otherwise it has value 0.

ML_IMAGE_DOMINANCE_INT32

Sets the dominance of the video signal. Allowable values are **ML_DOMINANCE_F1** and **ML_DOMINANCE_F2**. The default dominance is **ML_DOMINANCE_F1**. Ignored for progressive signals.

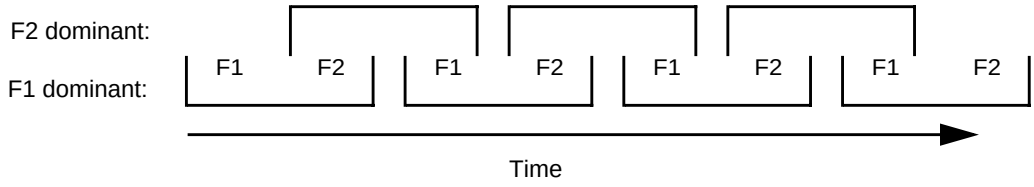


Figure 8.3 Field Dominance

Field dominance defines the order of fields in a frame and can be either F1-dominant or F2-dominant. F1-dominant specifies a frame as an F1 field followed by an F2 field. F2-dominant specifies a frame as an F2 field followed by an F1 field.

ML_IMAGE_ROW_BYTES_INT32

Only used for the general image buffer layout. The number of bytes along one row of the image buffer. If this value is 0, each row is exactly **ML_IMAGE_WIDTH_INT32** pixels wide. Default is 0.

Note that in physical memory there is no notion of two dimensions, the end of the first row continues directly at the beginning of the second row. For interlaced image data the two fields can be stored in two separate image buffers or they can be stored in interleaved form in one image buffer.

ML_IMAGE_SKIP_PIXELS_INT32

Only used for the general image buffer layout. The number of pixels to skip at the start of each row in the image buffer. Default is 0. Must be 0 if **ML_IMAGE_ROW_BYTES_INT32** is 0. Default is 0.

ML_IMAGE_SKIP_ROWS_INT32

Only used for the general image buffer layout. The number of rows to skip at the start of each image buffer. Default is 0.

ML_IMAGE_TEMPORAL_SAMPLING_INT32

Specifies whether the image temporal sampling is progressive or interlaced. May be one of:

- **ML_TEMPORAL_SAMPLING_FIELD_BASED**
- **ML_TEMPORAL_SAMPLING_PROGRESSIVE**

ML_IMAGE_INTERLEAVE_MODE_INT32

Only used for interlaced images. This parameter specifies whether the two fields have been interleaved into a single image (and reside in a single buffer) or are stored in two separate fields (hence in two separate buffers). This is ignored for signals with progressive timing.

- **ML_INTERLEAVED_MODE_INTERLEAVED** the two fields are interleaved into a single image (and reside in a single buffer).
- **ML_INTERLEAVED_MODE_SINGLE_FIELD** the two fields are stored separately and the **ML_IMAGE_HEIGHT_1_INT32** and **ML_IMAGE_HEIGHT_2_INT32** parameters specify the height of the two image buffers (F1 and F2).

ML_IMAGE_ORIENTATION_INT32

The orientation of the image.

- **ML_ORIENTATION_TOP_TO_BOTTOM** “natural video order” pixel [0,0] is at the top left of the image.
- **ML_ORIENTATION_BOTTOM_TO_TOP** “natural graphics order” pixel [0,0] is at the bottom left of the image.

ML_IMAGE_COMPRESSION_INT32

An image can be stored in a buffer in a compressed form, as in the case of the output of a codec. For an image being transferred into a buffer, this parameter controls the type of compression to be applied. For an image being transferred out of a buffer, this parameter describes the compression format of the stored image. Common compression formats are:

ML_COMPRESSION_UNCOMPRESSED
ML_COMPRESSION_BASELINE_JPEG
ML_COMPRESSION_LOSSLESS_JPEG
ML_COMPRESSION_DV_625
ML_COMPRESSION_DV_525
ML_COMPRESSION_DVCPRO_625
ML_COMPRESSION_DVCPRO_525
ML_COMPRESSION_DVCPRO50_625
ML_COMPRESSION_DVCPRO50_525
ML_COMPRESSION_MPEG2
ML_COMPRESSION_UNKNOWN

If the image data is in uncompressed format, the value of this parameter is **ML_COMPRESSION_UNCOMPRESSED**. If a transcoder is unable to determine the type of compression **ML_COMPRESION_UNKNOWN** is returned for **ML_IMAGE_COMRESSION_INT32**.

When an image is compressed, some of the parameters that normally describe the image data (that is, height, width, color space, etc.) may not be meaningful or known. The only parameters that are always known are the compression type, **ML_IMAGE_COMPRESSION_INT32,** and the size of the compressed image, **ML_IMAGE_SIZE_INT32**. Thus the image buffer layout parameters (**ML_IMAGE_SKIP_ROWS**, **ML_IMAGE_SKIP_PIXELS**, and **ML_IMAGE_ROW_BYTES**) typically do not apply to compressed images.

For more information on JPEG compression, refer to W. B. Pennebaker and J. L. Mitchell, *JPEG: Still Image Data Compression Standard*, New York, NY: Van Nostrand Reinhold, 1993.

For more information on DV compression, refer to *Specification of Consumer-Use Digital VCRs using 6.3mm magnetic tape*, HD Digitial VCR Conference, December 1990.

For more information on DVCPRO and DVCPRO50 compression, refer to SMPTE 314M, *Television - Data Structure for DV-Based Audio, Data and Compressed Video - 25 and 50 Mb/s*.

For more information on MPEG2, refer to ISO/IEC 13818-2, *Generic Coding of Moving Pictures and Associated Audio Systems*.

ML_IMAGE_BUFFER_SIZE_INT32

Size of the image buffer in bytes. This is a read-only parameter and is computed in the device using the current path control settings. This value represents the worst-case buffer size.

ML_IMAGE_COMPRESSION_FACTOR_REAL32

For compressed images only, this parameter describes the desired compression factor. A value of 1 indicates no compression, a value of x indicates that approximately x compressed buffers require the same space as 1 uncompressed buffer. The size of the uncompressed buffer depends on image width, height, packing and sampling.

The default value is implementation-dependent, but should represent a reasonable trade-off between compression time, quality and bandwidth. The specified compression factor should be a number larger than 1.

ML_IMAGE_PACKING_INT32

The image packing parameter describes, in detail, how a single pixel or group of pixels is stored in memory. In the following discussion, fields in corner brackets <> are optional. Fields in square brackets [] are required.

ML_PACKING_<*type*>*[bitPacking]*

- *type* is the base type of each component. Leave blank for an unsigned integer, use S for a signed, 2's complement integer.
- *bitPacking* defines the number of bits per component. *bitPacking* may refer to simple, padded, or complex packings.
  - For the simplest formats, every component is the same size and there is no additional space between components. Here, where a single numeric value specifies the number of bits per component, *bitPacking* takes the form: *[size]*<*_order*>. The first component consumes the first *size* bits, the next consumes the next *size* bits, and so on. Space is only allocated for components which are in use (that depends on the sampling mode, see later). For these formats the data must always be interpreted as a sequence of bytes. For example, ML_PACKING_8 describes a packing in which each component is an unsigned 8-bit quantity. ML_PACKING_S8 describes the same packing except that each component is a signed, 2's complement, 8-bit quantity.

    order is the order of the components in memory. Leave blank for natural ordering (1,2,3,4), use R for reversed ordering (4,3,2,1). For all other orderings, specify the component order explicitly. For example, 4123 indicates that the fourth component is stored first in memory, followed by the remaining three components. Here, we compare a normal, a reversed, and a 4123 packing:

```
                          31              int             0
Packing                   +-----------------------------+
8                         11111111222222223333333344444444
8_R                       44444444333333332222222211111111
8_4123                    44444444111111112222222233333333
```

    where 1 is the first component, 2 is the second component, and so on.
  - For padded formats, each component is padded to a wider total size. In this case, *bitPacking* takes the form: [*bits*]in[*space*][*alignment*] where:

    bits is the number of bits of information per component

space is the total size of each component

alignment values L, L0, or R indicate, respectively, whether the information is left justified and padded, left justified and 0-filled, or right justified in that space

In this case, each component in use consumes *space* bits and those bits must be interpreted as a short integer. (Unused components consume no space). For example, here are some common packings (note that the signed-ness of the component values does matter):

```
                        15  int short  0
Packing                 +-------------+
12in16R                 0000iiiiiiiiiiii
S12in16R                eeeesiiiiiiiiii
12in16L                 iiiiiiiiiiiipppp
S12in16L                siiiiiiiiiiipppp
S12in16L0               siiiiiiiiiii0000
```

where **s** indicates the sign bit, **e** indicates sign-extension bits, **i** indicates the actual component information, **0** indicates 0-fill bits, and **p** indicates padding (replicated from the most significant bits of information).

Note: These bit locations refer to the locations when the 16-bit component has been loaded into a register as a 16-bit integer quantity.

- For the most complex formats, the size of every component is specified explicitly, and the entire pixel must be treated as a single 4-byte integer. *bitPacking* takes the form *size1_size2_size3_size4*, where *size1* is the size of component 1, *size2* is the size of component 2, and so on. In this case, the entire pixel is a single 4-byte integer of length equal to the sum of the component sizes. Any space allocated to unused components must be zero-filled. The most common complex packing occurs when 4 components are packed within a 4-byte integer. For example, **ML_PACKING_10_10_10_2** is:

```
                        31              int             0
Packing                 +-------------------------------+
10_10_10_2              11111111112222222222333333333344
```

where 1 is the first component, 2 is the second component, and so on. The bit locations refer to the locations when this 32-bit pixel is loaded into a register as a 32-bit integer quantity. If only three components were in use (determined from the sampling), then the space for the fourth component would be zero-filled.

order is the order of the components in memory. Leave blank for natural ordering (1,2,3,4), use R for reversed ordering (4,3,2,1). For all other orderings, specify the component order explicitly. For example, 4123 indicates that the fourth component is stored first in memory, followed by the remaining three components. Here, we compare a normal, a reversed, and a 4123 packing:

```
                        31              int             0
Packing                 +-------------------------------+
10_10_10_2_R            44333333333322222222221111111111
10_10_10_2_4123         44111111111122222222223333333333
```

where 1 is the first component, 2 is the second component, and so on. Since this is a complex packing, the bit locations refer to the locations when this entire pixel is loaded into a register as a single integer.

For recommendations on packing and component ordering see Appendix B: “Recommended Practices”.

ML_IMAGE_COLORSPACE_INT32

The colorspace parameters describe how to interpret each component. The full colorspace parameter is:

ML_COLORSPACE_*representation_standard_range*

where:

- *representation* is either **RGB** or **CbYCr**.
  This controls how to interpret each component. The following table shows this mapping (assuming for now that every component is sampled once per pixel):

Colorspace Representation	Component 1	Component 2	Component 3	Component 4
RGB	Red	Green	Blue	Alpha
CbYCr	Cb	Y	Cr	Alpha

Figure 8.4 Mapping Colorspace *representation* Parameters

The packing dictates the size and order of the components in memory, while the colorspace describes what each component represents. For example, here we show the effect of colorspace and packing combined; assuming a 4444 sampling.

```
Color                    31                              0
Space      Packing       +------------------------------+
RGB        8             RRRRRRRRGGGGGGGGBBBBBBBBAAAAAAAA
RGB        8_R           AAAAAAAABBBBBBBBGGGGGGGGRRRRRRRR
RGB        10_10_10_2    RRRRRRRRRRGGGGGGGGGGBBBBBBBBBBAA
RGB        10_10_10_2_R  AABBBBBBBBBBGGGGGGGGGGRRRRRRRRRR
CbYCr      10_10_10_2    bbbbbbbbbbYYYYYYYYYYrrrrrrrrrrAA
CbYCr      10_10_10_2_R  AArrrrrrrrrrYYYYYYYYYYbbbbbbbbbb
```

- *standard* indicates how to interpret particular values as actual colors. Choosing a different standard alters the way the system converts between different color representations. Defined values of *standard* are **601**, **709**, and **240** which designate the Rec. 601, Rec. 709 and SMPTE 240M standards respectively.
- *range* is either **FULL**, where the smallest and largest values are limited only by the available packing size, or **HEAD**, where the smallest and largest values are somewhat less than the theoretical min/max values to allow some "headroom". Full range is common in computer graphics. Headroom range is common in video, particularly when sending video signals over a wire (for example, values outside the legal component range may be used to mark the beginning or end of a video frame). When constructing a colorspace, an application must specify a representation, a standard and a range.

For example, **ML_COLORSPACE_CbYCr_601_HEAD** indicates a Rec. 601 standard CbYCr colorspace with headroom range.

ML_IMAGE_SAMPLING_INT32

The sampling parameters take their names from common terminology in the video industry. They describe how often each component is sampled for each pixel. In computer graphics, its normal for every component to be sampled once per pixel, but in video that need not be the case.

For all RGB colorspaces, the legal samplings are:

- **ML_SAMPLING_444** indicates that the R, G and B components are each sampled once per pixel, and only the first 3 channels are used. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4444** indicates that the R, G, B and A components are sampled once per pixel.

For all CbYCr colorspaces, the legal samplings are:

- **ML_SAMPLING_444** indicates that the Cb, Y, and Cr components are each sampled once per pixel and only the first 3 channels are used. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4444** indicates that the Cb, Y, Cr and Alpha components are each sampled once per pixel.
- **ML_SAMPLING_422** indicates that the Y component is sampled once per pixel and the Cb and Cr components are sampled once per pair of pixels. In this case, Cb and Cr are interleaved on the 1st channel (Cb is first, Cr is second), and Y occupies the 2nd channel. If used with an image packing that provides space for a 3rd or 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_4224** indicates that the Y and Alpha components are sampled once per pixel and the Cb and Cr components are sampled once per pair of pixels. In this case, Cb and Cr are interleaved on the 1st channel, Y is on the 2nd channel, and Alpha is on the 3rd channel. If used with an image packing that provides space for a 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_411** indicates that the Y component is sampled once per pixel and the Cb and Cr components are sampled once per 4 pixels. In this case, Cb is component 1, Cr is component 2 and Y occupies component 3. If used with an image packing that provides space for a 4th component then those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_420** indicates that the Y component is sampled once per pixel and the Cb or Cr component is sampled once per pair of pixels on alternate lines. In this case, Cb or Cr is interleaved on the 1st channel, and Y occupies the 2nd channel. If used with an image packing that provides space for a 3rd or 4th channel, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_400** indicates that only the Y component is sampled per pixel (a greyscale image). If used with an image packing that provides space for additional channels, those bits should have value 0 on an input path and will be ignored on an output path.
- **ML_SAMPLING_0004** indicates that only the Alpha component is sampled per pixel. If used with an image packing that provides space for additional channels, those bits should have value 0 on an input path and will be ignored on an output path.

The following table shows the combined effect of sampling and colorspace on the component definition:

Sampling	Colorspace Representation	Comp 1	Comp 2	Comp 3	Comp 4
4444	**RGB**	Red	Green	Blue	Alpha
444	**RGB**	Red	Green	Blue	
0004	**RGB**	Alpha			
4444	**CbYCr**	Cb	Y	Cr	Alpha
444	**CbYCr**	Cb	Y	Cr	
4224	**CbYCr**	Cb/Cr	Y	Alpha	
422	**CbYCr**	Cb/Cr	Y		
400	**CbYCr**	Y			
420	**CbYCr**	Cb/Cr*	Y		
411	**CbYCr**	Cb	Cr	Y	
0004	**CbYCr**	Alpha			

Table 8.1 Effect of Sampling and Colorspace on Component Definitions

*: Cb and Cr components are multiplexed with Y on alternate lines (not pixels).

ML_IMAGE_SWAP_BYTES_INT32

Parameter **ML_IMAGE_SWAP_BYTES_INT32** may be available on some devices. When set to 0 (the default) this has no effect. When set to 1, the device reorders bytes as a first step when reading data from memory, and as a final step when writing data to memory. The exact reordering depends on the packing element size. For simple and padded packing formats, the element size is the size of each component. For complex packing formats, the element size is the sum of the four component sizes.

The **ML_IMAGE_SWAP_BYTES_INT32** parameter reorders bits as follows:

Element Size	Default ordering	Modified ordering
16 bit	[15..0]	[7..0][15..8]
32 bit	[31..0]	[7..0][15..8][23..16][31..24]
other	[n..0]	[n..0] (no change)

Table 8.2 Effect of **ML_IMAGE_SWAP_BYTES_INT32** on Image Bit Reordering

CHAPTER

9

ML AUDIO PARAMETERS

Audio Buffer Layout

The digital representation of an audio signal is generated by periodically sampling the amplitude (voltage) of the signal. The samples represent periodic "snapshots" of the signal amplitude. The sampling rate specifies the number of samples per second. The audio buffer pointer points to the source or destination data in an audio buffer for processing a fragment of a media stream. For audio signals, a fragment typically corresponds to between 10 milliseconds and 1 second of audio data. An audio buffer is a collection of sample frames. A *sample frame* is a set of audio samples that are coincident in time. A sample frame for mono data is a single sample. A sample frame for stereo data consists of a left-right sample pair.

Stereo samples are interleaved; left-channel samples alternate with right-channel samples. 4-channel samples are also interleaved, with each frame usually having two left/right sample pairs, but there can be other arrangements.

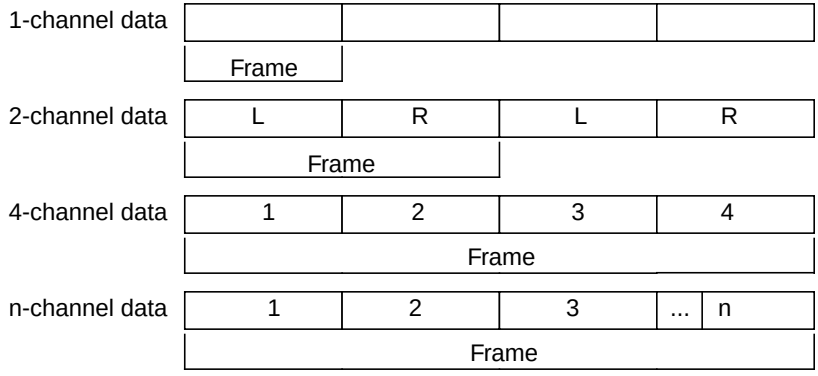


Figure 9.1 Different Audio Sample Frames

This illustration shows the relationship between the number of channels and the frame size of audio sample data.

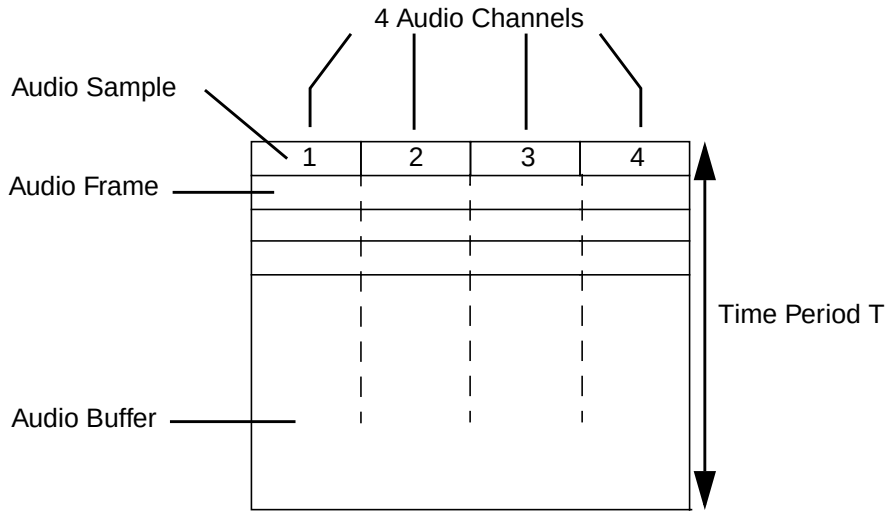


Figure 9.2 Layout of an Audio Buffer With 4 Channels

This illustration shows the layout of an audio buffer in memory.

Audio Parameters

The following parameters are defined for audio data:

ML_AUDIO_BUFFER_POINTER

A pointer to the first byte of an in-memory audio buffer. The buffer address must comply with the alignment constraints for buffers on the particular path to which it is being sent. (See **mlGetCapabilities** for details of determining alignment requirements).

ML_AUDIO_FRAME_SIZE_INT32

The size of an audio sample frame in bytes. This is a read-only parameter and is computed in the device using the current path control settings.

ML_AUDIO_SAMPLE_RATE_REAL64

The sample rate of the audio data in Hz. The sample rate is the frequency at which samples are taken from the analog signal on input or pass out of the audio jack on output. Sample rates are measured in hertz (Hz). A sample rate of 1 Hz is equal to one sample per second. For example, when a mono analog audio signal is digitized at a 44.1 kilohertz (kHz) sample rate, 44100 digital samples are generated for every second of

the signal. Sample rates are dependent on the hardware, but are usually between 8000 and 96000. The default is hardware-specific. Common sample rates are 8000, 16000, 32000, 44100, 48000 and 96000.

ML_AUDIO_PRECISION_INT32

The maximum width in bits for an audio sample at the input or output jack. For example, a value of 16 indicates a 16-bit audio signal. **ML_AUDIO_PRECISION_INT32** specifies the precision at the Audio I/O jack, whereas **ML_AUDIO_FORMAT_INT32** specifies the packing of the audio samples in the audio buffer. If **ML_AUDIO_FORMAT_INT32** is different than **ML_AUDIO_PRECISION_INT32**, the system will convert between the two formats. Such a conversion might include padding and/or truncation.

ML_AUDIO_FORMAT_INT32

Specifies the format in which audio samples are stored in memory. The interpretation of format values is:

ML_AUDIO_FORMAT_[*type*][*bits*]

- [*type*] is **U** for unsigned integer samples, **S** for signed (2's compliment) integer samples, **R** for real (floating point) samples
- [*bits*] is the number of significant bits per sample.

For sample formats in which the number of significant bits is less than the number of bits in which the sample is stored, the format of the values is:

ML_AUDIO_FORMAT_[*type*][*bits*]**in**[*size*][*alignment*]

- [*size*] is the total size used for the sample in memory, in bits.
- [*alignment*] is either **R** or **L** depending on whether the significant bits are right- or left-shifted within the sample. For example, here are three of the most common audio buffer formats:

```
ML_AUDIO_FORMAT_U8          7 char 0
                            +------+
                            iiiiiiii

ML_AUDIO_FORMAT_S16         15  short int  0
                            +--------------+
                            iiiiiiiiiiiiiiii

ML_AUDIO_FORMAT_S24in32R    31            int              0
                            +-------------------------------+
                            ssssssssiiiiiiiiiiiiiiiiiiiiiiii
```

where **s** indicates sign-extension, and **i** indicates the actual component information. The bit locations refer to the locations when the 8-, 16-, or 32-bit sample has been loaded into a register as an integer quantity. If the audio data compression parameter **ML_AUDIO_COMPRESSION_INT32** indicates that the audio data is in compressed form, the **ML_AUDIO_FORMAT_INT32** indicates the data type of the samples after decoding. Common formats are:

ML_FORMAT_U8
ML_FORMAT_S16
ML_FORMAT_S24in32R
ML_FORMAT_R32

Default is hardware-specific.

ML_AUDIO_GAINS_REAL64_ARRAY

The gain factor in decibels (dB) on the given path. There will be a value for each audio channel. Negative values represent attenuation. Zero represents no change of the signal. Positive values amplify the signal. A gain of negative infinity indicates infinite attenuation (mute).

ML_AUDIO_CHANNELS_INT32

The number of channels of audio data in the buffer. Multi-channel audio data is always stored interleaved, with the samples for each consecutive audio channel following one another in sequence. For example, a 4-channel audio stream will have the form:

123412341234...

where 1 is the sample for the first audio channel, 2 is the sample for the second audio channel, and so on.

Common values include the following:

ML_CHANNELS_MONO
ML_CHANNELS_STEREO
ML_CHANNELS_4
ML_CHANNELS_8

ML_AUDIO_COMPRESSION_INT32

This parameter specifies the compression format of the data. The compression format may be an industry standard such as MPEG-1 audio or a device dependent format.

Common values include the following:

ML_COMPRESSION_MU_LAW
ML_COMPRESSION_A_LAW
ML_COMPRESSION_IMA_ADPCM
ML_COMPRESSION_MPEG1
ML_COMPRESSION_MPEG2
ML_COMPRESSION_AC3

When the data is uncompressed, the value of this parameter is **ML_COMPRESSION_UNCOMPRESSED**.

Uncompressed Audio Buffer Size Computation

The following equation shows how to calculate the number of bytes for an uncompressed audio buffer given the sample frame size, sampling rate and the time period that the audio buffer represents:

$$\mathbf{N} = \mathbf{F} \cdot \mathbf{R} \cdot \mathbf{T}$$

where:

N audio buffer size in bytes

F the number of bytes per audio sample frame (**ML_AUDIO_FRAMESIZE_INT32)**

R the sampling rate in Hz (**ML_AUDIO_SAMPLE_RATE_REAL64)**

T the time period the audio buffer represents in seconds

Example 8-1 Buffer Size Computation

If:

- **F** is 4 bytes (if *format* is **S16** and there are two channels)
- **R** (sampling rate) is 44,100 Hz
- **T** = 40 ms = 0.04 s.

then the resulting buffer size **N** is 7056 bytes.

CHAPTER

10

ML PROCESSING

ML is concerned with two types of interfaces: paths for digital media through jacks into and out of the machine, and pipes for digital media to and from transcoders. Both share common control, buffer, and queueing mechanisms. These mechanisms are first described in the context of a complete program example. Subsequently, the individual functions are presented.

ML Program Structure

ML programs are composed of the following structure. Each of the functions are described later in this chapter (except where noted).

```
// get list of available media devices
// (See Chapter 6: “ML Capabilities” for function description)
mlGetCapabilities( systemid, &capabilities );

// search the devices to find the desired jack, path, or transcoder to open
// (See Chapter 6: “ML Capabilities” for function description)
mlGetCapabilities( deviceid, &capabilities );

// query the jack, path, or transcoder to discover allowable open options and parameters
// (See Chapter 6: “ML Capabilities” for function description)
mlGetCapabilities( objectid, &capabilities );

// query for individual parameter characteristics
// (See Chapter 6: “ML Capabilities” for function description)
mlPvGetCapabilities( deviceid, &capabilities );

// free memory associated with any of the above get capabilities:
// (See Chapter 6: “ML Capabilities” for function description)
mlFreeCapabilities( capabilities );
```

```
// open a logical connection to the desired object
mlOpen( objectId, options, &openid );

// get and set any necessary immediate controls
mlGetControls( openid, controls );
mlSetControls( openid, controls );

// send any synchronous controls
mlSendControls( openid, controls );

// pre-roll buffers
mlSendBuffers( openid, buffers );

// prepare for asynchronous processing by getting a wait handle
mlGetWaitHandle( openid, &WaitHandle );

// start the path or transcoder transferring
mlBeginTransfer( openid );

// perform synchronous work
mlXcodeWork( openid );

// check on the status of the queues
mlGetSendMessageCount( openid, &messageCount );
mlGetReceiveMessageCount( openid, &messageCount );

// process return messages
mlReceiveMessage( openid, &messageType, &receiveMessage );

// find specific returned parameters
mlPvFind( msg, param );

// repeat mlSendControls, mlSendBuffers, mlXcodeWork, etc. as required

// stop the transfer
mlEndTransfer( openid );

// close the logical connection
mlClose( openid );

// other useful functions:
mlGetVersion( &majorVersion, &minorVersion );
mlGetSystemUST( systemId, &returnedUST );
mlStatusName( status );
mlMessageName( messageType );
```

Parameter Access Controls

Parameter access control flags describe when and how each parameter can be used. The set of parameter access control flags associated with a parameter is returned by **mlPvGetCapabilities** as **ML_PARAM_ACCESS_INT32**. This value is a bitwise “or” of one or more such flags.

These values are an intrinsic aspect of each parameter and cannot be changed by the application. They are available to help the application use each parameter correctly. If a parameter is used in a manner that is not consistent with its access control flags, then an error will be reported.

The parameter access control flags are described in the following table where the string in the Access Control column is a shortened form of the full name. The full name is of the form **ML_ACCESS_***access*, where *access* is the string listed in the Access Control column. For example, the full name of **READ** is **ML_ACCESS_READ**.

Access Control	Description
READ	The parameter can be used in an **mlGetControls** or **mlQueryControls** message to retrieve a device control value.
WRITE	The parameter can be used in an **mlSendControls**, **mlSetControls**, or **mlSendBuffers** message to set a device control value.
PASS_THROUGH	The value of the param/value pair will not be changed by the device, nor will any device controls be changed as a result of this parameter. This flag is typically applied to parameters that are enqueued; such parameters may be used by an application as markers in the queue of messages. User parameters created with the **ML_USERDATA_DEFINED** macro (refer to Chapter 5: “ML Parameters”) are given **PASS_THROUGH** access so that they can be used for this purpose.
OPEN_OPTION	The parameter can be set when the corresponding device is opened by **mlOpen.** All parameters in the **mlOpen** *options* message must have this access.
IMMEDIATE	The parameter can be used to set or retrieve a device control value “out of band”. If the parameter has **READ** access, then the parameter can be included in a message passed to **mlGetControls**. If the parameter has **WRITE** access, then the parameter can be included in a message passed to **mlSetControls**.
QUEUED	The parameter can be used to set or retrieve a device control value “in band”. If the parameter has **READ** access, then the parameter can be included in a message enqueued by **mlQueryControls**. If the parameter has **WRITE** access, then the parameter can be included in a message enqueued by **mlSendControls**.
SEND_BUFFER	The parameter can be included in an “in band” message enqueued by **mlSendBuffers**. If the parameter also has **WRITE** access then it can be used to set a device control.
DURING_TRANSFER	The parameter can be used to set or retrieve a control value during buffer transfers...after the application has called **mlBeginTransfer**. A device control that takes a long time to set (and therefore could compromise real time buffer transfers) might not have this access control.

Table 10.1 Parameter Access Control Values

Note that buffer pointer parameters such as **ML_IMAGE_BUFFER_POINTER** and **ML_AUDIO_BUFFER_POINTER** do not have the **ML_ACCESS_SEND_BUFFER** flag. For these kinds of parameters, this access is implicit.

Opening a Jack, Path, or Transcoder

In order to communicate with a Jack, Path, or Transcoder, a connection must be opened. A physical device (e.g. a PCI card) may simultaneously support several such connections. These connections are made by calling **mlOpen**:

MLstatus mlOpen (const MLint64 *objectId***, MLpv*** *options***, MLopenid*** *openid***);**

objectId is the 64-bit unique identifier for the object (jack, path or transcoder) to be opened. *options* is an **ML_END** terminated list of param/value pairs that specify the initial configuration of the device to be opened. These parameters are described in Tables 10.2, 10.3, and 10.4.

On successful completion, the handle of the open instance of the object is returned in *openid* and **ML_STATUS_NO_ERROR** is returned. The status value **ML_STATUS_INVALID_ID** is returned if the *objectid* is invalid.

The **mlOpen** operation can fail because of an incorrectly structured *options* list. **ML_STATUS_INVALID_PARAMETER** is returned if one of the **param** values in the *options* list is invalid. **ML_STATUS_INVALID_VALUE** is returned if one of the **value** components in the *options* list is invalid. If the *options* list specifies an open access mode that is not available on the device, then **ML_STATUS_ACCESS_DENIED** is returned. In addition, **ML_STATUS_INVALID_ARGUMENT** is returned if one of the arguments to **mlOpen** is otherwise invalid.

Resources are allocated or reserved as a side effect of **mlOpen**. **ML_STATUS_OUT_OF_MEMORY** is returned if there is insufficient memory available to perform the operation, such as the space needed to allocate the queues for messages between the application and the device. **ML_STATUS_INSUFFICIENT_RESOURCES** is returned if some other required resource is not available, possibly by being already in use by this or another application.

A device may not be available, perhaps from being powered off, or removed from the system. In such a case, **ML_STATUS_DEVICE_UNAVAILABLE** is returned. Finally, **ML_STATUS_INTERNAL_ERROR** is returned if the operation fails due to a system or device I/O error.

The following tables lists the **mlOpen** options defined for jacks, paths, and transcoders. For a particular device, only some of the options might be available. The set of available open options is returned in the **ML_OPEN_OPTIONS_IDS** param/value pair returned by **mlGetCapabilities**. The allowable values associated with one of these options can then be determined using **mlPvGetCapabilities**.

In these tables, the string in the Parameter column is a shortened form of the full parameter name, which is of the form **ML**_*parameter_type*, where the *parameter* and *type* are the strings listed in the Parameter and Type columns respectively. For example, the full parameter name of **OPEN_MODE** is **ML_OPEN_MODE_INT32**.

Following are the **mlOpen** *options* parameters for jacks:

Parameter	Type	Description
OPEN_MODE	**INT32**	Application's intended use for the device. Defined values are: • **ML_MODE_RO** for read only access • **ML_MODE_RWS** for shared read/write access • **ML_MODE_RWE** for exclusive access The default is defined by the device's capabilities.

Table 10.2 mlOpen Options for **Jacks**

Parameter	Type	Description
OPEN_RECEIVE_QUEUE_COUNT	**INT32**	Application's preferred size (number of messages) for the receive queue. This influences the amount of memory allocated for this queue when the device is opened. Default is device-dependent. A null value indicates that the application does not expect to receive any events from the jack.
OPEN_EVENT_PAYLOAD_COUNT	**INT32**	Application's preferred size (number of messages) for the queue event payload area. This payload area holds the contents of event messages on the receive queue. Default is device-dependent. A null value indicates that the application does not expect to receive any events from the jack.

Table 10.2 mlOpen Options for **Jacks**

I

Following are the **mlOpen** *options* parameters for paths:

Parameter	Type	Description
OPEN_MODE	**INT32**	Application's intended use for the device. Defined values are: • **ML_MODE_RO** for read only access • **ML_MODE_RWS** for shared read/write access • **ML_MODE_RWE** for exclusive access The default is defined by the device's capabilities.
OPEN_SEND_QUEUE_COUNT	**INT32**	Application's preferred size (number of messages) for the send header queue. This influences the amount of memory allocated for this queue when the device is opened. Default is device-dependent.
OPEN_RECEIVE_QUEUE_COUNT	**INT32**	Applications' preferred size (number of messages) for the receive header queue. This influences the amount of memory allocated for this queue when the device is opened. Default is device-dependent
OPEN_MESSAGE_PAYLOAD_SIZE	**INT32**	Application's preferred size (in bytes) for the queue message payload area. The payload area holds messages on both the send and receive queues. Default is device-dependent.
OPEN_EVENT_PAYLOAD_COUNT	**INT32**	Application's preferred size (number of messages) for the queue event payload area. This payload area holds the contents of event messages on the receive queue. Default is device-dependent.

Table 10.3 mlOpen Options for **Paths**

Parameter	Type	Description
OPEN_SEND_SIGNAL_COUNT	**INT32**	Application's preferred low-water level (number of empty message slots) in the send queue. When the device dequeues a message and causes the number of empty slots to exceed this level, then the device will signal the send queue event. Default is device-dependent.

Table 10.3 mlOpen Options for **Paths**

Following are the **mlOpen** *options* parameters for transcoders:

Parameter	Type	Description
OPEN_MODE	**INT32**	Application's intended use for the device. Defined values are: • **ML_MODE_RO** for read only access • **ML_MODE_RWS** for shared read/write access • **ML_MODE_RWE** for exclusive access The default is defined by the device's capabilities.
OPEN_SEND_QUEUE_COUNT	**INT32**	Application's preferred size (number of messages) for the send queue. This influences the amount of memory allocated for this queue when the device is opened. Default is device-dependent.
OPEN_RECEIVE_QUEUE_COUNT	**INT32**	Applications' preferred size (number of messages) for the receive queue. This influences the amount of memory allocated for this queue when the device is opened. Default is device-dependent
OPEN_MESSAGE_PAYLOAD_SIZE	**INT32**	Application's preferred size (in bytes) for the queue message payload area. The payload area holds messages on both the send and receive queues. Default is device-dependent.
OPEN_EVENT_PAYLOAD_COUNT	**INT32**	Application's preferred size (number of messages) for the queue event payload area. This payload area holds the contents of event messages on the receive queue. Default is device-dependent.
OPEN_SEND_SIGNAL_COUNT	**INT32**	Application's preferred low-water level (number of empty message slots) in the send queue. When the device dequeues a message and causes the number of empty slots to exceed this level, then the device will signal the send queue event. Default is device-dependent.

Table 10.4 mlOpen Options for **Transcoders**

Parameter	Type	Description
OPEN_XCODE_MODE	**INT32**	Application's preferred mode for controlling a software transcoder. This parameter does not apply to paths. Defined values are: • **ML_XCODE_MODE_SYNCHRONOUS** when processing by a software transcoder is to be initiated by the application. • **ML_XCODE_MODE_AYNCHRONOUS** when processing by a software transcoder is to be initiated by ML Default is **ML_XCODE_MODE_ASYN-CHRONOUS**
OPEN_XCODE_STREAM	**INT32**	Selects between single and multi-stream transcoders. In single stream mode, source and destination buffers are processed at the same rate. In multi-stream mode, the source and destination pipes each have their own queue of buffers and may run at different rates (this is more complicated to program, but may be more efficient for some intra-frame codecs). Defined values are: • **ML_XCODE_STREAM_SINGLE** • **ML_XCODE_STREAM_MULTI** Default is **ML_XCODE_STREAM_SINGLE** Only **ML_XCODE_STREAM_SINGLE** is currently supported. It is expected that **ML_XCODE_STREAM_MULTI** will be supported in a future release of OpenML.

Table 10.4 mlOpen Options for **Transcoders**

Transcoder Component Selection

To set or retrieve the controls of a pipe, a message is sent to the transcoder which owns the pipe. A transcoder has at least two pipes, a source pipe and a destination pipe. A message to a transcoder can include parameters for the source pipe, for the destination pipe and for the transcode itself. The **ML_SELECT_ID_INT64** parameter sets a device control in the transcoder which determines to which component of the transcoder subsequent parameters are applied.

If **ML_SELECT_ID_INT64** has **value** 0, then subsequent parameters are applied to the transcoder itself. Values of **ML_XCODE_SRC_PIPE** and **ML_XCODE_DST_PIPE** cause subsequent parameters to be applied to the source and destination pipes respectively.

By default, parameters in a message to a transcoder are applied to the transcoder itself. That is, the value of the **SELECT_ID** device control is effectively set to 0 at the start of each message to a transcoder.

If a transcoder does not recognize an **ML_SELECT_ID_INT64** value, it will ignore subsequent parameters until the next valid **ML_SELECT_ID_INT64** value or until the end of the message.

Set Controls

Controls on a logical connection that do not affect the buffer size needed for a media I/O operation may be performed asynchronously to an ongoing data transfer. For example, changing the packing of a video image (**ML_IMAGE_PACKING_IN32)** can affect the buffer size needed to contain an image, while changing the video brightness (**ML_VIDEO_BRIGHTNESS_INT32)** does not. These controls may be set in an "*out of band"* message using the **mlSetControls** operation:

MLstatus mlSetControls(MLopenid *openid***, MLpv*** *controls* **);**

openid is the identifier, returned by **mlOpen**, of the jack, path or transcoder whose parameters are to be set. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The *controls* parameter is a message consisting of parameter values to be set. The **mlSetControls** operation can fail because of an incorrectly structured *controls* message. **ML_STATUS_INVALID_PARAMETER** is returned if one of the **param** values in the *controls* message is not recognized. **ML_STATUS_INVALID_VALUE** is returned if one of the **value** components in the *controls* message is invalid. **ML_STATUS_INVALID_CONFIGURATION** is returned if the resulting set of parameter values would be inconsistent if the operation were performed. For all of these failure cases, the **length** component of the first invalid param/value pair is set to -1.

The **mlSetControls** operation sends a message containing a list of control parameters directly to a previously-opened digital media device. The *controls* message is not enqueued on the send queue but instead is sent directly to the device. The device will attempt to process the message "as soon as possible".

This call blocks until the device has processed the *controls* message. This means that, on return, the parameters have been validated and sent to the device (i.e. in most cases this means that they reside in registers)

Other than to identify an invalid param/value pair by setting its **length** to -1, the *controls* message will not be altered in any way and may be reused.

All the control changes within a single *controls* message are considered to occur atomically. If any one control change in the message fails, then the entire message has no effect

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Get Controls

Controls on a logical connection may be queried asynchronously to an ongoing data transfer:

MLstatus mlGetControls(MLopenid *openid***, MLpv*** *controls* **);**

openid is the identifier, returned by **mlOpen**, of the jack, path or transcoder whose parameters are to be queried. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The *controls* parameter is a message consisting of parameters to be queried. The **mlGetControls** operation can fail because of an incorrectly structured *controls* message. **ML_STATUS_INVALID_PARAMETER** is returned if one of the **param** values in the *controls* message is not recognized. In this case, the **length** component corresponding to the first invalid **param** value is set to -1. In this case all returned values must be considered invalid.

The **mlGetControls** operation sends a message containing a list of control parameters to be queried directly to a previously-opened digital media device. The *controls* message is not enqueued on the send queue but instead is sent directly to the device. The device will attempt to process the message "as soon as possible".

This call blocks until the device has processed the *controls* message. This means that, on return, the parameters have been validated and the *controls* message contains the values obtained.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Send Controls

Other controls on a logical connection must be applied “synchronously” because they affect the buffer size that is needed in a data transfer. Changes to these controls should be set in an “*in band”* message using the **mlSendControls** operation. Note that controls that can be sent using **mlSetControls** can also be set using **mlSendControls**.

MLstatus mlSendControls(MLopenid *openid*, MLpv* *controls*);

openid is the identifier, returned by **mlOpen**, of the path or transcoder whose parameters are to be set.The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The *controls* argument is a message containing various parameters as described in the preceding chapters. The **mlSendControls** operation can fail because of an incorrectly structured *controls* message. **ML_STATUS_INVALID_PARAMETER** is returned if one of the **param** values in the *controls* message is not recognized. **ML_STATUS_INVALID_VALUE** is returned if one of the **value** components in the *controls* message is invalid. **ML_STATUS_INVALID_CONFIGURATION** is returned if the resulting set of parameter values would be inconsistent if the operation were performed. For all of these failure cases, the **length** component of the first invalid param/value pair is set to -1.

The **mlSendControls** operation sends a message containing a list of control parameters to a previously-opened digital media device. This message is enqueued on the send queue in sequence with any other messages to that device. Any control changes are thus guaranteed not to have any effect until all previously enqueued messages have been processed. **ML_STATUS_SEND_QUEUE_OVERFLOW** is returned if there is not enough space on the send queue for this message and **ML_STATUS_RECEIVE_QUEUE_OVERFLOW** is returned if there is not enough room on the receive queue for a reply to this message.

mlSendControls returns as soon as the *controls* message has been enqueued to the send queue. It does not wait until the message has actually taken effect.

All the control changes within a single message are considered to occur atomically. If any one control change in the message fails, then the entire message has no effect

Enqueueing entails a copy operation, so the application is free to delete/alter the message array as soon as the call returns. Any error return value indicates the control change has not been enqueued and will thus have no effect.

On successful completion, **ML_STATUS_NO_ERROR** is returned. A successful return does not guarantee that resources will be available to support the requested control change at the time it is processed by the device.

When the device has completed processing the enqueued *controls* message, it enqueus a reply message for return to the application. By examining that reply, the application may obtain the result of processing the requested controls. Note that a device may take an arbitrarily long time to generate a reply (it may, for example, wait for several messages before replying to the first).

Send Buffers

mlSendBuffers enqueues buffers for subsequent processing by a previously opened path or transcoder:

MLstatus mlSendBuffers(MLopenid *openid*, MLpv* *buffers*);

openid is the identifier, returned by **mlOpen**, of the path or transcoder to which buffers are being sent. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

buffers is a message consisting of a list of buffer parameters. It can include only a single buffer of any given type (audio or image) but can include a buffer of each different type.

buffers is enqueued on the send queue in sequence with other messages to that device. All the buffers within a single message are considered to apply to the same point in time. For example, a single message could contain image and audio buffers, each specified with its own buffer parameter in the buffers message. **ML_STATUS_SEND_QUEUE_OVERFLOW** is returned if there is not enough space on the send queue for this message and **ML_STATUS_RECEIVE_QUEUE_OVERFLOW** is returned if there is not enough room on the receive queue for a reply to this message.

The **mlSendBuffers** operation can fail because of an incorrectly structured *buffers* message. **ML_STATUS_INVALID_PARAMETER** is returned if one of the **param** values in the *buffers* message is not recognized. **ML_STATUS_INVALID_VALUE** is returned if one of the **value** components in the *buffers* message is invalid or if the resulting set of parameter values would be inconsistent if the operation were performed. For both of these failure cases, the **length** component of the first invalid param/value pair is set to -1 and the entire message is ignored.

mlSendBuffers returns as soon as the *buffers* message has been enqueued to the send queue. It does not wait until the message has been processed by the device. Any error return value indicates the message has not been enqueued and will thus have no effect. Processing of messages enqueued by **mlSendBuffers** is deferred if buffer transfers are not enabled (cf. **mlBeginTransfer**).

Enqueueing entails a copy operation, so the application is free to delete/alter the message array as soon as the call returns. Any error return value indicates the control change has not been enqueued and will thus have no effect.

The memory for the buffers is designated by the **ML_IMAGE_BUFFER_POINTER** or **ML_AUDIO_BUFFER_POINTER** value, and is always owned by the application. However, after a buffer has been sent, it is “on loan” to the system and must not be touched by the application. After the buffer has been returned via **mlReceiveMessage** or if **mlSendBuffers** fails, the application is again free to modify or delete it.

When sending a buffer to be output, the application must set the buffer **length** to indicate the number of valid bytes in the buffer. In this case **maxLength** is ignored by the device (it doesn’t matter how much larger the buffer may be, since the device won’t read past the last valid byte).

When sending a buffer to be filled (on input), the application must set the buffer **maxLength** to indicate the maximum number of bytes which may be written by the device to the buffer. As the device processes the buffer, it will write no more than the **maxLength** bytes and then set the returned **length** to indicate the last byte written. The **maxLength** is returned without change.

It is acceptable to send the same buffer multiple times to an output device. If the device is unable to get a buffer while transferring, the device will generate and send a **SEQUENCE_LOST** exception event to the application.

On successful completion, **ML_STATUS_NO_ERROR** is returned. A successful return value from the **mlSendBuffers** guarantees only that the message has been enqueued. A successful return does not guarantee that processing of the message by the device will succeed.

When the device has completed processing the enqueued *buffers* message, it enqueus a reply message for return to the application. By examining that reply, the application may obtain the result of processing the buffers.

Query Controls

To obtain the control values on a logical connection that are synchronous with other commands, an “*in band”* operation, **mlQueryControls**, is used:

MLstatus mlQueryControls(MLopenid *openid,* MLpv* *controls*);

openid is the identifier, returned by **mlOpen**, of the device whose parameters are to be set. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The *controls* argument is a message containing various parameters as described in the preceding chapters. The **mlQueryControls** operation can fail because of an incorrectly structured *controls* message. **ML_**

STATUS_INVALID_PARAMETER is returned if one of the **param** values in the *controls* message is not recognized. In this case, the **length** component of the first invalid param/value pair is set to -1.

The **mlQueryControls** operation sends a message containing a list of control parameters to a previously-opened digital media device. This message is enqueued on the send queue in sequence with any other messages to that device.The control values return are thus guaranteed to reflect the effects of all previously enqueued messages. **ML_STATUS_SEND_QUEUE_OVERFLOW** is returned if there is not enough space on the send queue for this message and **ML_STATUS_RECEIVE_QUEUE_OVERFLOW** is returned if there is not enough room on the receive queue for a reply to this message.

mlQueryControls returns as soon as the *controls* message has been enqueued to the send queue. It does not wait until the message has actually taken effect.

Enqueueing entails a copy operation, so the application is free to delete/alter the message array as soon as the call returns. Any error return value indicates the message has not been enqueued and will thus have no effect.

On successful completion, **ML_STATUS_NO_ERROR** is returned. A successful return does not guarantee that processing of the message by the device will succeed.

When the device has completed processing the enqueued *controls* message, it enqueus a reply message for return to the application. By examining that reply, the application may obtain the result of processing the queried controls. Note that a device may take an arbitrarily long time to generate a reply (it may, for example, wait for several messages before replying to the first).

Get Wait Handle

When processing a number of digital media streams asynchronously, there exists a need for the application to know when processing is required on each individual stream. The **mlGetSendWaitHandle** and **mlGetReceiveWaitHandle** functions are provided to facilitate this processing:

MLstatus mlGetSendWaitHandle(MLopenid *openid***, MLwaitable*** *waitHandle* **);**

MLstatus mlGetReceiveWaitHandle(MLopenid *openid***, MLwaitable*** *waitHandle* **);**

openid is the identifier, returned by **mlOpen**, of a path or transcoder. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The requested wait handle, on which an application may wait, is returned in *waitHandle*. On IRIX, UNIX and Linux, **MLwaitable** is a file descriptor for use in **select**(). On Windows, **MLwaitable** is a **HANDLE** which may be used in the win32 functions **WaitForSingleObject** or **WaitForMultipleObjects**.

The send queue handle is signaled whenever the device dequeues a message and the number of empty message slots exceeds a preset level (set by the parameter **ML_OPEN_SEND_SIGNAL_COUNT_INT32** specified when the object was opened). Thus, if the send queue is full, an application may wait on this handle for notification until space is available for additional messages.

The receive queue handle is signaled whenever the device enqueues a reply message. Thus, if the receive queue is empty, the application may wait on this handle for notification that additional reply messages are ready.

The returned handles were created when the device was opened and are automatically destroyed when the path is closed.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Begin Transfer

mlBeginTransfer enables the transferring of buffers to the logical media connection:

MLstatus mlBeginTransfer(MLopenid *openid*);

openid is the identifier, returned by **mlOpen**, of the path or transcoder. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

mlBeginTransfer enables the processing of *buffer messages*, that is, messages enqueued on the send queue by **mlSendBuffers**.

Processing of buffer messages, messages enqueued by **mlSendBuffers**, can be enabled or disabled. When processing of buffer messages is disabled, a message enqueued by **mlSendControls** or **mlQueryControls** can be processed when it reaches the head of the queue. However, a buffer message that reaches the head of the send queue will stall processing until such processing is enabled again. **mlBeginTransfer** enables the processing of buffer messages.

When a path or transcoder logical device is opened, processing of buffer messages is disabled. Typically applications will open a device, send several buffers ("pre-rolling" the queue) and then call **mlBeginTransfer**.

This call returns as soon as the device has begun processing transfers. It does not block until the first buffer has been processed. The status **ML_STATUS_NO_OPERATION** is returned if processing of buffer messages was already enabled, otherwise **ML_STATUS_NO_ERROR** is returned.

The delay between a call to **mlBeginTransfer** and the transfer of the first buffer is implementation dependent. To begin sending data at a particular time, an application should start the transfer early (enqueueing blank buffers) and use the UST/MSC mechanism to synchronize the start of real data.

Transcoder Work

An application can control exactly when and in which thread the processing for a software transcoder is performed using:

MLstatus mlXcodeWork(MLopenid *openid*);

openid is the identifier, returned by **mlOpen**, of a previously opened transcoder. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The default behavior of transcoders is for processing of buffer messages to occur automatically as a side effect of enqueueing messages to the device. **mlXcodeWork** only applies to software transcoders that are opened with the **ML_XCODE_MODE_SYNCHRONOUS** open option.

This function performs one unit of processing for the specified codec. The processing is done in the thread of the calling process and the call does not return until the processing is complete.

For most codecs a "unit of work" is the processing of a single buffer from the source queue and the writing of a single resulting buffer on the destination queue. If there were no buffers to be processed, **ML_STATUS_NO_OPERATION** is returned.

On completion of a unit of work **ML_STATUS_NO_ERROR** is returned. This does not mean that the unit of work completed successfully. The application must examine the reply message to determine whether such processing was successful.

Get Message Count

During the processing of messages it is sometimes necessary to inquire as to the "fullness" of the message queues. These functions provide that capability:

MLstatus mlGetSendMessageCount (MLopenid *openid*, **MLint32*** *messageCount*);
MLstatus mlGetReceiveMessageCount (MLopenid *openid*, **MLint32*** *messageCount*);

openid is the identifier, returned by **mlOpen**, of a path or pipe. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

The count of the number of messages in the send or receive queues of a device is returned in *messageCount*. The send queue contains messages queued by the application for processing by the device while the receive queue holds messages which have been processed and are waiting to be read by the application. A message is considered to reside in the send queue from the moment it is enqueued by the application until the moment the device begins processing it. A message resides in the receive queue from the moment the device enqueues it, until the moment the application dequeues the corresponding reply message. The message counts are intended to aid load-balancing in sophisticated applications. They are not a reliable method for predicting UST/MSC pairs.

Some devices can begin processing one or more subsequent messages before the processing of a previous message has completed. Thus, the sum of the send and receive queue counts may be less than the difference between the number of messages which have been enqueued and dequeued by the application. Note also that the time lag between a message being removed from the send queue, and the time at which it affects data passing through a physical jack, is implementation dependent. The message counts are not a reliable method for timing or synchronizing media streams.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Receive Message

In order for applications to obtain the results of previous digital media requests, the **mlReceiveMessage** function is used.

MLstatus mlReceiveMessage(MLopenid *openid***, MLint32*** *messageType***, MLpv ***message* **);**

openid is the identifier, returned by **mlOpen**, of a path or transcoder. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

A message on the receive queue can be the result of processing a message sent by **mlSendControls**, **mlSendBuffers**, or **mlQueryControls**; we call such messages *reply messages*. For each message placed on the send queue, a single reply message will be placed on the receive queue. Alternatively, a message on the receive queue can have been generated spontaneously by the device to advise the application of some exceptional event; we call such messages *event messages*. **mlReceiveMessage** returns the oldest message on the receive queue regardless of whether it is a reply message or an exception message.

For reply messages, the value returned in *messageType* indicates not only the initiating function, **mlSendControls**, **mlSendBuffers**, or **mlQueryControls**, but also whether processing of the sent message was successful. The message returned by *message* has the same list of params as the sent message. The **value**, **length**, and **maxLength** components may have been changed as described for each of the initiating functions.

For exception messages, the value returned in *messageType* indicates the event that is being reported. The message returned in *message* is event and device specific. It is the application's responsibility to parse and decode the message.

The contents of a message returned by *message* are guaranteed to remain valid until the next call to **mlReceiveMessage**. Thus an application may modify the reply message and then send it to the same device or to another device by calling **mlSendControls**, **mlSendBuffers**, or **mlQueryBuffers**.

ML_STATUS_RECEIVE_QUEUE_EMPTY is returned if the receive queue is empty. On some devices, triggering of the receive wait handle does not guarantee that a message is waiting on the receive queue. Thus applications should always check for the **ML_STATUS_RECEIVE_QUEUE_EMPTY** return status.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

The following tables describe the values that are returned in *messageType* for replies to **mlSendControls**, **mlSendBuffers**, and **mlQueryBuffers***:*

Following are the message types for replies to **mlSendControls:**

Message type	Description
ML_CONTROLS_COMPLETE	The controls were processed without error.
ML_CONTROLS_ABORTED	Processing of the controls was aborted due to some asynchronous event such as execution of **mlEndTransfer** on this device.
ML_CONTROLS_FAILED	Processing of controls failed because the values were not accepted at the time of processing. This can occur both because parameters in the buffers message were invalid or because, due to the current control settings at the time of processing (because of previous **mlSendControls** messages), the processing of buffers would be invalid. Since preceding control messages may be incomplete, but each of the individual set or send controls may be valid, there still exists a point in time where the processing of buffers must be accomplished using those aggregate controls. If for some reason, the "combination of controls" is invalid, the processing is aborted and the event **ML_BUFFERS_FAILED** is returned. The **length** component of the first invalid param/value pair is set to -1

Table 10.5 mlSendControls Reply Message Types

Following are the message types for replies to **mlSendBuffers:**

Message type	Description
ML_BUFFERS_COMPLETE	The buffers were processed without error.
ML_BUFFERS_ABORTED	Processing of the buffers was aborted due to some asynchronous event such as execution of **mlEndTransfer** on this device.
ML_BUFFERS_FAILED	Processing of buffers failed because the values were not accepted at the time of processing. This can occur both because parameters in the buffers message were invalid or because, due to the current control settings at the time of processing (because of previous **mlSendControls** messages), the processing of buffers would be invalid. Since preceding control messages may be incomplete, but each of the individual set or send controls may be valid, there still exists a point in time where the processing of buffers must be accomplished using those aggregate controls. If for some reason, the "combination of controls" is invalid, the processing is aborted and the event **ML_BUFFERS_FAILED** is returned. The **length** component of the first invalid param/value pair is set to -1

Table 10.6 mlSendBuffers Reply Message Types

Following are the message types for replies to **mlQueryControls:**

Message type	Description
ML_QUERY_CONTROLS_COMPLETE	The query controls were processed without error.
ML_QUERY_CONTROLS_ABORTED	Processing of the query controls was aborted due to some asynchronous event such as execution of **mlEndTransfer** on this device.

Table 10.7 mlQueryControls Reply Message Types

Following are the message types for exception messages

Message type	Description
ML_EVENT_DEVICE_ERROR	Device encountered an error and is unable to recover.
ML_EVENT_DEVICE_UNAVAILABLE	The device is not available for use.
ML_EVENT_VIDEO_SEQUENCE_LOST	A video buffer was not available for an I/O transfer.
ML_EVENT_VIDEO_SYNC_LOST	Device lost output genlock sync signal.
ML_EVENT_VIDEO_SYNC_GAINED	Device detected valid output genlock.
ML_EVENT_VIDEO_SIGNAL_LOST	Device lost input video signal.
ML_EVENT_VIDEO_SIGNAL_GAINED	Device detected valid input video signal.
ML_EVENT_VIDEO_VERTICAL_RETRACE	A video vertical retrace occurred.
ML_EVENT_AUDIO_SEQUENCE_LOST	An audio buffer was not available for an I/O transfer.
ML_EVENT_AUDIO_SAMPLE_RATE_CHANGED	The audio input sampling frequency changed.

Table 10.8 Exception Message Types

End Transfer

For an application to invoke an orderly shutdown of a digital media stream, the **mlEndTransfer** function should be issued.

MLstatus* mlEndTransfer(MLopenid *openid* **);**

openid is the identifier, returned by **mlOpen**, of a path or transcoder. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

mlEndTransfer disables the transferring of buffers on the specified path or transcoder. This call advises the device to stop processing buffers and aborts any remaining messages on its input queue. This is a blocking call. It does not return until transfers have stopped and any messages remaining on the device input queue have been aborted and reply messages placed on the receive queue. Calling **mlEndTransfer** on a device on which transfers are already disabled will cause the send queue to be flushed. Any mes-

sages which are flushed will be marked to indicate they were aborted. Buffer messages are marked **ML_BUFFERS_ABORTED**, while control messages are marked **ML_CONTROLS_ABORTED**.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Close Processing

After an application is finished with a digital media connection, it should terminate that connection. The **mlClose** function is provided for that use. Note that an **mlClose** call is implied if an application terminates (for any reason) before an **mlClose** function is explicitly called.

MLstatus mlClose(MLopenid *openid***);**

openid is the identifier, returned by **mlOpen**, of the device to be closed. The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

When a digital media object is closed, all messages in the message queues of the device are discarded. The device handle *openid* becomes invalid; any subsequent attempt to use it to refer to the closed object will result in an error.

The pipes opened as a side-effect of opening a transcoder are also closed as a side-effect of closing a transcoder. Pipes should not be closed explicitly.

mlClose is a blocking call that returns only after the device has been closed and associated resources have been freed.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Utility Functions

There are a number of other useful functions available in the ML API. They are described here.

Get Version

MLstatus mlGetVersion(MLint32 ***majorVersion*, MLint32** **majorVersion* **);**

mlGetVersion returns the ML version number. The major version number is returned in *majorVersion* while the minor version number is returned in *minorVersion*. **ML_STATUS_INVALID_ARGUMENT** is returned if either *majorVersion* or *minorVersion* is a **NULL** pointer. The version number is of the form *majorVersion.minorVersion*, for example 1.0. Changes in major numbers indicate a potential incompatibility, while changes in minor numbers indicate small backward-compatible enhancements. Major version numbers start at 1 and increase monotonically. Within a particular major version, the minor version numbers will start at 0 and increase monotonically.

Note that this is the version number of the ML core library; the version numbers for device-dependent modules are available in the capabilities list for each physical device.

On successful completion, **ML_STATUS_NO_ERROR** is returned.

Status Name

const char *mlStatusName(MLstatus *status*);

Intended mainly as an aid in debugging, **mlStatusName** accepts an ML status value and returns the corresponding string. For example, the value **ML_STATUS_NO_ERROR**, is converted to the string “ML_STATUS_NO_ERROR”. **NULL** is returned if *status* is an invalid status value.

Message Name

const char *mlMessageName(MLint32 *messageType*);

Intended mainly as an aid in debugging, **mlMessageName** accepts an ML message type and returns the corresponding string. For example, the value **ML_CONTROLS_FAILED**, is converted to the string "ML_CONTROLS_FAILED". **NULL** is returned if *status* is an invalid status value.

MLpv String Conversion routines

These routines convert between MLpv param/value pairs and strings. They are of benefit to applications writing lists of parameters to or from files, but are most commonly used as an aid to debugging.

MLstatus mlPvValueToString(MLint64 *objectId*, **MLpv*** *pv*,
char* *buffer*, **MLint32*** *bufferSize*);

MLstatus mlPvParamToString(MLint64 *objectId*, **MLpv*** *pv*,
char* *buffer*, **MLint32*** *bufferSize*);

MLstatus mlPvToString(MLint64 *objectId*, **MLpv*** *pv*,
char* *buffer*, **MLint32*** *bufferSize*);

MLstatus mlPvValueFromString(MLint64 *objectId*, **const char*** *buffer*,
MLint32* *bufferSize*, **MLpv*** *pv*,
MLbyte* *arrayData*, **MLint32** *arraySize*);

MLstatus mlPvParamFromString(MLint64 *objectId*, **const char*** *buffer*,
MLint32* *bufferSize*, **MLpv*** *pv*);

MLstatus mlPvFromString(MLint64 *objectId*, **const char*** *buffer*,
MLint32* *bufferSize*, **MLpv*** *pv*,
MLbyte* *arrayData*, **MLint32** *arraySize*);

These routines make use of parameter capability data (see **mlPvGetCapabilities)** to generate and interpret human-readable ASCII strings. The interpretation of a param/value pair depends on the parameter, its value, and the device on which it will be used. Thus, all these functions require a 64-bit device identifier, supplied in *objectid*.

objectid may be a static id (obtained from a call to **mlGetCapabilities)**, the open id of a jack, path or transcoder (obtained from a call to **mlOpen**), or it may be the id of an open pipe (obtained by calling **mlGetCapabilities** on a transcoder). The status value **ML_STATUS_INVALID_ID** is returned if the *openid* is invalid.

mlPvParamToString converts *pv->param* to a string representation.

mlPvValueToString converts *pv->value* to a string representation.

mlPvToString converts pv into a string representation composed of the parameter name and value separated by '='.

In the preceding routines, the resulting string is returned in **buffer.* On input, *bufferSize* specifies the size of the *buffer* in bytes. On return, *bufferSize* is the length of the resulting string (excluding the terminating '\0').

ML_STATUS_INVALID_PARAMETER is returned if *pv->param* is invalid, and **ML_STATUS_INVALID_VALUE** is returned if pv->value is invalid.

In all the following routines, the string to be converted is given in *buffer* and its length (in bytes and excluding the terminating '\0') is given in *bufferSize*. *pv* points to a structure to receive the conversion results.

mlPvParamFromString interprets a string as a param ID and writes the result in *pv->param*. It expects the string to be as created by **mlPvParamToString**.

In the following routines, *arrayData* points to buffer owned by the application whose length (in bytes) is given in *arraySize.*

mlPvValueFromString interprets a string as the value of a param/value pair. For scalar values, the result is written to *pv->value*; **arrayData* and *arraySize* are unchanged. For array values, the string is converted to an array of data values and the results are returned in **arrayData*; *arraySize* is set to the number of bytes written. It expects the string was created by **mlPvValueToString**.

mlPvFromString interprets a string as a param/value pair and writes the resulting param value to *pv->param*. For scalar values, the result is written to *pv->value*; **arrayData* and *arraySize* are unchanged. For array values, the string is converted to an array of data values and the results are returned in **arrayData*; *arraySize* is set to indicate the number of bytes written.

It expects the string was created by **mlPvToString**.

Each of the **ml*xxx*FromString** routines expects the string to be interpreted to have a format as if generated by the corresponding **ml*xxx*ToString** routine. **ML_STATUS_INVALID_PARAMETER** is returned if the string does not convert to a valid parameter ID, and **ML_STATUS_INVALID_VALUE** is returned if the string does not convert to a valid value.

ML_STATUS_INVALID_ARGUMENT is returned if an arguments could not be interpreted correctly, perhaps because the bufferSize or arraySize are too small to hold the result of the operation. On successful completion, **ML_STATUS_NO_ERROR** is returned.

This example prints the interpretation of a video timing parameter by a previously-opened video path. Note that the calls could fail if that path did not accept the particular timing value we have chosen here. Note also that, since the interpretation is coming from the device, this will work for device-specific parameters.

```
char buffer[200];
MLpv control;

control.param = ML_VIDEO_TIMING_INT32;
control.value = ML_TIMING_1125_1920x1080_5994i;

mlPvParamToString(someOpenPath, &control, buffer, sizeof(buffer));
printf("control.param is %s\n", buffer);
mlPvValueToString(someOpenPath, &control, buffer, sizeof(buffer));
printf("control.value is %s\n", buffer);
mlPvToString(someOpenPath, &control, buffer, sizeof(buffer));
printf("control is %s\n", buffer);
```

The output created by this example would be:

```
control.param is ML_VIDEO_TIMING_INT32
control.value is ML_TIMING_1125_1920x1080_5994i
control is ML_VIDEO_TIMING_INT32 = ML_TIMING_1125_1920x1080_5994i
```

CHAPTER

11

SYNCHRONIZATION IN ML

This chapter describes ML support for synchronizing digital media streams. The described techniques are designed to enable accurate synchronization even when there are large (and possibly unpredictable) processing delays.

UST

To timestamp each media stream, some convenient representation for time is needed. In ML, time is represented by the Unadjusted System Time (UST) counter. The UST counter increases approximately linearly with respect to time during periods that OpenML is actively being used. It is guaranteed to never be set back to a smaller value, even when system clocks are set back. It is also guaranteed to not wrap back to zero during an ML session of any conceivable duration (likely taking hundreds of years to wrap). Its initial value at boot will be close enough to zero to ensure this last constraint.

The accuracy of the UST depends on how frequently it is updated and is in general system dependent. The units will always be nanoseconds, but how frequently it is updated will vary from system to system, and can vary within a system. Because applications will depend on it for measuring drift between media streams, the average frequency at which the UST counter is updated must be at least 5 (five) times faster than the highest media device slot count (MSC) frequency the system intends to support. It is possible that consecutive reads of the UST observe the same value.

While the UST counter is well defined as guaranteed above, observing such well-defined behavior is more difficult. This is due to inherent varying latencies involved in querying the UST counter, especially on non-real-time systems. ML and ML drivers will provide "views" of the UST counter, which are recent copies of its value. These views may compensate for known latencies, but cannot always be guaranteed correct. Most commonly, views of the UST counter must differ from the UST counter, and from each other, by less than the highest frequency MSC rate the system supports. However, context switches and long interrupts prevent guarantees for all cases.

It is expected that the UST time-stamp for a slot corresponds to the value of the UST counter when the slot started. However, it is device dependent precisely what is meant by "when the slot started". Note that while there is one global UST, the multiple device views of the UST differ not due just to random error, but also because of different slot lengths and positions.

ML UST timestamps are signed 64-bit integers with units of nanoseconds, representing a view of the UST counter. A recent view of the system UST is obtained by using the **mlGetSystemUST** function call:

MLstatus mlGetSystemUST(MLint64 *systemId***, MLint64*** *ust***);**

Currently *systemId* must be **ML_SYSTEM_LOCALHOST,** otherwise the status **ML_STATUS_INVALID_ID** is returned. The resulting UST value is placed at the address *ust*. The status **ML_STATUS_INVALID_ ARGUMENT** is returned if *ust* is invalid. The status **ML_STATUS_NO_ERROR** is returned on a successful execution.

MSC

Each logical media device capable of time-stamping must partition time into a sequence of slots. Slots are spans of time used to partition the data stream coming through a jack. For video, a slot typically corresponds to a field or a frame. For audio, a slot typically corresponds to a single audio sample. These slots exist whether or not data is being transferred.

Devices keep a Media Stream Counter (MSC). MSCs are incremented once per slot. This is true even when the application is not currently transferring data to or from the device. Hence, MSC values for particular slots can be used to detect underflow or to schedule data to go through a jack at a particular slot in the future. Just how to do this will be described later in this chapter.

UST/MSC/ASC Parameters

Basic support for synchronization requires that the application know when video or audio buffers passed through a jack. In ML this is achieved with the UST/MSC buffer parameters:

ML_AUDIO_UST_INT64, ML_VIDEO_UST_INT64

The unadjusted system time (UST) is used as the timestamp for the most recently processed slot in the audio or video stream. For video devices, the UST time corresponds to the time at which the field/frame started to pass through the jack. For audio devices, the UST time corresponds to the time at which the first sample in the buffer passed through the jack.

Typically, an application will pass **mlSendBuffers** a video message containing an **ML_IMAGE_BUFFER_ POINTER**, an **ML_VIDEO_MSC** and an **ML_VIDEO_UST** (and possibly an **ML_VIDEO_ASC -** see below), or an audio message containing an **ML_AUDIO_IMAGE_POINTER**, an **ML_AUDIO_UST** and an **ML_ AUDIO_MSC**. In some cases, a message may contain both audio and video parameters.

Each message is processed as a single unit, and a reply is returned to the application via **mlReceiveMessage**. That reply will contain the completed buffers and the UST/MSC(/ASC) corresponding to the time at which the data in the buffers passed in or out of the jack. Note that, due to hardware buffering on some cards, it is possible to receive a reply message before the data has finished flowing through an output jack, but never before it has started.

ML_AUDIO_MSC_INT64, ML_VIDEO_MSC_INT64

The media stream count (MSC) is the most recently processed slot in the audio or video stream. This is snapped at the same instant as the UST time described above. Note that MSC increases by one for each potential slot in the media stream through the jack. For interlaced video timings, each slot contains one video field, for progressive timings, each slot contains one video frame. This means that when 2 fields are interlaced into one frame and sent as one buffer, then the MSC will increment by 2 (once for each field).

Furthermore, the system guarantees that the least significant bit of the MSC will reflect the state of the Field Bit; 0 for Field 1 and 1 for Field 2. For audio, each slot contains one audio frame.

ML_AUDIO_ASC_INT64, ML_VIDEO_ASC_INT64

The application stream count (ASC) is provided to aid the developer in predicting when the audio or video data will pass through an output jack. See the “UST/MSC for Output” section below for further information on the use of the ASC parameter.

UST/MSC Example

For example, here we send an audio buffer and video buffer to an I/O path and request both UST and MSC stamps:

```
MLpv message[7];

message[0].param = ML_IMAGE_BUFFER_POINTER;
message[0].value.pByte = someImageBuffer;
message[0].length = sizeof(someImageBuffer);
message[0].maxLength = sizeof(someImageBuffer);
message[1].param = ML_VIDEO_UST_INT64;
message[2].param = ML_VIDEO_MSC_INT64;
message[3].param = ML_AUDIO_BUFFER_POINTER;
message[3].value.pByte = someAudioBuffer;
message[3].length = sizeof(someAudioBuffer);
message[3].maxLength = sizeof(someAudioBuffer);
message[4].param = ML_AUDIO_UST_INT64;
message[5].param = ML_AUDIO_MSC_INT64;
message[6].param = ML_END;

mlSendBuffers(device, message);
```

After the device has processed the buffers, it will enqueue a reply message back to the application. That reply will be an exact copy of the message sent in, with the exception that the MSC and UST values will be filled in. (For input, the buffer parameter length will also be set to the number of bytes written into it).

UST/MSC For Input

On input the application can detect if any data is missing by examining the MSC value of frames that it receives. If MSC has incremented by one for each frame received, then no data is missing. Data will be lost if an application does not provide buffers fast enough to capture all of the signal which arrived at the jack.

(An alternative to detecting breaks in the MSC sequence of frames, is to turn on the events **ML_AUDIO_SEQUENCE_LOST** or **ML_VIDEO_SEQUENCE_LOST**. Those will fire whenever the send queue underflows.)

Given the UST/MSC stamps for two different buffers (**UST1**,**MSC1**) and (**UST2**,**MSC2**), the input sample rate in samples per nanosecond can be computed as:

$$\text{sampleRate} = \frac{(\text{MSC2} - \text{MSC1})}{(\text{UST2} - \text{UST1})}$$

One common technique for synchronizing different input streams is to start recording early, stop recording late, and then use the UST/MSC stamps in the recorded data to find exact points for trimming the input data.

An alternative way to start recording several streams simultaneously is to use predicate controls (see later).

UST/MSC For Output

On output, the actual output sample rate can be computed in exactly the same way as the input sample rate:

$$\text{sampleRate} = \frac{(\text{MSC2} - \text{MSC1})}{(\text{UST2} - \text{UST1})}$$

Some applications must determine exactly when the next buffer sent to the device actually goes out the jack. Doing this requires two steps. First, the application must maintain its own field/frame count. This parameter is called the **ASC**. The **ASC** may start at any desired value and should increase by one for every audio frame or video field enqueued. (For convenience, the application may wish to associate the ASC with the buffer by embedding it in the same message. The parameters **ML_AUDIO_ASC_INT64** and **ML_VIDEO_ASC_INT64** are provided for this use.)

Now, assume the application knows the (UST,MSC,ASC) for two previously-output buffers, then the application can detect if there was any underflow by comparing the number of slots the application thought it had output, with the number of slots which the system actually output. If (ASC2 - ASC1) == (MSC2 - MSC1) then underflow has not occurred.

Assuming all is well, and that the application knows the current ASC, then the next data the application enqueues may be predicted to have a system sequence count of:

$$\text{currentMSC} = \text{currentASC} + (\text{MSC2} - \text{ASC2})$$

and may be predicted to hit the output jack at time:

$$\text{currentUST} = \text{UST2} + \frac{(\text{currentASC} - \text{ASC2})}{\text{sampleRate}}$$

Note that the application should periodically recompute the actual sample rate based on measured MSC/UST values. It is not sufficient to rely on a nominal sample rate since the actual rate may drift over time.

So, in summary: given the above mechanism, the application knows the UST/MSC pair for every processed buffer. Using the UST/MSC's for several processed buffers it can compute the frame rate. Given a UST/MSC pair in the past, a prediction of the current MSC, and the frame rate, the application can predict the UST at which the next buffer to be enqueued will hit the jack.

Predicate Controls

Predicate controls allow an application to insert conditional commands into the queue to the device. Using these controls, the application can pre-program actions, allowing the device to respond immediately, without needing to wait for a round-trip through the application.

Unlike the UST/MSC timestamps, predicate controls are not required to be supported on all audio and video devices. To see if they are supported on any particular device, the application can look for the desired parameter in the list of supported parameters on each path. (see **mlGetCapabilities**).

The simplest predicate controls are:

ML_WAIT_FOR_AUDIO_MSC_INT64, ML_WAIT_FOR_VIDEO_MSC_INT64

When a message containing this control reaches the head of the queue it causes the queue to stall until the specified MSC value has passed. Then that message, and subsequent messages, are processed as normal.

For example, here is code which uses **WAIT_FOR_AUDIO_MSC** to send a particular buffer out after a specified stream count:

```
MLpv message[3];

message[0].param = ML_WAIT_FOR_AUDIO_MSC_INT64;
message[0].value.int64 = someMSCInTheFuture;
message[1].param = ML_AUDIO_BUFFER_POINTER;
message[1].value.pByte = someBuffer;
message[1].value.length = sizeof(someBuffer);
message[2].param = ML_END;

mlSendBuffers(someOpenPath, message);
```

This places a message on the queue to the path and then immediately returns control to the application. As the device processes that message, it will pause until the specified media MSC value has passed before allowing the buffer to flow through the jack.

Note, if both **ML_IMAGE_DOMINANCE** and **ML_WAIT_FOR_VIDEO_MSC** controls are set and do not correspond to the same starting output field order, the **ML_WAIT_FOR_VIDEO_MSC_INT64** control will override **ML_IMAGE_DOMINANCE_INT32** control settings.

Another set of synchronization predicate controls are:

ML_WAIT_FOR_AUDIO_UST_INT64, ML_WAIT_FOR_VIDEO_UST_INT64

When the message containing this control reaches the head of the queue it causes the queue to stall until the specified UST value has passed. Then that message, and subsequent messages, are processed as normal. Note that the accuracy with which the system is able to implement the **WAIT_FOR_UST** command is device-dependent - see device-specific documentation for limitations.

For example, here is code which uses **WAIT_FOR_AUDIO_UST** to send a particular buffer out after a specified time:

```
MLpv message[3];

message[0].param = ML_WAIT_FOR_AUDIO_UST_INT64;
message[0].value.int64 = someUSTtimeInTheFuture;
message[1].param = ML_AUDIO_BUFFER_POINTER;
message[1].value.pByte = someBuffer;
message[1].value.length = sizeof(someBuffer);
message[2].param = ML_END;

mlSendBuffers(someOpenPath, message);
```

This places a message on the queue to the path and then immediately returns control to the application. As the device processes that message, it will pause until the specified video UST time has passed before allowing the buffer to flow through the jack.

Using this technique an application can program several media streams to start in-sync by simply choosing some UST time in the future and program each to start at that time.

ML_IF_VIDEO_UST_LT, ML_IF_AUDIO_UST_LT

When included in a message, this control will cause the following logical test: If the UST is less than the specified time then the entire message is processed as normal. Otherwise, the entire message is skipped.

Regardless of the outcome, any following messages are processed as normal. Skipping over a message takes time, and so there is a limit to how many messages a device can skip before the delay starts to become noticeable.

SECTION

II

OPENGL REQUIREMENTS AND EXTENSIONS

OpenGL is not a part of OpenML *per se*, but is a key component of the OpenML Programming Environment. OpenML compliance requires an OpenGL implementation that also supports certain OpenGL extensions. Some of these extensions are defined by external sources such as the OpenGL Architecture Review Board (ARB) or individual vendors, and some are defined in the OpenML specification itself.

The revision of OpenGL required for OpenML compliance and the set of required extensions are enumerated in Appendix A, “OpenML Programming Environment Requirements”.

A high level overview of the required OpenGL extensions is provided in the following chapter. The extensions fall into three broad categories:

- Extensions that facilitate integration of OpenGL with components of OpenML, principally with its media input/output facilities.
- Extensions that provide improved rendering quality.
- Extensions that provide enhanced control of OpenGL facilities.

CHAPTER

12

INTEGRATION OF OPENGL AND ML

Video Image Formats

The OpenGL extensions described here provide mechanisms for upsampling and deinterlacing external pixel data, converting them into OpenGL's internal representation, and for the inverse downsampling and interlacing operations when reading pixel data back from the OpenGL pipeline. These mechanisms ease interchange of pixel data between ML and OpenGL.

Color Space Conversion

OpenML does not mandate mechanisms for converting between color spaces in the OpenGL pixel pipeline. However, using the OpenGL color matrix and other features of the OpenGL 1.2 imaging subset, arbitrary conversions can be programmed by applications. Refer to the "Color Space Conversion with OpenGL Extensions" section in Appendix B for further details.

Upsampled and Downsampled Images

The **GL_OML_subsample** and **GL_OML_resample** extensions add support for 4:2:2 and 4:2:2:4 pixel data in host memory. This is commonly used for YCrCb and YCrCbA video data.

To draw pixels or download texels in subsampled formats, use a pixel format corresponding to the actual format of data in application memory. Possible values are:

Pixel Format	Host memory data format	Comments
`GL_FORMAT_SUBSAMPLE_24_24_OML`	CbY / CrY	4:2:2 subsampling
`GL_FORMAT_SUBSAMPLE_244_244_OML`	CbYA / CrYA	4:2:2:4 subsampling

Table 12.1 Subsampled Pixel Formats and Corresponding Host Memory Data Formats

To read pixels or texels in subsampled formats, use a pixel format corresponding to the desired format of data in host memory after readback. The same subsampled formats may be used on readback.

When using a subsampled pixel format, not all possible pixel types are supported; using a packed pixel type other than **GL_UNSIGNED_INT_10_10_10_2** will cause an **INVALID_OPERATION** error.

Subsampled pixel formats are only supported by **glDrawPixels**, **glReadPixels**, **glTexImage**, **glTexSubImage**, and **glGetTexImage.**

When upsampling data, component values must be generated for lower frequency components on pixels where they are not given. Three of the many possible means of generating these values may be specified by setting the **glPixelStore** parameter GL_UNPACK_RESAMPLE_OML. Possible values are:

GL_RESAMPLE_REPLICATE_OML - Generated components are replicated from supplied components of the previous pixel in a scanline.

GL_RESAMPLE_ZERO_FILL_OML - Generated components are set to 0.

GL_RESAMPLE_AVERAGE_OML - Components are generated using a simple hat filter.

More flexible filtering algorithms for generating upsampled component values may be implemented by using **GL_RESAMPLE_ZERO_FILL_OML** followed by convolution in the imaging pipeline using an application-defined filter kernel.

The full OpenGL extension specifications for **GL_OML_subsample** and **GL_OML_resample** are included in Appendix A.

Interlaced Images

The **GL_OML_interlace** extension adds support for scanline interlaced data in host memory.

To draw pixels or download texels in interlaced format, enable the parameter GL_INTERLACE_OML using **glEnable**. When enabled, each row *m* of an image is treated as if it belongs to row *2m*, effectively doubling the specified height of the image. When drawing pixels, only these rows are converted to fragments; when uploading textures, only these rows are written to texture memory. GL_INTERLACE_OML only affects the operation of **glDrawPixels**, **glCopyPixels**, **glTexImage**, **glTexSubImage**, **glCopyTexImage**, and **glCopyTexSubImage**.

To read pixels in interlaced format, enable the parameter GL_INTERLACE_READ_OML using **glEnable**. When enabled, each row *m* of the destination image in host memory is obtained from row *2m* of the source image in the frame buffer. GL_INTERLACE_READ_OML only affects the operation of **glReadPixels**, **glCopyPixels**, **glCopyTexImage**, **glCopyTexSubImage**, and **glCopyConvolutionFilter**; it does **not** affect **glGetTexImage.**

The full OpenGL extension specification for **GL_OML_interlace** is included in Appendix A.

Synchronization

The WGL, GLX, and OpenGL extensions described here provide mechanisms for synchronizing OpenGL operations with ML operations, as well as for initiating asynchronous OpenGL operations.

Stream / Buffer Swap Synchronization

In addition to the UST and MSC counters described previously in the ML specification, a new counter, the Swap Buffer Counter or SBC, is defined by OpenGL. The SBC is a per-window quantity initialized to zero and incremented when a buffer swap is initiated by the graphics driver.

The MSC is incremented by the graphics driver at the time the first scan line of the display begins passing through the video output port. For a non-interlaced display, this means that the MSC value is incremented at the beginning of each frame. For an interlaced display, it means that the MSC value is incremented at the beginning of each field.

Mechanisms are provided for querying the UST, MSC, and SBC counters; scheduling buffer swaps when a specified MSC value is reached (e.g. synchronizing buffer swaps to vertical retrace); and blocking execu-

tion until a specified MSC value is reached. These functions are implemented via the **WGL_OML_sync_control** extension for OpenML implementations running under Microsoft Windows, and via the **GLX_OML_sync_control** extension for OpenML implementations running under the X Window System.

Querying UST, MSC, and SBC

To query the current UST / MSC / SBC triple under Windows, call

BOOL wglGetSyncValuesOML(HDC *hdc*, INT64 **ust*, INT64 **msc*, INT64 **sbc*)

Under X, call

Bool glXGetSyncValuesOML(Display **dpy*, GLXDrawable *drawable*, int64_t **ust*, int64_t **msc*, int64_t **sbc*)

Getting the MSC Rate

To query the MSC rate for the OpenGL display device under Windows, call

BOOL wglGetMscRateOML(HDC *hdc*, INT32 **numerator*, INT32 **denominator*)

Under X, call

Bool glXGetMscRateOML(Display **dpy*, GLXDrawable *drawable*, int32_t **numerator*, int32_t **denominator*)

These functions return the rate at which the MSC will be incremented for the OpenGL display device.. The rate is expressed in Hertz as *numerator* / *denominator*. If the MSC rate in Hertz is an integer, then *denominator* will be 1 and *numerator* will be the MSC rate.

Scheduling Buffer Swaps

To schedule buffer swaps at a specified MSC value under Windows, call

INT64 wglSwapBuffersMscOML(HDC *hdc*, INT64 *target_msc*, INT64 *divisor*, INT64 *remainder*)

Under X, call

int64_t glXSwapBuffersMscOML(Display **dpy*, GLXDrawable *drawable*, int64_t *target_msc*, int64_t *divisor*, int64_t *remainder*)

These swap buffer functions do not perform an implicit **glFlush**. Instead, the indicated swap will not occur until all prior rendering commands affecting the buffer have been completed. Then, if the current MSC is less than *target_msc*, the buffer swap will occur when the MSC value becomes equal to *target_msc*. Alternatively, if the current MSC is greater than or equal to *target_msc*, the buffer swap will occur the next time the MSC value is incremented to a value such that MSC mod *divisor* = *remainder*. If *divisor* = 0, the swap will occur when MSC becomes greater than or equal to *target_msc*.

Under Windows (but not X), an additional scheduling function is defined

INT64 wglSwapLayerBuffersMscOML(HDC *hdc*, INT *fuPlanes*, INT64 *target_msc*, INT64 *divisor*, INT64 *remainder*)

The behavior of **wglSwapLayerBuffersMscOML** is identical to **wglSwapBuffersMscOML**, except that only the layers of the window specified by *fuPlanes* are swapped. *fuPlanes* has the same meaning as the corresponding parameter of **wglSwapLayerBuffers**.

Blocking on MSC

To block execution until a specified MSC value under Windows, call

BOOL wglWaitForMscOML(HDC *hdc*, INT64 *target_msc*, INT64 *divisor*, INT64 *remainder*, INT64 **ust*, INT64 **msc*, INT64 **sbc*)

Under X, call

Bool glXWaitForMscOML(Display **dpy*, GLXDrawable *drawable*, int64_t *target_msc*, int64_t *divisor*, int64_t *remainder*, int64_t **ust*, int64_t **msc*, int64_t **sbc*)

target_msc, *divisor*, and *remainder* have the same meaning as when scheduling buffer swaps. However, instead of swapping buffers, these functions simply wait until the specified MSC value has been reached and then return the current values of UST, MSC, and SBC.

Blocking on SBC

To block execution until a specified SBC value under Windows, call

BOOL wglWaitForSbcOML(HDC *hdc*, INT64 *target_sbc*, INT64 **ust*, INT64 **msc*, INT64 **sbc*)

Under X, call

Bool glXWaitForSbcOML(Display* *dpy*, GLXDrawable *drawable*, int64_t *target_sbc*, int64_t **ust*, int64_t **msc*, int64_t **sbc*)

These functions wait until the *target_sbc* value for the specified window has been reached and then return the current values of UST, MSC, and SBC. If the current SBC is already greater than or equal to *target_sbc*, they return immediately. If *target_sbc* is 0, they wait until all previous swaps requested with **wglSwapBuffersMscOML** or **glXSwapBuffersMscOML** for the specified window have completed, then return.

The full WGL and GLX extension specifications for **WGL_OML_sync_control** and **GLX_OML_sync_control** are included in Appendix A.

Rasterization and Texturing

The OpenGL functionality described here provides extended control over the pixel transfer pipeline, as well as control over certain aspects of texturing behavior.

Imaging Functions

The optional **GL_ARB_imaging** functionality of OpenGL 1.2, referred to as the *imaging subset*, adds operations enabling simple image processing operations in the pixel transfer pipeline. These functions include:

- RGBA color table lookup near the start of pixel transfer operations.
- Convolutions using either one-dimensional, separable, or two-dimensional filter kernels. Convolution border modes controlling filtering behavior at image borders.
- RGBA color table lookup following convolution.
- Arbitrary 4x4 color matrix transformation of pixel color components, useful for reassigning and duplicating components, as well as performing simple color space conversions.
- RGBA color table lookup following color matrix transformation.
- Histogram and min/max statistics gathering following all other pixel transfer operations.

The imaging subset also adds new fragment blending functions including a constant blend color input parameter specified by the application, min/max functions, and functions to subtract one blend color from another.

The imaging subset specification is included in the OpenGL 1.2 Specification.

Texture Border Clamping

The **GL_ARB_texture_border_clamp** extension enables additional control of texture filtering behavior at texture borders.

To change filtering behavior, call

void glTexParameteri(GLenum *target*, GLenum *pname*, GL_CLAMP_TO_BORDER_ARB)

Where *target* specifies the texture target and *pname* specifies the texture coordinate to affect (`GL_TEXTURE_WRAP_S`, `GL_TEXTURE_WRAP_T`, or `GL_TEXTURE_WRAP_R`). Afterwards, texture coordinates will be clamped such that the texture filter always samples border texels for fragments whose corresponding texture coordinate is sufficiently far outside the range [0,1]. The color returned when clamping is derived only from the border texels of the texture image, or from the constant border color if the texture image does not have a border.

The full OpenGL extension specification for **GL_ARB_texture_border_clamp** is referenced in Appendix A.

Texture Color Mask

The **GL_SGIS_texture_color_mask** extension allows applications to update a subset of components in an existing texture during texture downloads, just as **glColorMask** allows applications to update only a subset of components in the frame buffer during rendering.

To change the texture color mask, call:

GLvoid glTextureColorMaskSGIS(GLboolean *r*, GLboolean *g*, GLboolean *b*, GLboolean *a*)

The *r*, *g*, *b*, and *a* parameters indicate whether R, G, B, and A texture components, respectively, are written. A value of `GL_TRUE` means the component is written; a value of `GL_FALSE` means it is not. Initially each mask value is `GL_TRUE`. If the base internal format of the texture has a luminance component instead of RGB components, then the *r* parameter controls whether the luminance component is written.

The full OpenGL extension specification for **GL_SGIS_texture_color_mask** is referenced in appendix A.

Texture Level of Detail Bias

The **GL_EXT_texture_lod_bias** extension affects texturing by adding an additional, user specified offset to the calculated level of detail prior to selecting the mipmap level(s) to be used for texture filtering.

To change the bias, call

glTexEnvf(TEXTURE_FILTER_CONTROL_EXT, TEXTURE_LOD_BIAS_EXT, GLfloat *bias*)

bias specifies the offset (positive or negative) to be added to the calculated level of detail.

The full OpenGL extension specification for **GL_EXT_texture_lod_bias** is referenced in Appendix A.

SECTION

IV

MLDC VIDEO DISPLAY INQUIRY AND CONTROL

Description

MLdc stands for “ML Display Control”. MLdc is an application programming interface meant to control the display of video streams in a system. It is a key component of the OpenML interface standard and provides application developers a portable and powerful control API over video output devices, some of which may not be available through the native windowing environment. The display may be a desktop screen or another device such as a special studio monitor. The control of such devices includes setting the refresh rate, setting the pixel resolution, setting the external synchronization (genlock), and setting gamma correction lookup tables.

CHAPTER

13

OVERVIEW OF MLDC

The OpenML Display Control API (MLdc) provides an interface to initialize, set and change parameters to control video output devices (see Figure 13.1). A video output device generates and controls the video streams coming out its video output ports. Such a video stream is usually meant for immediate display, typically on a physical monitor. The video output device controlled by MLdc may or may not be known about by the native windowing system. MLdc also facilitates communication to and from monitors capable of sending and receiving commands.

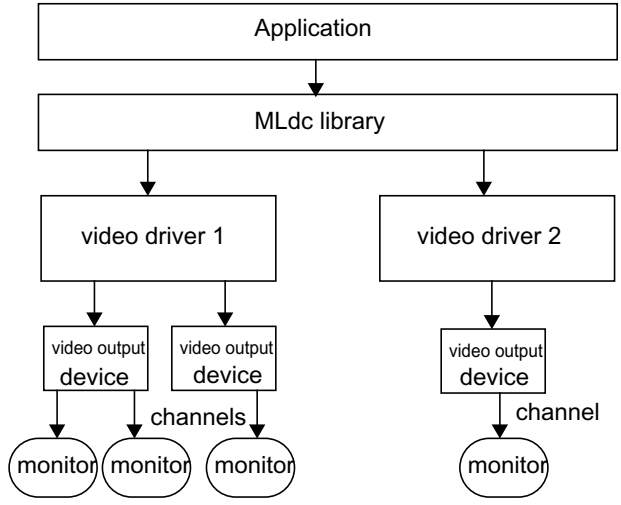


Figure 13.1 MLdc and Video Output Devices

Components of the MLdc

The MLdc is based on the following components:

- A mechanism to query the presence of MLdc controlled video output devices in a system, and initialize them.
- A mechanism to set and query controls of the video output device.
- Messages, passed from the video device to the application.
- A queuing system for buffering messages received from the video output device.
- A mechanism to communicate with a monitor that has the capability to send and receive commands.
- An extension mechanism that enables vendors to write their own API extensions to MLdc.
- A remote protocol that allows applications to connect to a video output device on a different system than the one the application is running on.

Terminology

Various MLdc concepts and terminology used in later chapters are explained in this section.

MLdc organizes a system's video topology into two levels, video output devices and channels. There are one or more channels per video output device (see Figure 13.1).

Video Output Device

A video output device generates and controls video streams. Each video output device controls one or more channels (see Figure 13.2). What MLdc enumerates as a single video output device does not necessarily correlate to an OS or native windowing system view of the same hardware, especially in multi-monitor configurations.

Display area

A display area is associated with each video output device. It is the source for all the video streams that a single video output device generates and controls (see Figure 13.2). A display area is addressable using a single rectangular coordinate system.

Channels

MLdc associates one channel with each output of a video output device. A channel carries a rectangular subregion of the display area for its video device, called a channel input rectangle (see Figure 13.2). Multiple channels can exist within the display area, each potentially running with independent video formats, gamma ramps, and synchronization sources. Channel input rectangles can overlap, either partially or entirely, in display area space. Currently, MLdc only supports one monitor per channel.

Gamma Correction

Many video output devices have color lookup tables associated with them that allow the application to programmatically adjust for differences in monitor color phosphor response (see Figure 13.2). These color

tables are commonly referred to as gamma correction tables because the color ramp that is loaded into them follows a mathematical gamma function curve that is adjusted to fit the monitor. A given MLdc-controlled monitor may or may not have gamma-correction tables available for it. MLdc provides functions for setting and querying the contents of such tables.

Genlock

The term *genlock* is used to describe the act of synchronizing the refresh of a computer video monitor with some outside time pulse (see Figure 13.2). MLdc allows the application to turn genlock on/off and to specify one of several possible sources for the synchronization signal. The application can also adjust the *reaction time* to the genlock signal, a delay or advance of the video refresh by some small amount so that dissimilar devices can appear to run in sync. On some devices, genlock capabilities may be channel specific, while on other devices, genlock may be a global setting affecting all channels.

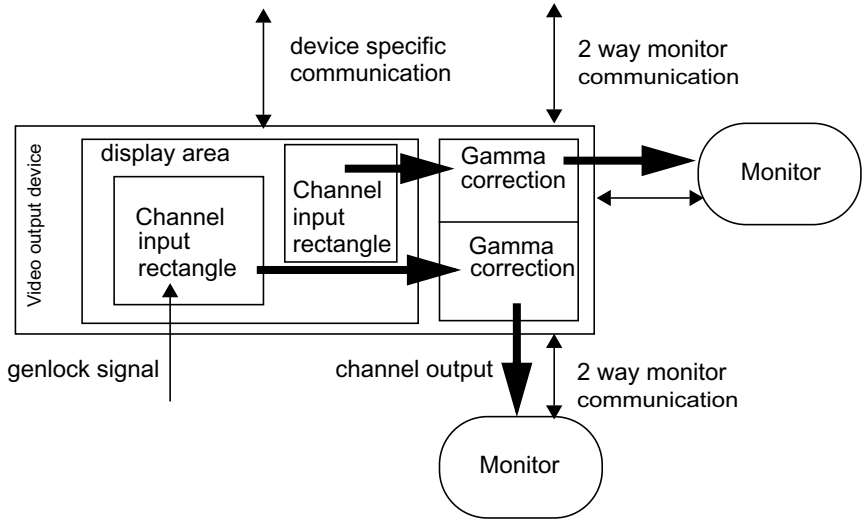


Figure 13.2 A Video Output Device with a Display Area, Channels, Genlock and Gamma Correction

Initialization

MLdc is capable of running over a protocol. Therefore, an application that uses MLdc will first have to establish a connection to the system with the video output device that is going to be controlled (see Figure 13.3). This is done through **mldcConnect**. After a connection is established to a system, a list of MLdc compatible devices on that system can be obtained by calling **mldcQueryAvailableDevices**. The capabilities of each device can then be queried using **mldcQueryVideoDeviceInfo**. Once a suitable device is found, it needs to be opened using **mldcOpen**, which returns a handle `hOutDev` to the device. The device is now ready for use by the application. This handle is used in most other MLdc calls. The capabilities of the monitor connected to a channel on `hOutDev` can be queried using **mldcQueryMonitorCapabilities**. See Chapter 14, "Initialization", for more details on the initialization steps.

Set calls are used to change video display parameters of the video output device. These calls are not queued. However, the device's completion of the set call is asynchronous, and may take a few seconds to complete. For example, changing the screen resolution. For this reason, the set functions initiate the parameter change, and then return, potentially before the change actually happens. All of the video display parameters that can be set can also be queried (see Figure 13.3). Querying is done synchronously and the query information is returned in one or more arguments of the query function. Most of the query functions allocate the memory in which information is to be returned. The application is responsible for freeing the memory, by calling **mldcFree**¸ once the information is no longer needed.

Events and Messages

When the application asks MLdc to set video display parameters, the system will eventually complete the request, and asynchronously send a completion message (or event or event message) back to the application (see Figure 13.3). The message is usually one of success or failure. Event messages are queued up in a receive queue by the video output device. The application can select which event messages, if any, it wants to receive, by calling **mldcSetEventMask**. It reads the event message from the queue using **mldcReceiveMessage**. OS and windowing specific mechanisms are used to indicate if the receive queue has any event messages in it. In addition, the system may also send special "genlock acquired" or "genlock lost" messages to the application. These are not necessarily the direct result of an MLdc function call, but are the result of activities on the system outside of the control of the application.

Errors

MLdc functions return an immediate MLDCstatus value. If the function returns without encountering an error the function will return **MLDC_STATUS_NO_ERROR**. In the event that a function encounters an error before returning, then the return code will indicate an error.

Several error status values are implicit for many or all MLdc routines: **MLDC_STATUS_INVALID_ARGUMENT** is returned if any arguments are invalid pointers. **MLDC_STATUS_INVALID_SYSTEM_HANDLE** is returned if a system handle is invalid. **MLDC_STATUS_INVALID_DEVICE** is returned if a device handle is invalid. **MLDC_STATUS_INVALID_CHANNEL** is returned if a channel number is invalid.

Some MLdc functions set in motion changes to the hardware state that will occur after the function returns. If an error occurs as part of this asynchronous processing then an error event message will be returned to the application via the event messaging mechanism. Error events may not be masked off by the application. Therefore, the application will always have to monitor the receive queue. The various possible error event messages are also described with each individual function in later chapters.

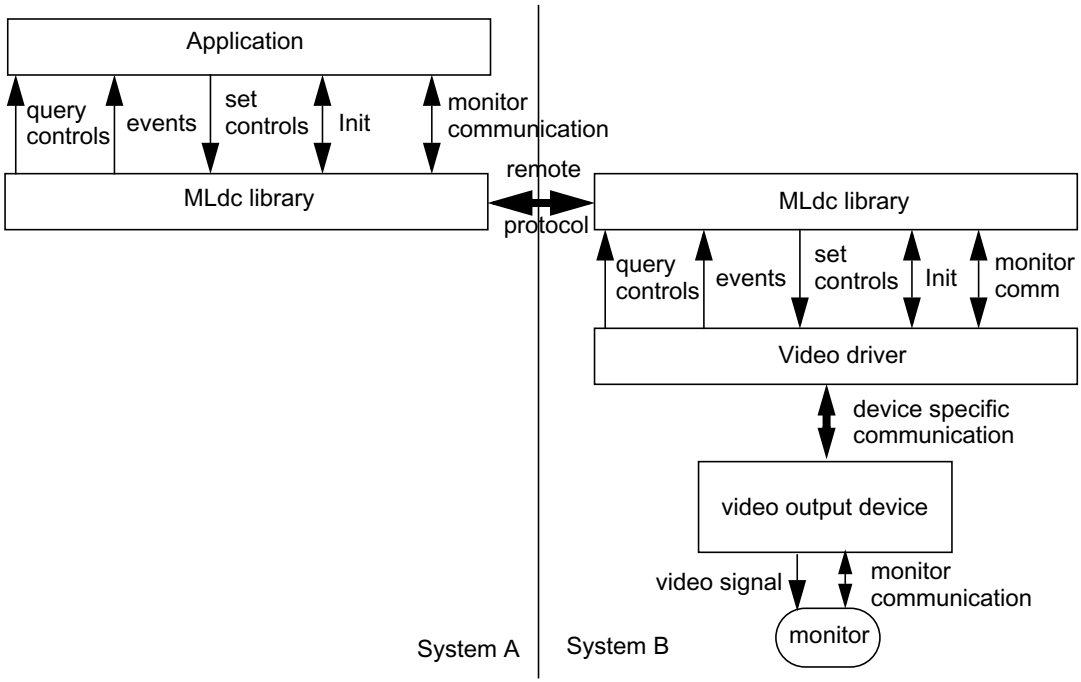


Figure 13.3 Communication Between the Application and MLdc

Monitor Communication

MLdc facilitates communication between the application and a physical monitor (see Figure 13.3). Applications are responsible for assembling the commands, and parsing the result from the monitor. MLdc acts as a transport layer only. Commands are sent using **mldcSendMonitorCommand**. If a response is expected, applications should use **mldcSendMonitorQuery**, which sends a command and waits for an answer.

For more information, see Chapter 15, "Setting and Querying Video Parameters", Chapter 16, "Receiving MLdc Event Messages" and Chapter 24, "Monitor Commands".

Extensions to MLdc

MLdc can be extended by vendor specific API entry points. This allows vendors to expose unique functionality through the MLdc API in a consistent way. The naming of extensions and querying of the existence of a particular extension is analogous to the OpenGL model. **mldcQueryExtensionNames** returns a space-seperated list of extension names. **mldcQueryExtensionPtr** returns the address of the extension. Additionally, MLdc provides a convenience function, **mldcIsExtensionSupported**¸ which can be used to determine if a particular extension is supported on the specified video out device.

CHAPTER

14

INITIALIZATION

Initializing MLdc

All applications that use the MLdc library to control a video output device on a specified host system must first initialize the library for that system by calling **mldcConnect.** This function performs any internal setup necessary, and must be called first before calling any other MLdc function. **mldcConnect** must be called once for each host system that has video output devices that the application wishes to control.

mldcConnect

```
MLDCstatus mldcConnect(MLDCchar *hostID,
                       MLDChandle *systemHandle)
```

hostID
: The *hostID* argument is a character string that has the format *host:display.screen*. On Unix systems, *host:display* specifies the X Server to connect to. The additional *screen* field specifies a particular screen of the desired X Server. If the host name is omitted, i.e *hostID* is NULL, the default display on the local host is initialized. Examples of valid *hostID* strings on Unix systems are “myhost:1”, “foo:0.1”, “:2”, and “:0.0”. On Windows systems, *hostID* must be the local host, i.e. NULL.

systemHandle
: This is a return argument. If MLdc can be successfully initialized for the target system defined by the *hostID* argument then a valid system handle is returned in *systemHandle*.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If the function fails it may mean that the versions of internal software do not match and the function will return one of the following. If the version of the device independent library is not compatible with the device dependent library or with the device driver, the function will return **MLDC_STATUS_INVALID_LIBRARY_VERSION.** If the version of the device dependent library is not compatible with the device driver, then the function will return **MLDC_STATUS_INVALID_DRIVER_VS_DDLIB_VERSION**. If the function was not able to establish a connection to the device specified by *hostID*, then the function will return **MLDC_STATUS_CONNECTION_FAILURE**.

The function **mldcConnect** must be the first MLdc function that is called by the application. If any other MLdc function call is made first, the results will be undefined.

On X Windows systems running multiple MLdc-compliant X servers, an application can use **mldcConnect** to connect with any MLdc-compliant X server. The resulting *systemHandle* can then be passed to **mldcQueryAvailableDevices**, which will return a list of all MLdc devices on the system. The set of devices in the list will be the same, regardless of which MLdc-compliant X server the connection is made through. The order of the devices may be different for different X server connections, but the first entry in the array returned by **mldcQueryAvailableDevices** will always match the string used in the call to **mldcConnect**.

Freeing Memory Allocated by MLdc

Several MLdc functions and operations generate messages or information, the memory for which is allocated by MLdc. The application is responsible for freeing the allocated memory by using the following function:

mldcFree

```
MLDCstatus mldcFree(void *memPtr);
```

The *memPtr* argument is a pointer to the memory to be freed. If the function is successful, it will return **MLDC_STATUS_NO_ERROR**. If the memPtr argument is not a valid pointer the function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Finding MLdc Video Output Devices

In order to obtain a list of the devices that are available and controlled by MLdc on a given system, the function **mldcQueryAvailableDevices** is called.

mldcQueryAvailableDevices

```
MLDCstatus mldcQueryAvailableDevices(MLDChandle systemHandle,
                    MLDCint32 *numOutDevs,
                    MLDCchar ***outDevNames)
```

systemHandle
: This argument is a system handle obtained from a call to **mldcConnect**.

numOutDevs
: Returns the number of available video output devices on the system that are controllable via MLdc.

outDevNames
: Returns an array of character strings giving a name to each video output device. The first entry in the array will always match the string that is used in the call to **mldcConnect**. Subsequent names on the list will follow the following convention. If the device is known about by the windowing system, then the device name will be the same name used to initialize the device in the call to **mldcConnect** by following the “hostname:display” convention. If the device is not known about by the windowing system, then the name is vendor-specific and may be any descriptive string.

The memory allocated for *outDevNames* is allocated by the function and should be freed by the application by calling **mldcFree** when the information is no longer needed.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If the *systemHandle* argument if not a valid system handle, the function will return **MLDC_STATUS_INVALID_SYSTEM_HANDLE**. If any of the other arguments are invalid pointers, the function will return **MLDC_STATUS_INVALID_ARGUMENT**.

If no errors are encountered, but there are no MLdc devices on the system, *numOutDevs* will be 0 and **outDevNames* will be NULL, and the function will return **MLDC_STATUS_NO_ERROR.**

Note that on any given system there may be several video output devices that are controllable via MLdc. These video output devices may be from different vendors. It is possible that not all of these video output devices are known about by the windowing system.

Opening and Closing an MLdc Video Output Device

In order to set or query any video parameters for a given video output device, the application must first open the device for communication with it. This is accomplished by calling the function **mldcOpen.**

mldcOpen

```
MLDCstatus mldcOpen(MLDCchar *outDevName,
                    MLDChandle *hOutDev)
```

outDevName
: Points to a string containing the name of the video output device to open. The name is one of the strings returned from the **mldcQueryAvailableDevices** function, and may be vendor-specific.

hOutDev
: A pointer to a handle for the video output device that was named in *outDevName*.

This function opens the named device and returns a handle to be used in all further MLdc function calls to access the device. When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *outDevName* is not a valid name for an available device, the function will return **MLDC_INVALID_DEVICE_NAME**. If *hOutDev* is not a valid pointer, the function will return **MLDC_STATUS_INVALID_ARGUMENT**. The function may also fail with **MLDC_STATUS_INVALID_LIBRARY_VERSION** if the DI and DD library versions are not compatible, or with **MLDC_STATUS_INVALID_DRIVER_VS_LIB_VERSION** if either library version is not compatible with the device driver version.

mldcClose

When the application is finished with a given video output device, the device should be closed using the following function:

```
MLDCstatus mldcClose(MLDChandle hOutDev)
```

hOutDev
: A handle to the video output device to be closed.

The function **mldcClose** closes the specified device.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. When the function fails, the return value will be **MLDC_STATUS_INVALID_DEVICE.**

Checking the MLdc Version

After initializing MLdc, all applications should verify that each video output device of interest has MLdc properly installed at the correct version level. The function **mldcQueryVersion** will return the major and minor library revision for MLdc. This specification defines version 1.0 of MLdc, major version 1, minor version 0.

mldcQueryVersion

```
MLDCstatus mldcQueryVersion(MLDChandle hOutDev,
                            MLDCint32 *di_major,
                            MLDCint32 *di_minor,
                            MLDCint32 *dd_major,
                            MLDCint32 *dd_minor,
                            MLDCint32 *driver_major,
                            MLDCint32 *driver_minor)
```

hOutDev
: Gives the handle to the video output device in question.

di_major
: Returns the MLdc major version number of the device independent library.

di_minor
: Returns the minor number of the device independent library.

dd_major
: Returns the MLdc major version number of the device dependent library.

dd_minor
: Returns the minor number of the device dependent library.

driver_major
: Returns the MLdc major version number of the device driver.

driver_minor
: Returns the minor number of the device driver.

If this function succeeds, **MLDC_STATUS_NO_ERROR** will be returned. If *hOutDev* is not a valid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE**. If any of the other arguments are invalid pointers, the function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Acquiring Information About the Video Output Device

Before doing any control of the video display, the application will need to query the video display hardware for its abilities. There are two functions that supply video hardware display information at the video output device level:

mldcQueryVideoDeviceInfo returns the number of supported channels, external sync ports, and genlock capabilities.

mldcQueryMonitorCapabilities returns the VESA standard E-EDID string from the physical monitor.

mldcQueryVideoDeviceInfo

This function returns a structure containing information about the video output device and its capabilities.

```
MLDCstatus mldcQueryVideoDeviceInfo(MLDChandle hOutDev,
                    MLDCvideoDeviceInfo *sinfo_return)
```

hOutDev
Handle of an MLdc video output device.

sinfo_return
A pointer to the **MLDCvideoDeviceInfo** structure that is to receive the corresponding information.

Description

mldcQueryVideoDeviceInfo returns in **sinfo_return* an **MLDCvideoDeviceInfo** structure containing video device information for a specified video output device, shown below:

```
typedef struct {
  MLDCint32       numChannels;        /* Number of output channels */
  MLDCboolean     lockOp;             /* mldcSetInputSyncSource usable */
  MLDCchar        graphicsType[MLDC_NAME_SIZE];    /* Name of gfx hw */
  MLDCint32       numExternalSync;    /* Num of external sync ports */
} MLDCvideoDeviceInfo;
```

In the above structure, the fields are defined as follows:

numChannels
Specifies the number of output channels on this video output device. The caller may use set or query operations on channels numbering 0 to *numChannels* - 1.

lockOp
Describes whether the video output device has the capability to lock to external sync sources via the **mldcSetInputSyncSource** function.

graphicsType
Contains a null-terminated ASCII string containing the name of the graphics hardware type. The name is unique for each type of graphics hardware.

numExternalSync
Contains the number of external sync sources.

This function returns **MLDC_STATUS_NO_ERROR** if successful. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *sinfo_return* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryMonitorCapabilities

This function returns information about the physical monitor and its capabilities.

```
MLDCstatus mldcQueryMonitorCapabilities(MLDChandle hOutDev,
                                        MLDCint32 channel,
                                        void **monitorCaps)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

monitorCaps
Returned address of a structure that gives the capabilities of the physical monitor in question. The information is in the format specified by the document “VESA Enhanced Extended Display Identification Data Standard” available from the VESA standards body. The specification is also referred to as the “E-EDID Standard”. A description of the standard and the data in the structure can be obtained from VESA (the Video Electronics Standards Association).

Description

This function will allocate and return to the client application a structure giving the capabilities of the specific physical monitor in question. The video output device is specified by passing the MLdc video output device handle and channel number that the physical monitor is connected to. Once the information has been received, the application should free the memory by calling **mldcFree.**

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *monitorCaps* is not a valid pointer this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

15

SETTING AND QUERYING VIDEO PARAMETERS

Setting Parameters

Video display parameters are changed via one of the several *Set* functions supplied by MLdc. Most of the parameters map to actual hardware characteristics of the display device. The parameters are most often set asynchronously because some changes may take a relatively long time to occur. For example, changing the screen resolution will often take a few seconds to accomplish. For this reason, the *Set* functions initiate the parameter change and return, perhaps before the event actually happens. Later, the application is notified that the change has occurred via the MLdc event-messaging queue.

The following table of functions set video parameters and will be discussed in detail later in this document. Along with each function is listed the event message that will eventually be returned to the application.

Set Functions	Event Message Type
mldcEnableChannel	**MLDC_VIDEO_FORMAT_NOTIFY**
mldcLoadVideoFormat	**MLDC_VIDEO_FORMAT_NOTIFY**
mldcLoadVideoFormatByName	**MLDC_VIDEO_FORMAT_NOTIFY**
mldcSendMonitorCommand	(none)
mldcSetChannelGammaMap	**MLDC_GAMMA_MAP_NOTIFY**
mldcSetChannelInputRectangle	**MLDC_CHANNEL_INPUT_RECTANGLE_NOTIFY**
mldcSetExternalSyncSource	**MLDC_INPUT_SYNCSOURCE_NOTIFY**
mldcSetInputSyncSource	**MLDC_INPUT_SYNCSOURCE_NOTIFY** **MLDC_LOCK_STATUS_CHANGE_NOTIFY**
mldcSetOutputBlanking	**MLDC_OUPUT_BLANKING_NOTIFY**
mldcSetOutputGain	**MLDC_OUTPUT_GAIN_NOTIFY**
mldcSetOutputPedestal	**MLDC_OUTPUT_PEDESTAL_NOTIFY**
mldcSetOutputPhaseH	**MLDC_OUTPUT_PHASE_H_NOTIFY**
mldcSetOutputPhaseSCH	**MLDC_OUTPUT_PHASE_SCH_NOTIFY**
mldcSetOutputPhaseV	**MLDC_OUTPUT_PHASE_V_NOTIFY**

Table 15.1 MLdc Event Message Types

Set Functions	Event Message Type
mldcSetOutputSync	**MLDC_OUTPUT_SYNC_NOTIFY**
mldcStoreGammaColors16	**MLDC_GAMMA_MAP_NOTIFY**
mldcStoreGammaColors8	**MLDC_GAMMA_MAP_NOTIFY**

Table 15.1 MLdc Event Message Types

Querying Video Parameters

All of the video display parameters that can be *Set* can also be *Queried*. Unlike the *Set* process, the *Query* process is done synchronously and the query information is returned in one or more arguments of the *Query* function.

Freeing Query Return Buffers

Most of the *Query* functions allocate memory in which to return information. The application is responsible for freeing the memory once the information has been copied or is no longer needed by calling the function **mldcFree**.

CHAPTER

16

RECEIVING MLDC EVENT MESSAGES

Selecting the Event Messages to Receive

The application may not be interested in receiving each of the event messages that are possible when setting video parameters. The default is that ***none*** of the event messages will be sent back to the application. The application must choose the events that it is interested in via a call to **mldcSetEventMask***:*

mldcSetEventMask

```
MLDCstatus mldcSetEventMask(MLDChandle hOutDev,
                            MLDCbitfield message_mask)
```

hOutDev
: Specifies the handle of the MLdc video output device.

message_mask
: Specifies a mask of values OR'd together to produce a value giving the events of interest to the application.

In this function the application indicates the messages that it is interested in receiving for a given video output device. The video output device of interest is specified by the *hOutDev* argument. The *message_mask* argument is a mask of bits OR'd together from the following constants:

MLDC_NONE_MASK
MLDC_VIDEO_FORMAT_NOTIFY_MASK
MLDC_CHANNEL_INPUT_RECTANGLE_NOTIFY_MASK
MLDC_INPUT_SYNCSOURCE_NOTIFY_MASK
MLDC_LOCK_STATUS_CHANGE_NOTIFY_MASK
MLDC_OUPUT_BLANKING_NOTIFY_MASK
MLDC_OUTPUT_GAIN_NOTIFY_MASK
MLDC_OUTPUT_PEDESTAL_NOTIFY_MASK
MLDC_OUTPUT_PHASE_H_NOTIFY_MASK
MLDC_OUTPUT_PHASE_SCH_NOTIFY_MASK
MLDC_OUTPUT_PHASE_V_NOTIFY_MASK

MLDC_OUTPUT_SYNC_NOTIFY_MASK
MLDC_GAMMA_MAP_NOTIFY_MASK

Each call to **mldcSetEventMask** replaces the previous settings for the specified video output device. That is, the results of calling this function multiple times are not cumulative.

If the function is successful, it will return **MLDC_STATUS_NO_ERROR**. Otherwise, the function will return **MLDC_STATUS_INVALID_DEVICE**.

mldcQueryEventMask

```
MLDCstatus mldcQueryEventMask(MLDChandle hOutDev,
                              MLDCbitfield *messageMask)
```

hOutDev
Specifies the handle for the MLdc video output device.

messageMask
Specifies a pointer to a variable that will receive the current event mask as an output of this function.

If the function is successful, it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *messageMask* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Receiving an Event Message

There are two available methods of receiving MLdc events within an application. First, the application may receive the events via the native windowing system event handling mechanism. In this method, MLdc events are integrated with the native windowing system events, and native windowing system functions are used to wait for and retrieve the events. In the second method, the application may receive MLdc events via the MLdc event queue using window system independent MLdc functions. The application can choose which method to use by calling the **mldcSetEventModel** function. Application writers concerned with maximizing application portability should use the window system independent MLdc functions.

mldcSetEventModel

```
MLDCstatus mldcSetEventModel(MLDCeventModel eventModel)
```

eventModel
This argument sets the event model to either **MLDC_NATIVE_EVENTS** or **MLDC_MLDC_EVENTS**:

Event Model	*Description*
MLDC_NATIVE_EVENTS	The events generated by MLdc are integrated with the native windowing system. The user must use the native windowing toolkit to wait for and retrieve the events. Note that **mldcSetEventMask**() must still be used to select which events will be sent by MLdc. Applications using the Windows native messaging queues for MLdc events will need to call one or more special MLdc functions to set up messaging parameters, described below. Applications that use the native X Window System event mechanism will need no additional MLdc function calls to setup the X Window System event mechanism.
MLDC_MLDC_EVENTS	MLdc will create its own event loop to capture events and return them to the application in a windowing system independent fashion.

Table 16.1 Event Model Types

Note that this function call sets the MLdc event-handling method for the application for all devices and systems that it is interacting with. It therefore takes no system handle argument or device handle argument.

The default setting for the method is **MLDC_NATIVE_EVENTS.**

If the function is successful, it will return **MLDC_STATUS_NO_ERROR**. Otherwise, the function will return **MLDC_STATUS_INVALID_EVENT_MODEL**.

Receiving MLdc Events Through Native Windowing Systems

If the application desires to handle MLdc events via the native windowing system event message mechanism there are some differences in MLdc setup functions between Windows and the X Window System. However, both of these windowing systems return MLdc event messages using a single MLdc event message type with the MLdc specific events seen as sub-types of the MLdc event. To get the MLdc event type an application will need to call the following function:

mldcQueryEventId

This function will return the native windowing system's event ID that will be the message type for all MLdc events that are returned to the application. When the application reads messages from the windowing system's message queue it will need to look for this ID as the message type for all MLdc events. Each MLdc event message will additionally contain the MLdc message structure described below which includes the MLdc message type.

```
MLDCstatus mldcQueryEventId(MLDCeventId *eventId)
```

eventId
: This argument will return the native windowing system's message ID for all MLdc events that are returned to the application.

This function is only viable when **MLDC_NATIVE_EVENTS** has been previously chosen in a call to **mldcSetEventModel**. Otherwise, this function call will have no effect and will always return **MLDC_STATUS_INVALID_EVENT_MODEL**. If this function is successful in returning a valid event Id, it will return **MLDC_STATUS_NO_ERROR**.

Receiving MLdc Events Via the X Window System

The X client will need to first make the MLdc function calls **mldcSetEventModel** and **mldcQueryEventId** described above. Following those calls, the X Window System mechanism can be used without any extra function support from MLdc. MLdc event types given above in Table 15.1 (the table of MLdc **Set** functions and the events that they return) are treated as subtypes and found in the event-specific fields that are part of the X event structure. Specifically, the MLdc type is found in the **mldcType** field of each MLdc event structure. MLdc event structures are defined and appended to the XEvent structure for each particular event. The individual structures are described in the specific description of MLdc events given below.

Receiving an Event Message Via Windows Messages

Windows applications will need to first make the MLdc function calls **mldcSetEventModel** and **mldcQueryEventId** described above. When an MLdc event is received on the Windows message queue, the MLdc event message structure will be pointed at by the “lparam” pointer in the Windows **MSG** message structure.

To use the Windows native messaging mechanism an extra function is required:

mldcSetWindowsMessageQueue

When using the Windows messaging queue to receive MLdc events on Windows systems, the following function is necessary to provide a way for the application to give MLdc the window handle of the window message queue that the application wants MLdc events delivered to.

`MLDCstatus mldcSetWindowsMessageQueue(HWND` *`hwnd`***`)`**

hwnd
: The handle of the window whose message queue MLdc events will be returned to on Windows systems.

If the application never makes this function call then all MLdc messages will be sent to the thread message queue of the thread that called **mldcConnect**.

This function is only viable on a Windows system. On a system using another windowing system this function call will have no effect and will always return **MLDC_INVALID_EVENT_MODEL**.

If this function is successful in returning a valid event ID, it will return **MLDC_STATUS_NO_ERROR**. If *hwnd* is not a valid window handle, it will return **MLDC_INVALID_WINDOW**.

Receiving An Event Message Via MLdc Messaging

mldcGetReceiveQueueWaitHandle

In order to receive an event message on the MLdc event queue the application must first obtain an event handle upon which it can wait to receive a message from the message queue. This event handle is obtained by calling **mldcGetReceiveQueueWaitHandle**:

`MLDCstatus mldcGetReceiveQueueWaitHandle(MLDChandle *`*`hEvent`***`)`**

`hEvent`
Specifies a pointer to a handle where the function can return an event handle that can be used to wait for an event message.

The *`hEvent`* argument will return the handle of an event that can be used in a call to **WaitForMultipleObjects** on Windows systems or **select** on Unix systems.

When an event message is waiting to be read on a given video output device's message queue, the video output device will signal the event. The application will then return from the call to **WaitForMultipleObjects** or **select**.

This function should only be called when receiving MLdc event messages via the MLdc event message queue. If this function is called when the application has declared that it desires to use the windowing system native event handling mechanism, then this function will have no effect and will return **MLDC_STATUS_INVALID_EVENT_MODEL**. If the function succeeds, it will return **MLDC_STATUS_NO_ERROR**.

After an application has been notified that an event message has arrived in the MLdc event message queue the application can then obtain the event message by calling **mldcReceiveMessage**:

mldcReceiveMessage

`MLDCstatus mldcReceiveMessage(MLDCgenericEvent **`*`ppMsg`***`)`**

`ppMSG`
Specifies the address of a pointer to an **MLDCgenericEvent** message structure.

The memory needed for the message itself is allocated by MLdc and should be freed by the application by calling **mldcFree**. The structure **MLDCgenericEvent** is defined below.

```
/* The MLDCGenericEvent event structure is used to examine
** the mldcType field so that the event's real type can be
** determined.
*/
typedef struct _MLDCgenericEvent
{
  MLDCint32 mldcType;      /* Event type */
  MLDChandle hOutDev;      /* video output device of the event */
  MLDCint32 channel;       /* channel of the event */
} MLDCgenericEvent
```

mldcType is one of the event types in Table 15.1. An application can obtain additional information about the event by casting to one of the following event message data types according to the event type returned in *mldcType*. As such, **mldcGenericEvent** is used as a proxy structure whose fields are identical with the first few fields of all other event message structures.

The other message structures that are available are as follows:

```
typedef struct
{
  MLDCint32 mldcType;       /* MLDC_VIDEOFORMAT_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
} MLDCvideoFormatEvent;

typedef struct
{
  MLDCint32 mldcType;        /* MLDC_CHANNEL_INPUTRECTANGLE_NOTIFY */
  MLDChandle hOutDev;        /* video output device of the event */
  MLDCint32 channel;         /* channel of the event */
  MLDCrectangle rct;         /* set rectangle */
} MLDCchannelInputRectangleEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_INPUT_SYNCSOURCE_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 voltage;        /* nominal video voltage or TTL-level sync */
  MLDCint32 source;         /* internal or external genlock source */
} MLDCinputSyncSourceEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_BLANKING_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCboolean enable;       /* TRUE if blanking enabled */
} MLDCblankingEvent;
```

```
/* In the following event, the graphics device may not be able to
** report intervening instances of rapidly changing lock state
** and therefore may report two consecutive instances of the same
** state; client programs must check the value of the status
** variable to determine the state of the lock.
*/
typedef struct
{
  MLDCint32 mldcType;       /* MLDC_LOCK_STATUS_CHANGED_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 status;         /* achieved or lost genlock */
} MLDClockStatusChangedEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_OUTPUT_GAIN_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 component;      /* RGBA component */
  MLDCint32 value;          /* new gain value */
} MLDCoutputGainEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_PEDESTAL_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCboolean enable;       /* TRUE if pedestal is enabled */
} MLDCpedestalEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_PHASE_H_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 value;          /* horizontal phase new value */
} MLDCphaseHEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_PHASE_SCH_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 value;          /* subcarrier horizontal phase new value */
} MLDCphaseSCHEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_PHASE_V_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 value;          /* subcarrier vertical phase new value */
} MLDCphaseVEvent;
```

```
typedef struct
{
  MLDCint32 mldcType;       /* MLDC_OUTPUT_SYNC_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 syncPortIndex;  /* port index */
  MLDCint32 syncType;       /* sync type */
} MLDCoutputSyncEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_PLATFORM_PARAM_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 parameterId;    /* Id of the device specif parameter */
} MLDCplatformParamEvent;

typedef struct
{
  MLDCint32 mldcType;       /* MLDC_GAMMA_MAP_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event */
  MLDCint32 mapId;          /* gamma map Id number */
} MLDCgammaMapEvent;
```

Receiving Error Events

Error event messages are a special case of event message and require some explanation. Error events are generated asynchronously as MLdc commands are processed by the video output device or its attending device-specific software. While an MLdc function to set a video parameter may have been called and then successfully executed, the actual setting of the parameter in hardware may occur much later. During this delayed processing, an error may occur. The error event message provides a vehicle to report the error back to the application. While other event messages may be masked off by setting the event mask, error messages may not be masked off and will always be sent to the application.

Each event message has within it two fields for reporting a device channel and a device gamma map for which the error occurred. Not all errors will involve one of these objects. If an error has no associated channel or gamma map, then these fields will be set to **MLDC_NOT_APPLICABLE**.

Each event message also includes an *errorCode* field that returns an error code for the given error. Specific error codes are documented with the functions that can cause them.

Finally, each event message includes the name of the function that generated the original command that eventually experienced the error *if this name is available to the implementation*. The name is given as a null-terminated string in the *funcName* field of the error event message. If the name is not available then the field will be returned as a null string.

```
typedef struct
{
  MLDCint32 mldcType;       /* MLDC_ERROR_NOTIFY */
  MLDChandle hOutDev;       /* video output device of the event */
  MLDCint32 channel;        /* channel of the event, if applicable */
  MLDCint32 gammaMap;       /* gamma map of the event, if applicable */
  MLDCint32 errorCode;      /* error code of the error. */
  MLDCchar *funcName[MLDC_NAME_SIZE]; /* function name */
} MLDCerrorEvent;
```

CHAPTER

17

CHANNELS

Channel Structures

The following structures are used when querying and setting channel parameters and channel video formats.

MLDCrectangle

```
typedef struct
{
  MLDCreal32            x, y;
  MLDCreal32            height, width;
} MLDCrectangle;
```

Figure 17.1 The MLDCrectangle Structure

The fields of the **MLDCrectangle** structure are defined as follows:

x, y
: The location of the upper-left corner of the rectangle in video memory.

height, width
: The width and height of the rectangle in pixels.

MLDCchannelSyncInfo

```
typedef struct
{
  MLDCint32       syncPort;          /* Identifies the sync port */
  MLDCint32       *syncTypeList;     /* Identifies the sync type */
  MLDCint32       syncTypeListCount; /* Cnt of items in syncTypeList */
} MLDCchannelSyncInfo;
```

Figure 17.2 The MLDCchannelSyncInfo Structure

The fields of the **MLDCchannelSyncInfo** structure are defined as follows:

syncPort
Identifies the sync port. This can be one of the following:

MLDC_SP_RED	Enable sync on the red channel output connector
MLDC_SP_GREEN	Enable sync on the green channel output connector
MLDC_SP_BLUE	Enable sync on the blue channel output connector
MLDC_SP_ALPHA	Enable sync on the alpha channel output connector
MLDC_SP_AUX0	Enable sync on the auxiliary channel 0 connector
MLDC_SP_AUX1	Enable sync on the auxiliary channel 1 connector
MLDC_SP_AUX2	Enable sync on the auxiliary channel 2 connector

Table 17.1 Sync Port Selection Constants

syncTypeList
This is a pointer to an array of sync types. Each item represents one of the different sync output modes to which this sync port can be set, and contains one of the following:

MLDC_SF_NONE	No sync
MLDC_SF_HORIZONTAL_VIDEO	Horizontal sync video level
MLDC_SF_VERTICAL_VIDEO	Vertical sync video level
MLDC_SF_COMPOSITE_VIDEO	Composite sync video level
MLDC_SF_HORIZONTAL_TTL	Horizontal sync, TTL level
MLDC_SF_VERTICAL_TTL	Vertical sync, TTL level
MLDC_SF_COMPOSITE_TTL	Composite sync, TTL level
MLDC_SF_HORIZONTAL_TRILEVEL	Horizontal sync, tri-level
MLDC_SF_VERTICAL_TRILEVEL	Vertical sync, tri-level
MLDC_SF_COMPOSITE_TRILEVEL	Composite sync, tri-level

Table 17.2 Sync Type Selection Constants

syncTypeListCount
The number of items in the *syncTypeList* array

MLDCfieldInfo

```
typedef struct
{
  MLDCint32       offset;           /* Line where this field starts */
  MLDCint32       stride;           /* y-increment to next line */
  struct
  {
    MLDCint32       backPorch;      /* Duration in pixels */
    MLDCint32       sync;           /* Duration in pixels */
    MLDCint32       syncPulse;      /* Duration in pixels */
    MLDCint32       frontPorch;     /* Duration in pixels */
    MLDCint32       active;         /* Duration in pixels */
  }               vertical;
  MLDCbitfield    colorActive;      /* Colors this field; MLDC_FI..*/
  MLDCbitfield    eyeActive;        /* Eye this field; MLDC_FI... */
} MLDCfieldInfo;
```

Figure 17.3 The MLDCfieldInfo Structure

The fields of the **MLDCfieldInfo** structure are defined as follows:

offset
: Line where this field starts.

stride
: y-increment to next line.

backPorch
: Duration in pixels of the vertical back porch.

sync
: Duration in pixels of vertical sync.

syncPulse
: Duration in pixels of vertical sync pulse.

frontPorch
: Duration in pixels of the vertical frontPorch.

active
: Duration in pixels of the vertical active region.

colorActive
: The color channels that are active in this field. This is a bit field that may have one or more of the following bits set: **MLDC_FI_COLOR_ACTIVE_RED**, **MLDC_FI_COLOR_ACTIVE_GREEN**, **MLDC_FI_COLOR_ACTIVE_BLUE**, or **MLDC_FI_COLOR_ACTIVE_ALPHA**.

eyeActive
: For stereo video formats, this field will indicate which eye is active for a given field. This is a bit field that may have one of the following bits set: **MLDC_FI_EYE_ACTIVE_LEFT** or **MLDC_FI_EYE_ACTIVE_RIGHT**.

MLDCvideoFormatInfo

```
typedef struct
{
  MLDCchar        name[MLDC_FORMATNAME_MAX];  /* Video format name */
  MLDCint32       height, width;     /* Active pixels */
  MLDCint32       totalHeight;       /* Includes blanking */
  MLDCint32       totalWidth;        /* Includes blanking */
  MLDCreal32      verticalRetraceRate;/* field or frame rate, in Hz */
  MLDCreal32      swapBufferRate;    /* Can be diff from frame rate */
  MLDCint32       pixelClock;        /* Pixels/second */
  struct
  {
    MLDCint32       backPorch;       /* Duration in pixels */
    MLDCint32       sync;            /* Duration in pixels */
    MLDCint32       frontPorch;      /* Duration in pixels */
    MLDCint32       active;          /* Duration in pixels */
  }               horizontal;
  MLDCint32       fieldCount;
  MLDCfieldInfo   *fieldInfo;        /* Array, size=fieldCount */
  MLDCbitfield    formatFlags;       /* See MLDC_VFI... fields */
} MLDCvideoFormatInfo;
```

Figure 17.4 The MLDCvideoFormatInfo Structure

The fields of the **MLDCvideoFormatInfo** structure are defined as follows:

name
: The name of the video format.

height, width
: The height and width of the active pixels.

totalHeight, totalWidth
: The total height and width in pixels of the video format, including non-viewable data.

verticalRetraceRate
: The field or frame rate, in hertz, of the video format.

swapBufferRate
: The rate at which multi-buffered viewing rectangles are swapped. This can be different from the frame rate.

pixelClock
: The duration in pixels of the pixel clock.

backPorch
: The duration of the horizontal back porch of the format.

sync
: The duration in pixels of the horizontal sync.

frontPorch
: The duration in pixels of the horizontal front porch.

active
: The size in pixels of the active horizontal pixel region.

fieldCount
: The number of fields in the format.

fieldInfo
: A pointer at an array of **MLDCfieldInfo** structures with information regarding each field. The size of the array is equal to *fieldCount*.

formatFlags
A set of flags defined as follows:

Flag	*Description*
MLDC_VFI_STEREO	This is a stereo video format.
MLDC_VFI_FIELD_SEQUENTIAL_COLOR	The color for this format differs from field to field.
MLDC_VFI_FULL_SCREEN_STEREO	The stereo format is full screen (this is an old SGI stereo format.)

Table 17.5 Possible Format Flags for Video Formats

MLDCvideoFormat

Before documenting the **MLDCvideoFormat** structure, the concept of video combination formats must be explained.

Video Format Combinations

On some video output devices it is possible that output channels may only be loaded with video formats that are compatible with each other. For example, the device may require that all channels be loaded with formats that have the same refresh rate. These allowable compatible video formats are referred to as **combination** formats. Combination formats consist of multiple **MLDCvideoFormatInfo** structures. They have a combination format name. The following **MLDCvideoFormat** structure provides a container that can describe either a combination format capable of being loaded into multiple channels, or a single format for loading into a single channel.

```
typedef struct
{
  MLDCchar            name[MLDC_FORMATNAME_MAX];/* Name of format */
  MLDCvideoFormatInfo *formats;                 /* Array of formats */
  MLDCint32           numFormats;               /* Elements in formats
                                                      array */
  MLDCint32           height, width;            /* Display surface
                                                      size */
} MLDCvideoFormat;
```

Figure 17.6 The MLDCvideoFormat Structure

The fields of the **MLDCvideoFormat** structure are defined as follows:

name
The name of this format. If this structure is being used to define a combination format, then this field will be the name of the combination, but each member format of the combination will have its own name found in the name field of the single **MLDCvideoFormatInfo** structure. If this structure is being used to define a single format, then this name will match the name that is given in the name field of the single **MLDCvideoFormatInfo** structure.

formats
A pointer to an array of **MLDCvideoFormatInfo** structures. In the case where this is a combination format, this array will hold two or more **MLDCvideoFormatInfo** structures detailing formats that are compatible. Otherwise, this array will hold a single **MLDCvideoFormatInfo** structure.

numFormats
Gives the number of elements in the *formats* array. If this number is one, then this is a single video format. If this number is greater than one, then this field is a combination video format.

height, width
The total height and width, in pixels, of the display surface that will be output to the video format channels.

MLDCchannelInfo

The **MLDCchannelInfo** structure defines attributes unique to a single channel, including a pointer to the **MLDCvideoFormatInfo** structure that describes the video format for the channel:

```
typedef struct
     {
       MLDCboolean     active;           /* channel is operating */
       MLDCrectangle   source;            /* Position on display surface */
       MLDCrectangle   outputRegion;     /* Rectangular output region*/
       MLDCvideoFormatInfo vfinfo;       /* Video format details */
       MLDCbitfield    channelFlags;     /* See MLDC_CIF... masks */
       MLDCint32       *gammaMaps;       /* Assignable gamma maps
                                                (ptr to array) */
       MLDCint32       gammaCount;       /* Returned count of gammaMaps */
       MLDCboolean     blankingOp;       /* mldcSetOutputBlanking usable */
       MLDCboolean     gainOp;           /* mldcSetOutputGain usable */
       MLDCboolean     pedestalOp;       /* mldcSetOutputPedestal usable */
       MLDCboolean     phaseHOp;         /* mldcSetOutputPhaseH usable */
       MLDCint32       phaseHMin;        /* Range of OutputPhaseH */
       MLDCint32       phaseHMax;
       MLDCboolean     phaseVOp;         /* mldcSetOutputPhaseV usable */
       MLDCint32       phaseVMin;        /* Range of OutputPhaseV */
       MLDCint32       phaseVMax;
       MLDCboolean     phaseSCHOp;       /* mldcSetOutputPhaseSCH usable */
       MLDCint32       phaseSCHMin;      /* Range of OutputPhaseSCH */
       MLDCint32       phaseSCHMax;
       MLDCboolean     syncOp;           /* mldcSetOutputSync usable */
       MLDCint32       syncPortCount;    /* Number of sync ports */
       MLDCchannelSyncInfo *syncInfo;    /* Info on all sync ports */
       MLDCint32       physicalID;       /* Physical port */
     } MLDCchannelInfo;
```

Figure 17.7 The MLDCchannelInfo Structure

The fields of the **MLDCchannelInfo** structure are defined as follows:

active
Field is **TRUE** if the queried channel is operational. Graphics devices with multiple channels may be programmed to run only some of the output channels. If the value of this field is **FALSE**, the remaining fields in the structure are undefined.

source
Is an **MLDCrectangle** structure that contains the portion of the display area that this channel displays. The **MLDCrectangle** structure describes a rectangle whose origin is at x,y and whose size is described by height and width. On graphics hardware platforms with only one channel, this source rectangle is frequently the entire managed area of the video output device. However, on graphics hardware platforms that have more than one channel for output, each channel may display a different portion of the display area.

outputRegion
The rectangular region within the output channel that will be used for output. The dimensions of the *outputRegion* generally match the output video format height and width. It is possible for an output video device to introduce a scaler which may change the offset or size of the *outputRegion*.

vfinfo
Contains the detailed information that describes the video format. This information is valid only if *active* is **TRUE**.

channelFlags
Is a set of flags that indicates information about the channel.

Flag Name	***Description***
MLDC_CIF_COMPOSITE_VIDEO	This channel uses composite video output.
MLDC_CIF_PER_COMPONENT_GAIN	Channel is capable of independent gain adjustment.

Table 17.8 Channel Flag Descriptions

gammaMaps
Is a pointer to an array of indexes; each index identifies a gamma map that may be assigned to this channel. The number of items is returned in *gammaCount*.

gammaCount
The number of elements in the *gammaMaps* array.

blankingOp
Is **TRUE** if the operations of the function **mldcSetOutputBlanking** are supported on this channel.

gainOp
Is **TRUE** if the operations of the function **mldcSetOutputGain** are supported on this channel.

phaseHMinReturn
Returns the minimum value to which horizontal phase may be set.

phaseHMaxReturn
Returns the maximum value to which horizontal phase may be set.

phaseVMinReturn
Returns the minimum value to which vertical phase may be set.

phaseVMaxReturn
Returns the maximum value to which vertical phase may be set.

phaseSCHMinReturn
Returns the minimum value to which SCH phase may be set.

phaseSCHMaxReturn
Returns the maximum value to which SCH phase may be set.

syncOp
TRUE if operations to set output sync are permitted on this channel. See the function **mldcSetOutputSync**.

syncPortCount
Is the number of sync ports available for this channel. This count includes the standard sync ports of **MLDC_SP_RED**, **MLDC_SP_GREEN**, **MLDC_SP_BLUE**, and **MLDC_SP_ALPHA** (if the ports are present and their output can be altered) as well as the auxiliary ports.

syncInfo
This is a pointer to an array of **MLDCchannelSyncInfo** structures. Each channel may have zero, one, or more sync ports for which the sync may be altered; each mutable sync port is represented by one **MLDCchannelSyncInfo** structure in the array. There are *syncPortCount* items in the array. All ports that can have their sync characteristics altered are included.

physicalID
This identifies the physical port number of this channel. This is the number as labeled on the chassis or cable of the video output. Graphics devices may take liberties in numbering output ports that are not strictly numbered (e.g., an encoder channel) such as using negative numbers or impossibly high numbers. This value is to be used only as a correlation to chassis number. Applications should use the other values in this structure to determine channel characteristics instead of relying on a special decoding of physical channel number.

Querying Channel Parameters

mldcQueryChannelInfo

The current parameters for a given video output device and channel can be queried via a call to this function.

```
MLDCstatus mldcQueryChannelInfo(MLDChandle hOutDev,
                                MLDCint32 channel,
                                MLDCchannelInfo **cinfo_return)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number. Channels are assigned numbers starting at zero. Subsequent channel numbers increase monotonically by one; thus, each channel number is unique for a given video output device. Because of this ordering constraint, the channel number may not correspond to physical channel numbers as labeled on the hardware chassis. The *physicalID* field of the **MLDCchannelInfo** structure contains the number of the physical channel.

cinfo_return
Returns a pointer to an **MLDCchannelInfo** structure that is allocated by MLdc.

The **mldcGetChannelInfo** function returns **MLDC_STATUS_NO_ERROR** upon success. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *cinfo_return* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Enabling and Disabling Channels

A Channel is either enabled or disabled. The active flag of the **MLDCchannelInfo** structure returned from **mldcQueryChannelInfo** can be used to determine the current state of a channel. A channel that is enabled will output a video signal on its physical jack. A disabled channel will not output a video signal.

mldcEnableChannel

This function enables a specific channel.

```
MLDCstatus mldcEnableChannel(MLDChandle hOutDev,
                             MLDCint32 channel,
                             MLDCboolean enable)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

enable
If **TRUE**, enables the channel's video output. If **FALSE**, disables a channel's video output. This may have the effect of reducing overall demand on the video device while terminating output. It is not necessary to disable a channel before loading a new video format.

The function **mldcEnableChannel** returns **MLDC_STATUS_NO_ERROR** if successful. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *enable* is not a valid boolean, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Events

When the channel's output condition has been changed from enabled to disabled, or from disabled to enabled, MLdc generates an **MLDC_VIDEO_FORMAT_NOTIFY** event.

Channel Input Rectangles

Each channel has a rectangular region in the display area, that it uses as its source for display, called the *channel input rectangle*. Rectangles are defined in terms of horizontal and vertical pixel coordinates. The channel input rectangle can be set using the following functions:

mldcSetChannelInputRectangle

This function allows the application to set the channel's input rectangle location and size.

```
MLDCstatus mldcSetChannelInputRectangle(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCrectangle *rectangle)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

rectangle
Defines the rectangle in the display area that the channel will display from. Refer to Figure 17.1, "The MLDCrectangle Structure"

The pixel location of the rectangle is given in display area coordinates and assumes that the "upper left" corner of the display area is (0,0).

If a video device permits changes to the input rectangle, the video device may impose restrictions on the values of both size and origin. That is, the final size of the rectangle may not be exactly as requested, but will be the "closest" size and location that the device is capable of supporting.

If this function can successfully set the input rectangle to the requested size and location, it will return a **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *rectangle* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Events

When the channel's input rectangle has been changed MLdc generates an **MLDC_CHANNEL_INPUT_RECTANGLE_NOTIFY** event.

mldcQueryBestChannelRectangle

The **mldcQueryBestChannelRectangle** function provides a means to determine the nearest valid rectangle to the size and origin desired by the application. Determination of the best rectangle is device-dependent, and different situations may yield different results.

```
MLDCstatus mldcQueryBestChannelRectangle(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCrectangle *rct,
                    MLDCrectangle *rrct)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

rct
An input argument that specifies a rectangle that the application would like to use.

rrct

An output argument pointing to an **MLDCrectangle** structure allocated by the application. Returns the best rectangle that is supported that approximates the input rectangle, *rct*.

mldcQueryBestChannelRectangle returns **MLDC_STATUS_NO_ERROR** if a rectangle is found of a valid supported size and origin (the size of which is found in the returned variables). This function returns **MLDC_STATUS_NO_VALID_RECTANGLE** when no valid rectangle was found (among which is the case when the video device does not support change of size or origin). If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *rct* or *rrct* *are* not valid pointers, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

18

VIDEO FORMATS

Video Format Names

The video industry has adopted a standard naming convention for video formats even though the names can be ambiguous: the name itself is not always descriptive enough to distinguish between two different formats. The convention for standard video format names is:

Widthx**Height_FrameRate**

where ***Height*** and ***Width*** specify the active portion of the format (i.e., the visible portion of the frame displaying pixels exclusive of the blanking regions). ***FrameRate*** specifies the field or frame rate in hertz, rounded to the nearest integer.

The name of the format may be appended by a single-character identifier. This suffix is a hint to the intended use of the format; detailed information can be derived from the **MLDCvideoFormatInfo** structure. Some suffix characters are:

f	The format is a variant of the standard format that can lock to a dissimilar format.
i	The format is interlaced.
k	Special alternative format.
p	The format is progressive
q	The format has its colors displayed in serial fields (color field sequential).
s	The format is a stereo format.

Table 18.1 Industry Standard Video Format Name Suffixes

Thus, for example, *1920x1080_60i,* describes an interlaced high-definition video format.

Note that such a video format name is a general convention. For detailed information regarding the timing specifications of a format, consult the returned structure.

Note that some graphics devices may alter the structure of the video format to conform to hardware restrictions. Also, not all graphics devices may have the capability to display all formats. Some graphics devices may list the same format under both a conventional name and an alias.

Querying Video Formats

The current video format for a given video output device and channel can be queried by calling the function **mldcQueryChannelInfo** previously described.

Listing Available Video Formats

A list of available video formats is returned by calling **mldcListVideoFormats.**

mldcListVideoFormats

mldcListVideoFormats returns a list of available video formats that match a specified pattern.

```
MLDCstatus *mldcListVideoFormats(MLDChandle hOutDev,
                    MLDCint32 *channelArray,
                    const MLDCvideoFormat *pattern,
                    MLDCbitfield *querymaskArray,
                    MLDCboolean matchMonitor,
                    MLDCboolean nonvolatile,
                    MLDCint32 maxformats,
                    MLDCint32 *actual_count_return,
                    MLDCvideoFormat **retFormatArray)
```

hOutDev
Specifies the handle of the MLdc video output device.

channelArray
Specifies an array of channel numbers. The array must have the number of elements that are specified in the *numFormats* field of the *pattern* argument. If the number of channels is greater than one, this function will return a list of combination formats that could be used for the multiple channels listed in *channelArray*. By convention, the channel numbers in the array must appear in the array in ascending order. However, channel numbers may skipped. For example, the array could hold the channel numbers 1,3,4.

pattern
Specifies an **MLDCvideoFormat** structure that provides attributes to match when listing the video formats. The *numFormats* field in the structure gives the number of formats in the pattern. If *numFormats* is equal to one, this is a search for single formats to be applied to a single channel. If searching for a combination format, the value of *numFormats* will be greater than one. The number of formats given in *numFormats* also determines the number of channels in the *channelArray* argument and the number of query masks in the *querymaskArray* argument. All video formats that match the query will be returned (up to *maxformats*).

querymaskArray
An array of masks that specify, as the bitwise inclusive OR of any of the manifest constants that have a prefix of **MLDC_QVF** (see Table 18.2), which fields in *pattern* are to be used for the query. If the *querymaskArray* is NULL, all video formats will be returned. The *querymaskArray* must have the number of elements specified in the *numFormats* field of the *pattern* argument. If searching for combination formats, the i^{th} element of the *querymaskArray* is applied to the i^{th} format in the *formats* array of the *pattern* argument when doing the search for a suitable format for the i^{th} channel given in *channelArray*.

matchMonitor
If **TRUE**, restricts queries to those formats which are within the operating range of the monitor for each channel. If **FALSE**, no constraint check is made.

nonvolatile
If **TRUE**, restricts queries to those formats which can only be changed through a nonvolatile load. If **FALSE**, only formats that can be changed dynamically are returned.

maxformats
Specifies the maximum number of **MLDCvideoFormat** structures to be returned.

actual_count_return
Returns the actual number of **MLDCvideoFormat** structures that are returned.

retFormatArray
Returns the list of formats that have been found. The array of **MLDCvideoFormatInfo** structures that are returned in the **MLDCvideoFormat** structure are in a particular order to match the channel numbers given in the *channelArray* argument. The first format in the first element of the format array corresponds to the first channel given in the *channelArray*.

The **mldcListVideoFormats** function returns in *retFormatArray* an array of available **MLDCvideo-Format** video format descriptions that match a pattern specification.

When listing the video formats that are available for a single channel, the caller gives only one **MLD-CvideoFormatInfo** structure in the *formats* array of the *pattern* argument and only one element of the *querymaskArray* argument. The query mask is applied to the given format to find all available formats that meet the requirements for a single channel.

When listing the combination video formats that are available for a group of *n* channels the caller gives *n* channels in the *channelArray* argument, *n* **MLDCvideoFormatInfo** structures in the *formats* array of the *pattern* argument, and *n* elements of the *querymaskArray* argument. Available matching combination formats are found by using the i^{th} format in the *formats* array of the *pattern* argument in conjunction with the i^{th} element of the *querymaskArray* to search for a suitable format for the channel found in the i^{th} element in the *channelArray* argument.

If no video formats match the query specification, the value 0 (zero) is returned in *actual_count_return*.

Fields that are not represented in the *querymaskArray* are not used to constrain the search (i.e., unconstrained fields are "don't care"). All query-constrained fields must be an exact match. For example, if *fieldCount* is specified as 2 and the *querymaskArray* element has the **MLDC_QVF_FIELD_COUNT** bit set, this function will return only those video formats that have two fields.

To return every video format available, specify the value NULL for *querymaskArray*. Queries may be specified using combinations of the following bits in each element of the *querymaskArray*:

Mask Bit	*Purpose*
MLDC_QVF_HEIGHT	Match the height in lines of the active region of the format.
MLDC_QVF_WIDTH	Match the width in pixels of the active region of the format.
MLDC_QVF_TOTAL_HEIGHT	Match the total number of lines of the format, including blanking lines.
MLDC_QVF_TOTAL_WIDTH	Match the total number of pixels in each line of the format, including blanking pixels.

Table 18.2 Video Format Query Mask Bits

MLDC_QVF_RETRACE_RATE	Match the retrace rate of the format. Note this value is specified as a floating-point number; however, all comparisons are integer-based. For this comparison, the values are rounded to int by adding 0.5 and truncating. For example, 59.94Hz will be rounded to 60 before comparing.
MLDC_QVF_SWAP_BUFFER_RATE	Match the swapbuffer rate of the format. This can be different from the retrace rate in some video formats. Note this value is specified as a floating-point number; however, all comparisons are integer-based. For this comparison, the values are rounded to int by adding 0.5 and truncating. For example, 29.97Hz will be rounded to 30 before comparing.
MLDC_QVF_FIELD_COUNT	Match the number of interlaced or stereo fields in the format.
MLDC_QVF_FLAGS	Match the formatFlags field of the format.

Table 18.2 Video Format Query Mask Bits

Note that the pixelClock and horizontal components of MLDCvideoFormatInfo are ignored when querying and setting video format, as are other components. There may not be corresponding bits for all fields.

Match Monitor Query

The field *matchMonitor* is a special constraint that specifies that MLdc should return only those video formats whose timing requirements fall within the range supported by the monitors connected to the channels listed in *channelArray* (see the function **mldcQueryMonitorName**).

While this constraint gives some assurance that a returned format will operate successfully on the monitor connected to the channel, it cannot be guaranteed. Nor can one be certain that the connected monitor can display all formats returned. The specification of the range of operation of a monitor and the description of the parameters of a video format are not sufficiently exact to reliably predict a proper match. Instead, consider this constraint to provide a high likelihood that the returned formats are the best matches for reliable operation.

The *matchMonitor* constraint further restricts the query specified in *querymask*.

The **mldcListVideoFormats** function returns a list of **MLDCvideoFormat** structures.

The client should call **mldcFree** when finished with the result to free the memory that was allocated and returned in *retFormatArray*.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other arguments are not valid values or valid pointers, this function will return **MLDC_STATUS_INVALID_ARGUMENT**. If no match is found, the function will return **MLDC_STATUS_NO_FORMAT_MATCH**.

Loading Video Formats

Video formats can be loaded by specifying a pattern, a video format name, or the name of a file which contains a video format specification.

Video formats can be loaded **dynamically** (which means that the new format will take place as soon as possible) or in a **nonvolatile** fashion (which means that the new format will take effect only after the graphics subsystem has been restarted). On Windows systems, restarting the graphics subsystem may require rebooting the system. On X Window Systems, restarting the graphics subsystem means that the X Server must be restarted.

mldcLoadVideoFormat

This function will load a video format that matches a pattern given as an argument. If more than one video format matches the pattern the first one that matches will be loaded. This function is equivalent to **mldcListVideoFormats**, except that it will load the first format that matches the query instead of returning the full list of formats.

```
MLDCstatus mldcLoadVideoFormat(MLDChandle hOutDev,
                    MLDCint32 *channelArray,
                    const MLDCvideoFormat *pattern,
                    MLDCbitfield *querymaskArray,
                    MLDCboolean matchMonitor,
                    MLDCboolean nonvolatile)
```

hOutDev
: The handle of the MLdc video output device.

channelArray
: Specifies an array of channel numbers. The array must have the number of elements that are specified in the *numFormats* field of the *pattern* argument. If the number of channels is greater than one, then this function will load the first combination format that could be used for the multiple channels listed in *channelArray*. By convention, the channel numbers in the array must appear in the array in ascending order. However, channel numbers may skipped. For example, the array could hold the channel numbers 1,3,4.

pattern
: Specifies an **MLDCvideoFormat** structure that provides attributes to match when loading the video format. The *numFormats* field in the structure gives the number of formats in the pattern. If *numFormats* is equal to one, this function will match a single format and load it into a single channel. If matching a combination format, the value of *numFormats* will be greater than one. The number of formats given in *numFormats* also determines the number of channels in the *channelArray* argument and the number of query masks in the *querymaskArray* argument.

querymaskArray
: An array of masks that specify, as the bitwise inclusive OR of any of the manifest constants that have a prefix of **MLDC_QVF** (see Table 18.2), which fields in *pattern* are to be used for the query. If the *querymaskArray* is NULL, the first video format found will be loaded. The *querymaskArray* must have the number of elements specified in the *numFormats* field of the *pattern* argument. If matching a combination format, the i^{th} element of the *querymaskArray* is applied to the i^{th} format in the *formats* array of the *pattern* argument, when doing the search for a suitable format for the i^{th} channel given in *channelArray*.

matchMonitor
: If **TRUE**, restricts loads to those formats which are within the operating range of the monitor. If **FALSE**, no constraint check is made.

nonvolatile
: If the requested format is capable of being loaded dynamically, it will be loaded dynamically, regardless of the value of this argument. However, if the requested format is not capable of being loaded dynamically, and if this argument is set to **TRUE**, then the requested format will be scheduled to be loaded in a nonvolatile fashion after the graphics system has been restarted.

Description

The **mldcLoadVideoFormat** function loads a video format into the specified channel, or a combination format into the specified channels. The newly loaded formats completely replace the channels' current video format.

The method by which the video format is specified is similar to the query performed in the function **mldcListVideoFormats.** The desired video format is described by populating the *pattern* structure, specifying the meaningful fields (query constraints) via the *querymaskArray* parameter. When more than one video format meets the query requirements, the first format is loaded. To unambiguously specify a video format, use **mldcLoadVideFormatsByName**. See **mldcListVideoFormats** for more information on specifying the arguments to this function.

Restrictions When Loading

On some systems certain video formats may require that the graphics system be restarted after loading.

Note: On some platforms, the user cannot request a nonvolatile load without root or administrator permissions. On other systems, loading any format may need root or administrator authorization.

Events

When the format changes, MLdc generates an **MLDC_VIDEO_FORMAT_NOTIFY** event. If no format can be found by device-dependent software that matches the criteria, an **MLDC_ERROR_NOTIFY** event is generated and the error code given in the event is **MLDC_STATUS_NO_FORMAT_MATCH.**

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcLoadVideoFormatByName

When the format name of the desired video format is known, either apriori through external means or by choosing a format from an **mldcListVideoFormats** query, then **mldcLoadVideoFormatByName** may be used to load that video format:

```
MLDCstatus mldcLoadVideoFormatByName(MLDChandle hOutDev,
                    MLDCint32 numChannels,
                    MLDCint32 *channelArray,
                    const MLDCchar *name,
                    MLDCboolean nonvolatile)
```

hOutDev
: The handle of the MLdc video output device.

numchannels
: The number of channels in the *channelArray* argument. If the number is one, then the format to be loaded is a single format loading into a single channel. If the number is greater than one, then the format to be loaded is a combination format.

channelArray
: Specifies an array of channel numbers to load a named format into. If the array holds only one channel, then the format is a single format. If the array has more than one channel, then the format name must be the name of a combination format. By convention, the channel numbers must appear in the array in ascending order, though the channel numbers need not be sequential.

name
The name of the format to load; a null-terminated string.

nonvolatile
If the requested format is capable of being loaded dynamically, then it will be loaded dynamically, regardless of the value of this argument. However, if the requested format is not capable of being loaded dynamically, and if this argument is set to **TRUE**, then the requested format will be scheduled to be loaded in a nonvolatile fashion after the graphics system has been restarted.

Description

The **mldcLoadVideoFormatByName** function loads a new video format into the specified channel, or a combination format into the specified channels. The newly loaded formats completely replace the channels' current video format.

The name of the format to load is normally taken as an internal implementation-dependent name. If a fully-qualified absolute path is supplied instead of a format name, that path will be used as the location of a video format file instead of as a format name. It is up to the caller to ensure that the path points to a valid video format file. The format files are implementation-dependent and beyond the scope of this document.

Restrictions When Loading

On some systems certain video formats may require that the graphics system be restarted after loading.

Note: On some platforms, the user cannot request a nonvolatile load without root or administrator permissions. On other systems, loading any format may need root or administrator authorization.

Events

When the format changes, MLdc generates an **MLDC_VIDEO_FORMAT_NOTIFY** event. If no format can be found by device-dependent software that matches the criteria, an **MLDC_ERROR_NOTIFY** event is generated and the error code given in the event is **MLDC_STATUS_NO_FORMAT_MATCH.**

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

19

BLANKING

When a channel is blanked the active video portion of the signal is disabled. However, normal video synchronization signals persist so that the video output device can remain locked. When blanking is disabled, the active video is restored and the video output device once again displays pictures.

mldcSetOutputBlanking

This function will enable or disable blanking on a channel.

```
MLDCstatus mldcSetOutputBlanking(MLDChandle hOutDev,
                                 MLDCint32 channel,
                                 MLDCboolean enable)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

enable
Specifies whether blanking should be enabled.

Description

mldcSetOutputBlanking enables and disables blanking on a channel. The value may be **TRUE** or **FALSE**.

Interaction with Screen Saver

Some screen saver programs will simply blank the screen as part or all of their function. The function of **mldcSetOutputBlanking** may be independent of that supplied by the screen saver, and may use a different mechanism to enable and disable output. The interaction between the screen saver and the mechanism used by this function is system-dependent and is not specified.

Events

When this control is altered, the MLdc library generates an **MLDC_OUTPUT_BLANKING_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputBlanking

This function will query the current state of blanking for a channel.

```
MLDCstatus mldcQueryOutputBlanking(MLDChandle hOutDev,
                                   MLDCint32 channel,
                                   MLDCboolean *enableReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

enableReturn
Returns whether blanking is enabled.

Description

mldcQueryOutputBlanking returns in the *enableReturn* argument the current settings for blanking on a channel. The value may be **TRUE** or **FALSE**.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

20

GAMMA CORRECTION TABLES AND OUTPUT GAIN

Gamma Correction

Many computer video display devices have color lookup tables associated with them that allow the application to programmatically adjust for differences in monitor color phosphor response. These color tables are commonly referred to as gamma correction tables because the color ramp that is loaded into them typically follows a mathematical gamma function curve that is adjusted to fit the monitor. A given MLdc-controlled video output device may or may not have gamma-correction tables available to it.

Cathode ray tubes (CRT's) have the characteristic that their display is non-linear: the intensity of light displayed at a pixel is not strictly proportional to the voltage supplied to the CRT at that pixel. Gamma correction is used to compensate for that non-linearity so the monitor does produce the proper intensity.

A video device may contain one or more gamma maps, each of which may perform an independent correction by serving as a color look-up.

Terminology

A **gamma map** has the following distinguishing features:

- A set of **tables**. There is one table for each color component that is handled by the map. There may be up to four tables, one each for red, green, blue, and alpha.
- A size for each table. The table for each component has a size, or a number of entries.
- A width for each table. The entries in each table have a certain width in bits or precision.

Graphics devices may assign a permanent gamma map to a channel, restrict channels to a subset of all maps, permit a channel to use one of all shared maps, or some combination thereof, depending on hardware configuration. If two channels share the same gamma map, changing the colors in that gamma map will affect both channels.

mldcQueryGammaMaps

This function returns the number of gamma maps that are available on a video output device.

```
MLDCstatus mldcQueryGammaMaps(MLDChandle hOutDev,
                              MLDCint32 *gammaMapsReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

gammaMapsReturn
The address of a variable to receive the number of gamma maps available on the video device.

Description

mldcQueryGammaMaps returns the number of separate gamma maps supported. Video output devices with no writable gamma map return zero (0).

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *gammaMapsReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryGammaMap

This function will return the sizes of a given gamma map's tables and their precision and attributes.

```
MLDCstatus mldcQueryGammaMap(MLDChandle hOutDev,
                             MLDCint32 gammaMap,
                             MLDCint32 *gammaSizeReturn,
                             MLDCint32 *gammaPrecisionReturn,
                             MLDCint32 *gammaMapAttributes)
```

hOutDev
Specifies the handle for the MLdc video output device.

gammaMap
Specifies the gamma map to be queried. Gamma map IDs are numbered implicitly, starting with 0.

gammaSizeReturn
Specifies the location of a four-element array that is to receive the number of entries or size of each component table in the gamma map. The order of component tables represented in the array is red, green, blue, and alpha.

gammaPrecisionReturn
Specifies the location of a four-element array that is to receive the precision in bits of each table in the gamma map. For example, if each entry in a table is 10 bits long, the call returns 10 for that component. The order of component tables represented in the array is red, green, blue, and alpha.

gammaMapAttributes
Specifies the location of a variable to receive a bitmask describing attributes of the gamma map. The bitmask may contain zero or more of the following attributes described below:

MLDC_GM_ALPHA_PRESENT	The gamma map has an alpha component in addition to the red, green, and blue components.
MLDC_GM_HARDWARE_APPROXIMATION	The video device hardware may use private techniques to approximate the stated size and precision of the gamma map, substituting a less thorough representation. In most cases when a gamma-shaped curve is loaded, the visual result will closely approximate the specified curve. Queries of the value of the colors of this gamma map will return the values as previously stored, not of the internal approximation. The techniques used to approximate the gamma map are implementation dependent.
MLDC_GM_WRITE_LOCK	The gamma map cannot be modified programmatically. The video device hardware may have a fixed gamma map or the video device does not implement alteration of this map.
MLDC_GM_READ_LOCK	The gamma map cannot be queried programmatically. The video device hardware may not permit readback or the video device does not implement readback of this map.

Table 20.1 Gamma Map Attribute Bits

Description

mldcQueryGammaMap returns information regarding a specified gamma map's configuration.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *gammaMap* is not a valid gamma map number, this function will return **MLDC_STATUS_INVALID_GAMMA_MAP.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryGammaColors

Occasionally an application may want to inquire the contents of a given gamma map. The query can be accomplished with the following function. Note: Some devices will report bigger tables than they really have and then interpolate values as the tables are loaded. If an application loads a table and then reads it back, the table being returned may not be exactly what was loaded. Also, see the **MLDC_GM_HARDWARE_APPROXIMATION** flag that can come back from **mldcQueryGammaMap**.

```
MLDCstatus mldcQueryGammaColors(MLDChandle hOutDev,
                    MLDCint32 gammaMap,
                    MLDCint32 requestedComponent,
                    MLDCint32 *itemCountReturn,
                    MLDCuint16 **gammaValueReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

gammaMap
Specifies the gamma map whose color table is to be returned. Gamma map ID's are numbered implicitly, starting with 0.

requestedComponent
Specifies the tables or color components that should be returned. The constants **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, and **MLDC_COMPONENT_ALPHA** may be Or-ed together to select the table(s) to be returned. The video device may ignore **MLDC_COMPONENT_ALPHA** if the gamma map does not have an alpha table; see **mldcQueryGammaMap**.

itemCountReturn
Specifies a pointer to an array of four integers where MLdc returns the number of elements in each of the tables. The order of the array is red, green, blue, and alpha. If a table is not selected, its count is set to zero.

gammaValueReturn
Specifies a pointer to an array where MLdc returns pointers to the arrays containing the table elements. The order of the array is red, green, blue, and alpha. If a table is not selected, its pointer is set to NULL.

Description

mldcQueryGammaColors returns the values for the specified component table. The number of items in the requested color component is returned in *itemCountReturn*. Use **mldcFree** to free the memory allocated in *gammaValueReturn*.

Operations on Colors During Query

The **mldcQueryGammaColors** function implicitly returns 16-bit quantities, irrespective of the precision of the underlying hardware. If the table's precision is less than 16 bits, the video device will return the significant bits of the precision in the uppermost bits of the returned 16-bit quantity; the least significant bits of the returned quantity will contain replicated copies of the table's MSB's.

This operation is similar and complementary to the actions taken during store operations. For example, if the hardware table has 11 significant bits, the 16-bit value returned to the client will contain the hardware's value in the upper 11 bits. The most significant five bits of the hardware's value will be replicated in the lower five bits of the returned value.

In general, the significant bits of the returned value may be determined via the following C-language statement (given *precision* as the width of the entry and *gammaValueReturn* as the returned value):

```
unsigned short sigBits;
...
sigBits = (gammaValueReturn >> (16 - precision));
```

Applications can use the function **mldcStoreGammaColors16** as a complementary store operation; that function expects a value with the significant bits similarly shifted into the MSB's.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *gammaMap* is not a valid gamma map number, this function will return **MLDC_STATUS_INVALID_GAMMA_MAP.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcStoreGammaColors16, mldcStoreGammaColors8

The following functions are used to set the values in a gamma correction lookup table:

```
MLDCstatus mldcStoreGammaColors8(MLDChandle hOutDev,
                    MLDCint32 gammaMap,
                    MLDCbitfield loadTables,
                    MLDCint32 *itemCount,
                    MLDCuint8 **gammaValue)

MLDCstatus mldcStoreGammaColors16(MLDChandle hOutDev,
                    MLDCint32 gammaMap,
                    MLDCbitfield loadTables,
                    MLDCint32 *itemCount,
                    MLDCuint16 **gammaValue)
```

hOutDev
Specifies the handle for the MLdc video output device.

gammaMap
Specifies the gamma map whose color table (or tables) is to be loaded. Gamma map ID's are numbered implicitly, starting with 0.

loadTables
Specifies the tables or color components that should be returned. The constants **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, and **MLDC_COMPONENT_ALPHA** may be Or-ed together to select the table(s) to be loaded

itemCount
A 4-element array that contains the number of elements in each table to be loaded. The order of the array is red, green, blue, and alpha. Note that the count of the number of entries to be loaded in each table must exactly equal the length of the table (returned via the parameter *gammaSizeReturn* in the function **mldcQueryGammaMap).**

gammaValue
A 4-element array containing pointers to each of the tables to be loaded. The order of the pointers in the array is red, green, blue, and alpha.

Description

The **mldcStoreGammaColors8** and **mldcStoreGammaColors16** functions change the gamma map table entries for the specified tables to the specified values, the former function loading 8-bit entries and the latter loading 16-bit entries. To load a gamma map, pass an array of table pointers via *gammaValue* and an array of table lengths via *itemCount*. The value of *loadTables* indicates which tables of the gamma map that will be changed.

Note: The hardware of some video devices may require the video device to load all components simultaneously in an encoded (packed) manner, so choosing a single color component may require the video device to query the gamma table to encode the component before writing it; thus, the most efficient use of this function may be to store all color components simultaneously.

The function **mldcStoreGammaColors8** is provided as an economy to the function **mldcStoreGammaColors16** because it minimizes traffic between the client and the video device. Use the operation that best suits the need: for rapid animations, an application may prefer the 8-bit function; for greater accuracy, the 16-bit function.

Operations on Colors During Store

If a gamma map's colors are stored using a function whose width is different than the width of the gamma map, the video device will alter the values when loading the gamma hardware. This alteration occurs for each color value specified.

If a function is used whose width is larger than that of the table, the video device will truncate, using only the most-significant bits (MSB's) of the values; for example, if the **mldcStoreGammaColors8** function is used to store values into a table that contains only five bits, the video device will use only the upper five MSB's of the color values, discarding the lower three bits.

If a function is used whose width is narrower than the table, the video device will use the stored values for the most-significant bits (MSB's), and store into the not-supplied least-significant bits (LSB's) a copy of the most significant bits; for example, if the **mldcStoreGammaColors8** function is used to store values into a table that contains 12 bits, the video device will store the values into the eight MSB's, copying the upper four bits of each of the values into each entry's LSB's.

When this control is altered, the video device generates a **MLDC_GAMMA_MAP_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle this function will return **MLDC_STATUS_INVALID_DEVICE.** If *gammaMap* is not a valid gamma map number this function will return **MLDC_STATUS_INVALID_GAMMA_MAP.** If any other argument is not a valid value or a valid pointer this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSetChannelGammaMap

This function will choose which of the available gamma maps to apply to the given channel.

```
MLDCstatus mldcSetChannelGammaMap(MLDChandle hOutDev,
                                  MLDCint32 channel,
                                  MLDCint32 gammaMap)
```

hOutDev
: Specifies the handle for the MLdc video output device.

channel
: Specifies the channel number.

gammaMapReturn
: Specifies which of the gamma maps within the video device should be affected. Gamma map ID's are numbered implicitly, starting with 0.

Description

mldcSetChannelGammaMap selects which gamma map to use for the specified channel. Some video devices do not have multiple gamma maps available, and one gamma map is applied to all channels. Other video output devices have gamma maps that are only available for a specific channel. In these cases, the gamma map assignments cannot be altered via this function. The assignment of gamma maps to channels at video device startup is not defined, and is vendor-specific.

When this control is altered, the video device generates a **MLDC_GAMMA_MAP_NOTIFY** event.

mldcQueryChannelGammaMap returns the gamma map ID associated with the specified channel.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *gammaMap* is not a valid gamma map number, this function will return **MLDC_STATUS_INVALID_GAMMA_MAP.**

mldcQueryChannelGammaMap

This function will return the gamma map ID of the gamma map that is associated with the given video output device and channel.

```
MLDCstatus mldcQueryChannelGammaMap(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 *gammaMapReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

gammaMapReturn
Specifies which of the gamma maps within the video device is being used for the given channel.

Description

mldcQueryChannelGammaMap returns the current gamma map ID associated with the specified channel.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *gammaMapReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

Output Gain

An application can control the modulation of colors by setting the output gain, which applies a modulation to all colors as they are displayed. Some video devices support the specification of a separate gain value for each color component. On other devices, a single gain value is applied to all color components. The **MLDC_CIF_PER_COMPONTENT_GAIN** in the *channelFlag* value returned by **mldecQueryChannelInfo** indicates the capability of the device. This value is **TRUE** when the video device supports independent gain adjustment of each color component.

mldcSetOutputGain

This function allows alteration of video gain values and is intended for use by color correction and gamma management tools. Arbitrary use of this control may conflict with these tools.

```
MLDCstatus mldcSetOutputGain(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 componentID,
                    MLDCreal32 *gain)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

componentID
The constants **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, and **MLDC_COMPONENT_ALPHA** may be OR-ed together to select which color components are to be set.

gain
A 4-element array of gain values. The order of the array is red, green, blue, and alpha.

Description

mldcSetOutputGain sets the video output gain of the components of a channel.

The gain values are specified in arbitrary units, where the following are points of interest:

0.0 Lowest useful value

1.0 Nominal value

10.0 Highest possible value

Precision depends upon the video device implementation, and although it is monotonically increasing, it is not guaranteed to be uniform across the full range. Applications should use **mldcQueryOutputGain** to retrieve the current settings from the video device after a set operation to determine the values to which the video device is set. For video devices that permit independent adjustment, any combination of **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, or **MLDC_COMPONENT_ALPHA** may be specified. For other video devices that have a single, common gain control, use **MLDC_COMPONENT_RED**.

When this control is altered, the MLdc library generates an **MLDC_OUTPUT_GAIN_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputGain

This function will return the color gains being used for a given channel.

```
MLDCstatus mldcQueryOutputGain(MLDChandle hOutDev,
                               MLDCint32 channel,
                               MLDCint32 componentID,
                               MLDCreal32 *gainReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

componentID
The constants **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, and **MLDC_COMPONENT_ALPHA** may be OR-ed together to select which color components are to be returned.

gainReturn
A 4-element array that is to receive the returned gain values. The order of the array elements is red, green, blue, and alpha. Elements which are not selected by the *componentID* parameter are set to 0.0.

Description

mldcQueryOutputGain returns the current settings for each of the selected components of a channel. The gain values returned are specified in arbitrary units, where the following are points of interest:

0.0	Lowest useful value
1.0	Nominal value
10.0	Highest possible value

Precision depends upon video device implementation and although it is monotonically increasing it is not guaranteed to be uniform across the full range. Applications should use **mldcQueryOutputGain** to retrieve the current settings from the video device after a set operation to determine the values to which the video device is set.

For video devices that permit independent adjustment, any combination of **MLDC_COMPONENT_RED**, **MLDC_COMPONENT_GREEN**, **MLDC_COMPONENT_BLUE**, or **MLDC_COMPONENT_ALPHA** may be specified. For video devices that support only a single, common gain value, use **MLDC_COMPONENT_RED**.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

21

EXTERNAL SYNCHRONIZATION (LOCK AND GENLOCK)

Terminology and Operation

The concept of ***locking*** refers to the ability of a video system to evaluate the synchronization portion of a video signal of an external source and produce a signal that is at the same rate as that external signal. Locking the video device to an external source is needed in environments where the video device's video output must be synchronized with other video or film sources in order to be mixed externally.

The term ***genlock*** describes a particular type of lock: one in which both horizontal and vertical synchronization signals are locked. It is often used as a general term for locking in environments where all video devices generate and use the same video formats; in this circumstance, the term genlock is correct. See the discussion of **Lock Quality** below.

A video device may operate in a stand-alone environment in the absence of a stable external locking signal. By using this ***internal lock***, the video device locks to a clock generated within the video device hardware. With ***external lock***, the video device locks to a signal supplied externally, either on an external sync connector or other means, such as internally connected special video hardware.

When the video device is instructed to use external sync (external lock), the video device examines the synchronization signal provided on the external input sync port. If the video device hardware recognizes the signal's pattern, the video device locks the rate to that of the signal. After the video device's rates have been set successfully, the video device is said to be locked to the external signal.

When the application specifies that the video device should use ***internal lock***, the video device will disregard any external signal. Because internal lock allows the video device to produce video at a rate independent of any external source, it is often described as being "not locked" or has disabled lock.

Usage

If the video device is used in a stand-alone environment, it is not necessary to set the sync source to anything but the internal source; the video device will produce its output locked to its own reference. However, in applications where the video output must be synchronized to an external source, the application can direct the video device to use the external source as lock reference.

Lock Quality

Different video devices have different capabilities when locking to an external source, and the quality of synchronization may vary depending on the input source and the generated output format.

Under some circumstances, the video device may be able to lock to both horizontal and vertical rates of the external signal: the most stable lock, commonly known as ***genlock***. Some circumstances may permit the video device to lock to only the vertical rate of the incoming signal. In other cases, the video device may be able to provide a reference at multiple instances within a frame, a quality between those two extremes. Finally, some combination of input and output format or some video devices may not permit any lock. Refer to your video device's documentation to determine the qualities of lock available.

External Sync Sources

Some video devices have more than one external sync source. For example, a video device may have more than one connector on which sync can be provided; or, a video device's hardware might have an option board that can also provide a sync source. Because of the nature of locking (see **Terminology and Operation** above), only one sync source may be selected at a time. The application must choose whether the sync source is internal or external, and if it is external, then the application must choose which of the possible external sync sources to use.

External Sync Functions

mldcSetInputSyncSource

This function controls whether a video device channel uses an internal or an external sync source. If the channel is set to use an external source, then external locking or genlock is enabled.

```
MLDCstatus mldcSetInputSyncSource(MLDChandle hOutDev,
                                  MLDCint32 channel,
                                  MLDCint32 syncVoltage,
                                  MLDCint32 syncSource)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

syncVoltage
Specifies the voltage. Should be specified as one of **MLDC_SYNC_VOLTAGE_VIDEO** (for nominal video voltage level) or **MLDC_SYNC_VOLTAGE_TTL** (for TTL-level sync). Not all video devices have the capability to accept both voltage levels; check documentation for the specific hardware being used.

syncSource
Use **MLDC_SYNC_SOURCE_EXTERNAL** to specify the external sync source, **MLDC_SYNC_SOURCE_INTERNAL** to specify the internal sync source.

Description

This function controls the source of input sync to the video subsystem. The input sync is used as a reference to which the video device can genlock. The information returned from the function **mldcQueryVideoDeviceInfo** can help determine whether the video device currently has the capability to lock to an external source.

Events

The sync source state change event reports dynamic input sync source state changes. The video device generates an **MLDC_LOCK_STATUS_CHANGED_NOTIFY** event when the video device achieves or loses lock. This allows an application to determine when a video device achieves lock. The video device may not be able to report intervening instances of rapidly changing lock state and therefore may report two consecutive instances of the same state; client programs must check the value of the status variable reported in the event to determine the state of the lock.

When this control is altered, the video device generates an **MLDC_INPUT_SYNC_SOURCE_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryInputSyncSource

This function returns the current settings of the sync source for the video output device. This function also returns the current state of the lock.

```
MLDCstatus mldcQueryInputSyncSource(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 *syncVoltageReturn,
                    MLDCint32 *syncSourceReturn,
                    MLDCboolean *lockAchievedReturn)
```

hOutDev
: Specifies the handle of the MLdc video output device.

channel
: Specifies the channel number.

syncVoltageReturn
: Returns the current sync voltage.

syncSourceReturn
: Returns the current sync source.

lockAchievedReturn
: Returns the state of lock (**TRUE** if lock achieved, **FALSE** if lock not achieved). See terminology, below, for explanation.

Description

This function queries the source of input sync to the video subsystem. The input sync is used as a reference to which the video device can genlock. The information returned from the function **mldcQueryVideoDeviceInfo** can help determine whether the video device currently has the capability to lock to an external source.

mldcQueryInputSyncSource returns the current settings of the sync source for the video output device. This function also returns the current state of the lock.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSetExternalSyncSource

This function selects which external source is to be used for locking for video devices with more than one external sync source.

```
MLDCstatus mldcSetExternalSyncSource(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 externalSyncSource)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

externalSyncSource
Specifies the external sync source. The values range from 0 to one less than the value returned in the *syncPortCount* field of the **MLDCchannelInfo** structure that is returned from **mldcQueryChannelInfo**.

Description

This function controls the source of external input sync to the video subsystem. The input sync is used as a reference to which the video device can genlock.

See the description in the section ***External Synchronization*** above for a detailed description of genlock functionality.

External Sync Sources

Some video devices have more than one external sync source. For example, a video device may have more than one connector on which sync can be provided; or, a video device's hardware might have an option board that can also provide a sync source. Because of the nature of locking, only one sync source may be selected at a time.

For video devices with more than one external sync source, **mldcSetExternalSyncSource** selects which external source is to be used for locking. Selecting an external sync source with **mldcSetExternalSync-Source** does not switch from the internal to the external sync source; it is still necessary to use the function **mldcSetInputSyncSource** to switch from internal to external sync source.

Events

When this control is altered, the video device generates an **MLDC_INPUT_SYNC_SOURCE_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *externalSync-Source* is not a valid value, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryExternalSyncSource

This function returns the currently selected external sync source.

```
MLDCstatus mldcQueryExternalSyncSource(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 *externalSyncSourceReturn)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

externalSyncSourceReturn
Returns the current external sync source.

Description

This function queries the source of external input sync to the video subsystem.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *externalSyncSourceReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryExternalSyncSourceName

This function returns the textual name associated with the sync source for convenience in presenting information to a user.

```
MLDCstatus mldcQueryExternalSyncSourceName(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 externalSyncSource,
                    MLDCchar  **retSyncSourceName)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

externalSyncSource
Specifies the external sync source. The values range from 0 to one less than the value returned in the *syncPortCount* field of the **MLDCchannelInfo** structure that is returned from **mldcQueryChannelInfo**.

retSyncSourceName
Returns the name of the sync source as a null-terminated string.

Description

For convenience in presenting information to a user, **mldcQueryExternalSyncSourceName** queries the name of the external source of input sync to the video subsystem. The input sync is used as a reference to which the video device can genlock. The application should free the returned string with **mldcFree**.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid

channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSetOutputPhaseH

Sets a value to use as a horizontal sync delay.

```
MLDCstatus mldcSetOutputPhaseH(MLDChandle hOutDev,
                               MLDCint32 channel,
                               MLDCint32 phaseH)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

phaseH
The value to which the horizontal phase should be set.

Description

This function allows alteration of the horizontal phase relationship to genlock input (also known as genlock delay). This control is only active when the graphics device is locked to an external source. The units are specified in terms of pixels, such that:

1 unit = 0.01 pixels

Accuracy is not guaranteed because of variations in hardware, but will be close to the value specified. Precision depends upon graphics device implementation and is not guaranteed to be uniform across the full range. Applications should get the current setting from the video device after a set operation to determine the value to which the video device is set.

The function **mldcQueryChannelInfo** returns the range of values that are valid for this channel.

Note that this function is valid only when the video device is genlocked to an external source; it is not valid when the video device is framelocked or is in frame reset mode.

Events

When this control is altered, the MLdc library generates an **MLDC_OUTPUT_PHASE_H_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseH* is not a valid value, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputPhaseH

This function returns the value currently used as a horizontal sync delay.

```
MLDCstatus mldcQueryOutputPhaseH(MLDChandle hOutDev,
                                 MLDCint32 channel,
                                 MLDCint32 *phaseHReturn)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

phaseHReturn
Returns the value to which the horizontal phase is set.

Description

This function allows querying of the horizontal phase relationship to genlock input (also known as genlock delay). The units are specified in terms of pixels, such that:

1 unit = 0.01 pixels

The function **mldcQueryChannelInfo** returns the range of values that are valid on this channel.

Note that this function is valid only when the video device is genlocked to an external source; it is not valid when the video device is framelocked or is in frame reset mode.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseHReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSetOutputPhaseV

This function sets a value to use as a vertical sync delay.

```
MLDCstatus mldcSetOutputPhaseV(MLDChandle hOutDev,
                               MLDCint32 channel,
                               MLDCint32 phaseV)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

phaseV
The value to which the vertical phase should be set.

Description

This function allows alteration of the **vertical** phase relationship to genlock input (also known as genlock delay). This control is only active when the video device refresh is locked to an external source. The units are specified in terms of lines, such that:

1 unit = 1 line

Accuracy is not guaranteed because of variations in hardware, but will be close to the value specified. Precision depends upon video device implementation and is not guaranteed to be uniform across the full range. Applications should get the current setting from the physical monitor device after a set operation to determine the value to which the video device is set.

The function **mldcQueryChannelInfo** returns the range of values that are valid on this channel.

Events

When this control is altered, the video output device generates an **MLDC_OUTPUT_PHASE_V_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseV* is not a valid value, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputPhaseV

This function returns the value currently used as a vertical sync delay.

```
MLDCstatus mldcQueryOutputPhaseV(MLDChandle hOutDev,
                                 MLDCint32 channel,
                                 MLDCint32 *phaseVReturn)
```

hOutDev
: Specifies the handle for the MLdc video output device.

channel
: Specifies the channel number.

phaseVReturn
: Returns the value to which the vertical phase is set.

Description

This function allows query of the vertical phase relationship to genlock input (also known as genlock delay). This control is only active when the video device refresh is locked to an external source. The units are specified in terms of lines, such that:

1 unit = 1 line

The function **mldcQueryChannelInfo** returns the range of values that are valid on this channel.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseVReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSetOutputPhaseSCH

This function sets a value to use as a subcarrier horizontal phase delay for composite video.

```
MLDCstatus mldcSetOutputPhaseSCH(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 phaseSCH)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

phaseSCH
The value to which the SCH phase should be set.

Description

This function sets a value to use as the subcarrier horizontal phase delay for composite video. The value is specified in degrees:

1 unit = 0.1 degrees

Accuracy is not guaranteed because of variations in hardware, but will be close to the value specified. Precision depends upon physical monitor device implementation and is not guaranteed to be uniform across the full range. Applications should get the current setting from the video output device after a set operation to determine the value to which the video output device is set.

The function **mldcQueryChannelInfo** returns the range of values that are valid on this channel.

Events

When this control is altered MLdc generates an **MLDC_OUTPUT_PHASE_SCH_NOTIFY** event.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseSCH* is not a valid value, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputPhaseSCH

This function returns the value currently used as a subcarrier horizontal phase delay.

```
MLDCstatus mldcQueryOutputPhaseSCH(MLDChandle hOutDev,
                    MLDCint32 channel,
                    MLDCint32 *phaseSCHReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

phaseSCHReturn
Returns the value to which the SCH phase is set.

Description

This function allows query of subcarrier to horizontal phase. This function is used on composite video channels. The value returned is in degrees:

1 unit = 0.1 degrees

The function **mldcQueryChannelInfo** returns the range of values that are valid on this channel.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *phaseSCHReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

22

OUTPUT SYNC

Terminology

The synchronization signal (or *sync* signal) is a series of pulses that communicate raster geometry to a display device. The horizontal sync (or *H-sync*) pulse typically indicates the termination of one scan line and the start of another, visually lower, line. The vertical sync (or *V-sync*) pulse typically indicates that the display device should reset its downward drawing of lines and start the next horizontal line at the top of the screen. When horizontal and vertical sync are combined in the same signal, the result is called composite sync (sometimes referred to as *H + V-sync*).

A synchronization pulse is a variation from one level to another. The output voltage can be generated at different voltages: nominal video level or TTL levels. In some video formats (e.g., some HDTV formats) a third level of excursion is required during some sync pulse sequences; this third level is employed in *tri-level sync*.

Configurations

These functions deal with the synchronization signal's presence on one of the channel's sync output ports. Different video devices may have different hardware available for sync output: some ports may be separate connectors (auxiliary sync outputs) on which sync is delivered; the red, green, and blue color component signals may contain sync; some video devices provide an alpha channel output connector, and sync may also be available on that port. Sync output may be unique to a channel - and video devices may not provide sync outputs uniformly, so each channel's ports must be considered separately.

Sync is available in different forms, depending on video device hardware. Video devices may permit a specific port to generate none, one, or both of horizontal and vertical sync; capabilities of the ports may not be uniform among channels, or even among ports for a single channel.

Especially for sync on the color components, a video device may support independent adjustment of each component's sync, or may support only a global change such that sync is enabled or disabled for all color components simultaneously. Refer to hardware documentation for information on video device support. Applications written for use on more than one type of hardware should query all color component values after setting one to determine whether the sync change was independently adjusted.

The entire set of all sync ports and sync types available for that port may be determined from the structure returned from the function **mldcQueryChannelInfo**.

mldcSetOutputSync

This function enables and disables sync on one of the sync output ports.

```
MLDCstatus mldcSetOutputSync(MLDChandle hOutDev,
                  MLDCint32 channel,
                  MLDCint32 syncPortIndex,
                  MLDCint32 syncType)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

syncPortIndex
Specifies which sync port. Use one of the following constants for the color components sync outputs: **MLDC_SP_RED**, **MLDC_SP_GREEN**, **MLDC_SP_BLUE**, and **MLDC_SP_ALPHA**. For the auxiliary sync ports, use one of the following constants: **MLDC_SP_AUX0**, **MLDC_SP_AUX1**, and **MLDC_SP_AUX2**. Alternatively, for the auxiliary sync ports, applications may use one of the constants defined in an include file that may be supplied that is specific to a particular hardware platform. Not all sync ports have uniform characteristics; use the function **mldcQueryChannelInfo** to determine characteristics for each sync port. The sync ports are summarized in Table 17.1

syncType
The sync type to enable on this port. The possible values are listed in Table 17.2

Description

This function enables and disables sync on one of the sync output ports for the given video output device and channel.

Events

When this control is altered, the video device generates an **MLDC_OUTPUT_SYNC_NOTIFY** event.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputSync

Returns the current settings for sync on one of the output ports.

```
MLDCstatus mldcQueryOutputSync(MLDChandle hOutDev,
                  MLDCint32 channel,
                  MLDCint32 syncPortIndex,
                  MLDCint32 *syncTypeReturn)
```

hOutDev
Specifies the handle for the MLdc video output device.

channel
Specifies the channel number.

syncPortIndex
Specifies which sync port. Use one of the following constants for the color components sync outputs: **MLDC_SP_RED**, **MLDC_SP_GREEN**, **MLDC_SP_BLUE**, and **MLDC_SP_ALPHA**. For the auxiliary sync ports, use one of the following constants: **MLDC_SP_AUX0**, **MLDC_SP_AUX1**, and **MLDC_SP_AUX2**. The defined sync port types are summarized in Table 17.1. Alternatively, for the auxiliary sync ports, applications may use one of the constants defined in an include file that may be supplied that is specific to a particular hardware platform. Not all sync ports have uniform characteristics; use the function **mldcQueryChannelInfo** to determine characteristics for each sync port.

syncTypeReturn
The sync type enabled on this port. Returns one of the values summarized in Table 17.2

Description

mldcQueryOutputSync returns the current settings for sync on one of the output ports.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *syncPortIndex* is not a valid port number, this function will return **MLDC_STATUS_INVALID_PORT.** If *syncTypeReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

23

OUTPUT PEDESTAL

Introduction

Video systems that use analog voltage signals may have a *7.5-percent setup*, also called a *pedestal*. Included in this category are composite 525/59.94 systems such as NTSC, and computer video systems that conform to the levels of the EIA RS-343-A standard. The *setup* level of 7.5 refers to the percentage of the voltage range that is used to designate reference black. If connecting to one of these types of monitors the application will want to enable the use of the *setup* or *pedestal*. Newer analog video standards such as HDTV have *zero setup* and will not need this parameter. *Setup* has also been abolished from component digital video. Also, many 525/59.94 component analog systems have adopted *zero setup*.

There are two functions that deal with *setup* or *pedestal*:

mldcSetOutputPedestal

This function will enable or disable the output pedestal for composite video.

```
MLDCstatus mldcSetOutputPedestal(MLDChandle hOutDev,
                                 MLDCint32 channel,
                                 MLDCboolean enable)
```

hOutDev
: Specifies the handle of the MLdc video output device.

channel
: Specifies the channel number.

enable
: Specifies whether pedestal should be enabled.

Description

Thus function deals with video pedestal, also known as setup. This operation is typically available only on composite NTSC channels. **mldcSetOutputPedestal** enables and disables pedestal on a channel. The value may be **TRUE** (enable) or **FALSE** (disable).

Events

When this control is altered, the graphics device generates an **MLDC_OUTPUT_PEDESTAL_NOTIFY** event.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *enable* is not a valid boolean, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryOutputPedestal

This function will query the current state (on or off) of the composite video pedestal.

```
MLDCstatus mldcQueryOutputPedestal(MLDChandle hOutDev,
                                   MLDCint32 channel,
                                   MLDCboolean *enableReturn)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

enableReturn
Returns whether pedestal is enabled.

Description

This function returns the current settings for pedestal on a channel. The value may be **TRUE** or **FALSE**. Video pedestal, also known as *setup*, is typically available only on composite NTSC channels.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If *enableReturn* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

24

MONITOR COMMANDS

Introduction

These functions allow an application to communicate with a physical monitor that has the capability to send and receive commands. Applications are responsible for composing monitor commands and for parsing the results; the video device simply transports strings between the application and the monitor.

The following functions provide inquiry and control of physical monitors.

mldcInitMonitorBaseProtocol

This function initializes the protocol the video device is going to use to communicate with the physical monitor before any commands or queries are sent to the physical monitor.

```
MLDCstatus mldcInitMonitorBaseProtocol(MLDChandle hOutDev,
                                       MLDCint32 channel)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

Description

The **mldcInitMonitorBaseProtocol** function must be called to initialize the protocol the video device is going to use to communicate with the physical monitor before any commands or queries are sent to the physical monitor. This function reinitializes the physical monitor protocol each time it is called, and may be called at any time.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.**

mldcQueryMonitorBaseProtocol

This function may be called to find out if the protocol has already been initialized.

```
MLDCstatus mldcQueryMonitorBaseProtocol(MLDChandle hOutDev,
                MLDCint32 channel)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

Description

mldcQueryMonitorBaseProtocol may be called to find out if the protocol has already been initialized.

When the base protocol has been initialized successfully, **MLDC_STATUS_NO_ERROR** is returned. If the base protocol has not been initialized, **MLDC_STATUS_BASE_PROTOCOL_NOT_INITIALIZED** is returned. **MLDC_STATUS_INVALID_DEVICE** is returned if *hOutDev* is an invalid device handle. **MLDC_STATUS_INVALID_CHANNEL** is returned if *channel* is not a valid channel number.

mldcQueryMonitorName

This function returns the name of the physical monitor connected to an output video channel.

```
MLDCstatus mldcQueryMonitorName(MLDChandle hOutDev,
                MLDCint32 channel,
                MLDCchar **mname_return)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

mname_return
A pointer to variable that is to receive the NULL-terminated character string. Use **mldcFree** to free the memory for the string when it is no longer needed.

Description

mldcQueryMonitorName returns the name of the monitor connected to the specified channel.

When the function succeeds, the return value is **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If no monitor is connected to the channel or the monitor does not support this function, the function will return **MLDC_STATUS_NO_MONITOR_NAME**, and *mname_return* will be set to **NULL**.

mldcSendMonitorCommand

This function sends a command to the physical monitor of the specified MLdc video output device and channel.

```
MLDCstatus mldcSendMonitorCommand(MLDChandle hOutDev,
                    MLDCint32 channel,
                    const MLDCchar *monitorCommand,
                    MLDCint32 commandLength)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

monitorCommand
The command to be sent to the monitor. The command string will be sent to the monitor exactly as specified.

commandLength
The length, in bytes, of *monitorCommand*.

Description

This function allows an application to communicate with a physical monitor that has the capability to send and receive commands. Applications are responsible for composing monitor commands and for parsing the results; the video device simply transports strings between the application and monitor.

mldcSendMonitorCommand sends a command -- for which no response is expected -- to the physical monitor of the specified MLdc video output device and channel.

If this function succeeds, it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number, this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcSendMonitorQuery

This function sends a command to the physical monitor of the specified channel and **waits** for a response before continuing.

```
MLDCstatus mldcSendMonitorQuery(MLDChandle hOutDev,
                    MLDCint32 channel,
                    const MLDCchar *monitorCommand,
                    MLDCint32 commandLength,
                    MLDCchar **monitorResponse,
                    MLDCint32 *responseLength)
```

hOutDev
Specifies the handle of the MLdc video output device.

channel
Specifies the channel number.

monitorCommand
The command to be sent to the monitor. The command sequence must be a valid command packet that will be sent unprocessed to the monitor connected to channel.

commandLength
: The length, in bytes, of *monitorCommand*.

monitorResponse
: Returns a pointer to a buffer containing the response returned from the monitor. This response will be returned unprocessed.

responseLength
: The length, in bytes, of *monitorResponse*.

Description

This function sends a command to the physical monitor of the specified channel and **waits** for a response before continuing. The response is placed in a buffer whose address is returned in *monitorResponse*. The client is responsible for calling **mldcFree** on the memory allocated by the library for *monitorResponse*.

If this function succeeds it will return **MLDC_STATUS_NO_ERROR**. If *hOutDev* is an invalid device handle this function will return **MLDC_STATUS_INVALID_DEVICE.** If *channel* is not a valid channel number this function will return **MLDC_STATUS_INVALID_CHANNEL.** If any other argument is not a valid value or a valid pointer this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

CHAPTER

25

EXTENDING MLDC

Introduction

An implementation of MLdc can extend the MLdc interface to provide special customized functionality. The mechanism for extending the API is patterned after the OpenGL extension mechanism under Windows. The goal of this mechanism is to allow the interface to be flexible, expandable and to provide for new features in a standardized way.

Extensions are identified by character string names provided by vendors and should follow the following naming convention. MLdc extension names should be null-terminated character strings. The name should not contain any blanks. Each extension name should begin with a prefix denoting the vendor that developed the extension, followed by an underscore. Like OpenGL extension names, if more than one company supports a given extension, the prefix can be promoted to "EXT". If the extension becomes generally supported and is endorsed by the Khronos SIG then the prefix can be promoted to "OML". Function entry points that are part of an extension use the same prefix characters as a suffix. For example, if “XYZ” is to be use as the extension identifier, then each extension name should be of the form "XYZ_some_ extensions_name". Similarly a function name should be of the form "mldcSomeFunctionNameXYZ.”

The application can query the API for a list of extension names that are supported for a given device. Extensions may introduce new functions or new video attributes or video abilities. Extension functions are called through function pointers that are obtained from the API by passing it a string holding the function name. For extensions that add additional structures or named constants to the API, an implementation will need to supply developers with header files with structure and constant definitions. However, once a given extension has been accepted by multiple vendors or by the Khronos SIG, the new structures and constants can be added by Khronos to header files that are delivered with the device-independent portion of MLdc.

When multiple MLdc-controlled devices are present on a system, not all of the devices will necessarily support the same extensions. Therefore applications must be careful not to assume that an extension for one video output device will also work for another.

Functions

There are three functions that deal with supporting MLdc extensions.

mldcQueryExtensionNames

This function returns an array of character strings that name the available MLdc extensions for a given video output device.

```
MLDCstatus mldcQueryExtensionNames(MLDChandle hOutDev,
                                   MLDCchar **extNames)
```

hOutDev
Specifies the handle of the MLdc video output device.

extNames
Returns a space-separated list of character strings that contain the names of all of the extensions that are supported for the given video output device. The memory needed for the character strings is allocated internally by MLdc. When the application no longer needs the extension name strings, it should free the memory by calling **mldcFree.**

Description

This function will return in *extNames* a string that names all of the extensions that are supported by MLdc on this video output device.

If the function can find extension names to return in *extNames*, then the function will return the names in *extNames*, otherwise it will return a NULL in *extNames*.

The function will return **MLDC_STATUS_NO_ERROR** whether there are any extension strings to report or not. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *extNames* is not a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcIsExtensionSupported

This function returns a **MLDC_STATUS_NO_ERROR** or **MLDC_STATUS_INVALID_DEVICE** indicating whether a named extension is supported for a given video output device.

```
MLDCstatus mldcIsExtensionSupported(MLDChandle hOutDev,
                                    MLDCchar *extName)
```

hOutDev
Specifies the handle of the MLdc video output device.

extName
Specifies a null-terminated character string that contains the name of an extension. The name must match an MLdc extension name exactly, including case.

Description

This function returns a **MLDC_STATUS_NO_ERROR** if an extension named by *extName* is supported for the video output device specified by *hOutDev*. The extension name must be exactly given in a null-terminated string pointed at by *extName*. Upper and lower case characters must also match.

If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If *extName* is not a valid extension name, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

mldcQueryExtensionFuncPtr

This function returns a pointer to a named function for a given video output device.

```
MLDCstatus mldcQueryExtensionFuncPtr(MLDChandle hOutDev,
                                     MLDCchar *functionName,
                                     MLDCproc *functionPtr)
```

hOutDev
Specifies the handle of the MLdc video output device.

functionName
Specifies the name of the function for which a function pointer will be returned in *functionPtr*.

functionPtr
The address of a function pointer where the function pointer will be returned.

Description

This function will return to the application a pointer to a function whose name is passed in a null-terminated character string pointed to by *functionName.* The name of the function and the extension must be exactly given and are case-sensitive.

If more than one device supports a given MLdc extension, **mldcQueryExtensionFuncPtr** will return a pointer to a device-independent function. That is, the function pointer will point to the same function for all devices supporting the extension. Applications will therefore not need to keep track of different pointers for the same extension function on different devices.

If this function succeeds, it will return **MLDC_STATUS_NO_ERROR** and the address of the extension function will be returned in *functionPtr*. If *hOutDev* is an invalid device handle, this function will return **MLDC_STATUS_INVALID_DEVICE.** If any other argument is not a valid value or a valid pointer, this function will return **MLDC_STATUS_INVALID_ARGUMENT**.

SECTION

V

APPENDICES

APPENDIX

A

OPENML PROGRAMMING ENVIRONMENT REQUIREMENTS

Window System Independent OpenGL Requirements

OpenML requires a large number of OpenGL extensions in addition to core OpenGL 1.2. The complete set of OpenGL features required for OpenML is documented in the following table.

Where existing extensions have been adopted for OpenML, they are defined by reference to the *OpenGL Extension Registry*. The registry contains specification of extensions in the form of changes to the core OpenGL Specification, and is maintained by SGI on the Web at URL

http://oss.sgi.com/projects/ogl-sample/registry/

OpenGL extension specifications that were created by the Khronos SIG are included in their entirety following the list of features.

Requirement	Where Documented	Comments
OpenGL 1.2	OpenGL 1.2.1 Specification **http://www.opengl.org**	Baseline features
GL_ARB_imaging	OpenGL 1.2.1 Specification	Imaging pipeline functionality is an optional part of OpenGL 1.2
GL_ARB_texture_border_clamp	Registry	Additional texture border filtering mode
GL_EXT_texture_lod_bias	Registry	Texture LOD bias control
GL_OML_subsample, GL_OML_resample	OpenML Specification	4:2:2 and 4:2:2:4 image formats
GL_OML_interlace	OpenML Specification	Interlaced image formats
GL_SGIS_texture_color_mask	Registry	Selective texture color component updates

Table 25.1 OpenGL Feature Requirements

Identifying OpenML OpenGL Extensions

In addition to identifying all required OpenGL extensions individually in the OpenGL extension string, an OpenML implementation must also include the symbol `GL_OML_openml1_0` in the extension string returned by **glGetString(**`GL_EXTENSIONS`**)**. This symbol does not correspond to a specific OpenGL extension, but rather identifies the presence of **all** required OpenML 1.0 OpenGL functionality as a group.

GL_OML_subsample Extension Specification

Name

OML_subsample

Name Strings

GL_OML_subsample

Contact

Jon Leech, Silicon Graphics (ljp 'at' sgi.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001
Author Revision: $Header: //depot/main/doc/registry/extensions/OML/subsample.spec#10 $

Number

240

Dependencies

This extension is written against the OpenGL 1.2.1 Specification,

Overview

Many video image formats and compression techniques utilize various component subsamplings, so it is necessary to provide a mechanism to specify the up- and down-sampling of components as pixel data is drawn from and read back to the client. Though subsampled components are normally associated with the video color space, YCrCb, use of subsampling in OpenGL does not imply a specific color space. Color space conversion may be performed using other extensions or core capabilities such as the color matrix.

This extension defines two new pixel storage formats representing subsampled data on the client. It is loosely based on the SGIX_subsample extension, but specifies subsampling with the data format parameter rather than pixel packing parameters. It also adds support for CYA subsampled data.

When pixel data is received from the client and an unpacking upsampling mode other than PIXEL_SUBSAMPLE_NONE_OML is specified, upsampling is performed via replication, unless otherwise specified by UNPACK_RESAMPLE_OML.

Similarly, when pixel data is read back to the client and a packing downsampling mode other than PIXEL_SUBSAMPLE_NONE_OML is specified, downsampling is performed via simple component decimation (point sampling), unless otherwise specified by PACK_RESAMPLE_OML.

Issues

* Which subsampled component orderings should be supported?

  Only CY and CYA component ordering, since this matches contemporary video hardware. YC and YCA ordering will require a separate extension defining new formats.

* The new enumerant naming scheme gives the component frequencies in the same order as the components themselves; that is, FORMAT_SUBSAMPLE_24_24_OML corresponds to CY 4:2:2, and FORMAT_SUBSAMPLE_244_244_OML corresponds to CYA 4:2:2:4. This makes naming YC and YCA orderings easier.

* Should subsampling be specified with new pixel storage parameters, like the SGIX_subsample extension, or with new formats, like the EXT_422 extension?

  With new formats. There are many invalid format/type combinations when specifying subsampling with a pixel storage parameter. Also, there's an ambiguity when doing this because the <format> parameter represents the after-upsampling data format, not the host format.

* Because subsampled data is inherently pixel / texture oriented, this extension only supports the new formats for pixel and texture operations; it does not support them for convolution filters, histograms, minmax, or color tables.

* The only packed pixel type supported is 10_10_10_2, since this is needed for video data interoperability. It would be possible to support many other packed pixel formats, but most are unused in practice.

Is support for other packed pixels types, particularly 2_10_10_10_REV, required?

* Should readbacks of non-even widths be allowed when downsampling?

No. This is not consistent with draw operations, where this constraint already exists. It also makes OML_resample more complex when using an AVERAGE filter, since the edge cases may also apply to even pixel coordinates. The spec may need to be more explicit about this restriction.

IP Status

No known issues.

New Procedures and Functions

None.

New Tokens

Accepted by the <format> parameter of DrawPixels, ReadPixels, TexImage1D, TexImage2D, TexImage3D, TexSubImage1D, TexSubImage2D, TexSubImage3D, and GetTexImage

FORMAT_SUBSAMPLE_24_24_OML	0x8982
FORMAT_SUBSAMPLE_244_244_OML	0x8983

Additions to Chapter 2 of the OpenGL 1.2.1 Specification (OpenGL Operation)

None.

Additions to Chapter 3 of the OpenGL 1.2.1 Specification (Rasterization)

- (3.6.4, p. 88 "Rasterization of Pixel Rectangles")

Add prior to the "Unpacking" subsection on page 90:

If <format> is FORMAT_SUBSAMPLE_24_24_OML or FORMAT_SUBSAMPLE_244_244_OML, and <type> is one of the packed pixel formats in table 3.8 other than UNSIGNED_INT_10_10_10_2, then the error INVALID_OPERATION occurs; if <width> is not a multiple of 2 pixels, or if the value of the UNPACK_SKIP_PIXELS or UNPACK_ROW_LENGTH parameters is not a multiple of 2 pixels, then the error INVALID_OPERATION occurs.

- Add new entries to table 3.6:

Format Name	Element Meaning and Order	Target Buffer
FORMAT_SUBSAMPLE_24_24_OML	CbY / CrY	Color
FORMAT_SUBSAMPLE_244_244_OML	CbYA / CrYA	Color

- Append to the caption of table 3.6:

  Subsampled formats yield components that are further modified during conversion to uniform sampling. The subsampled components are denoted as Cb, Y, Cr, and A, although subsampled data is not defined to be in any specific color space.

- Modify table 3.8:

<type> Parameter Token Name	GL Data Type	Number of Components	Matching Pixel Formats
UNSIGNED_INT_10_10_10_2	uint	2, 3, 4	RGBA, BGRA, FORMAT_SUBSAMPLE_24_24_OML, FORMAT_SUBSAMPLE_244_244_OML

- Append to the caption of table 3.8:

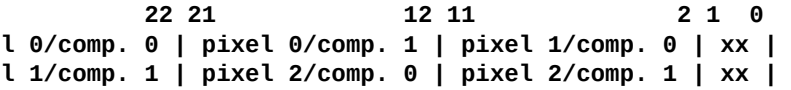
  Subsampled formats may pack components from multiple groups into a single uint.

- Modify table 3.11's UNSIGNED_INT_10_10_10_2 entry:

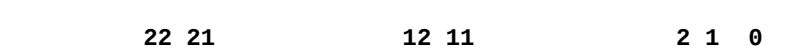
  UNSIGNED_INT_10_10_10_2, <format>s RGBA and BGRA:

  (use existing 4-component diagram)

  UNSIGNED_INT_10_10_10_2, <format> SUBSAMPLE_24_24_OML:



  UNSIGNED_INT_10_10_10_2, <format> SUBSAMPLE_244_244_OML:



- Change caption of table 3.11:

  Table 3.11: UNSIGNED_INT formats. Subsampled formats are packed into words, so components from a group may lie in different words. ``xx'' fields are unused.

- Add new subsection before "Conversion to RGB" on page 99:

  Conversion to Uniform Sampling

  This step is applied only to subsampled data. If <format> is FORMAT_SUBSAMPLE_24_24_OML, then the number of components per pixel is increased from two to three. If <format> is FORMAT_SUBSAMPLE_244_244_OML. then the number of components per pixel is increased from three to four.

  After conversion to uniform sampling (see figure 3.9). pixels are thereafter treated as though they were RGB (three component) or RGBA (four component) format.

  In the remainder of this section, the j'th component of the i'th pixel in a row is denoted by S_i,j (for source pixels in client memory) and D_i,j (for destination pixels in the color buffer).

  Destination component values are defined as:

  For even pixels ((i mod 2) == 0):

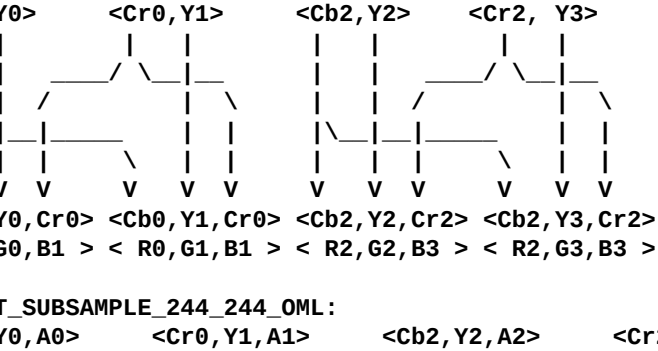
      D_i,0 = S_i,0
      D_i,1 = S_i,1
      D_i,2 = S_i+1,0
      D_i,3 = S_i,2

  For odd pixels ((i mod 2) == 1):

      D_i,0 = S_i-1,0
      D_i,1 = S_i,1
      D_i,2 = S_i,0
      D_i,3 = S_i,2

- Add new figure 3.9 (renumber following figures):

  FORMAT_SUBSAMPLE_24_24_OML:



  FORMAT_SUBSAMPLE_244_244_OML:

  <Cb0,Y0,A0> <Cr0,Y1,A1> <Cb2,Y2,A2> <Cr2,Y3,A3>

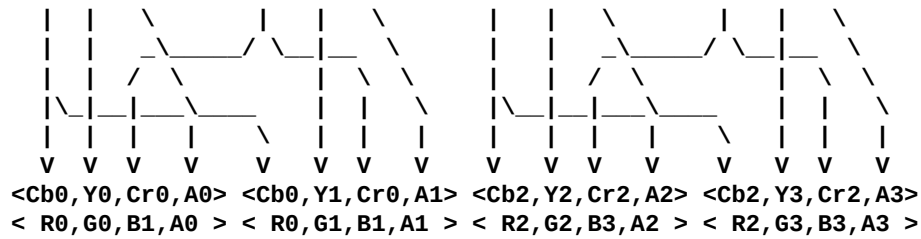


Figure 3.9: Upsampling with component replication of subsampled data from client memory to form RGB or RGBA pixels.

Additions to Chapter 4 of the OpenGL 1.2.1 Specification (Per-Fragment Operations and the Frame Buffer)

4.3.2 Reading Pixels

- Add new subsection before "Final Conversion" on page 160:

Conversion to Subsampled Form

This step is applied only if <format> is FORMAT_SUBSAMPLE_24_24_OML or FORMAT_SUBSAMPLE_244_244_OML.

In the remainder of this section, the j'th component of the i'th pixel in a row is denoted by S_i,j (for source pixels in the color buffer) and D_i,j (for destination pixels in client memory).

If <format> is FORMAT_SUBSAMPLE_24_24_OML, then the resulting pixels have 2 components; if <format> is FORMAT_SUBSAMPLE_244_244_OML, then the resulting pixels have 3 components (see figure 4.3). Destination component values are defined as:

For even pixels ((i mod 2) == 0):

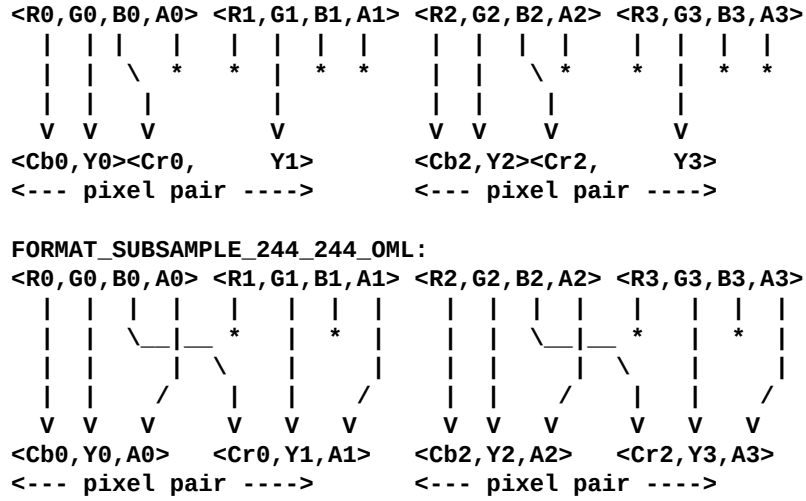
```
D_i,0 = S_i,0
D_i,1 = S_i,1
D_i,2 = S_i,3   (only for FORMAT_SUBSAMPLE_244_244_OML)
```

For odd pixels ((i mod 2) == 1):

```
D_i,0 = S_i-1,2
D_i,1 = S_i,1
D_i,2 = S_i,3   (only for FORMAT_SUBSAMPLE_244_244_OML)
```

- Add new figure 4.3 (renumber following figures):

FORMAT_SUBSAMPLE_24_24_OML:



FORMAT_SUBSAMPLE_244_244_OML:

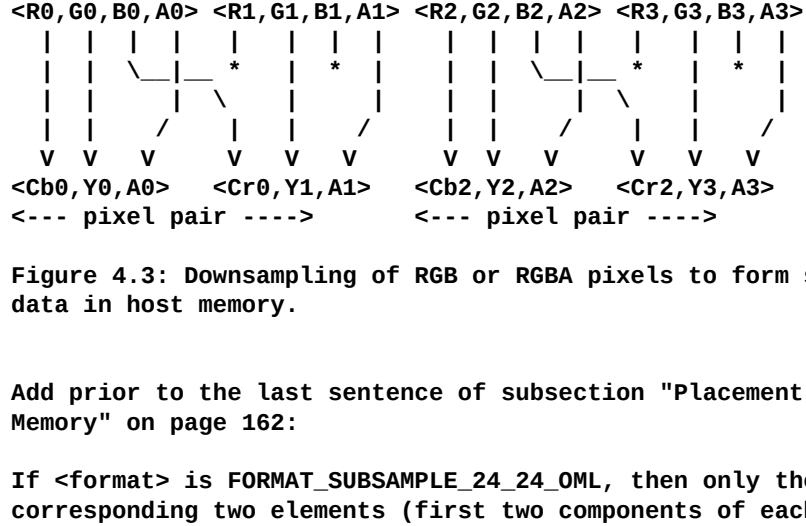


Figure 4.3: Downsampling of RGB or RGBA pixels to form subsampled data in host memory.

- Add prior to the last sentence of subsection "Placement in Client Memory" on page 162:

  If <format> is FORMAT_SUBSAMPLE_24_24_OML, then only the corresponding two elements (first two components of each group) are written. If <format> is FORMAT_SUBSAMPLE_244_244_OML, then only the corresponding three elements (first three components of each group) are written.

Additions to Chapter 5 of the OpenGL 1.2.1 Specification (Special Functions)

None.

Additions to Chapter 6 of the OpenGL 1.2.1 Specification (State and State Requests)

None.

Additions to the GLX 1.3 Specification

TBD. Discussion of image formats in the GLX Protocol Specification may need to be expanded.

Errors

See above.

New State

None.

New Implementation Dependent State

None.

Revision History

* Revision 10, 07/23/2001 - Finalized Status for OpenML 1.0.
* Revision 9, 07/16/2001 - Fix label in 24_24 packed pixel diagram.
* Revisions 7-8, 07/11/2001 - Assign enum values and extension number for the registry.
* Revision 6 - Correct errors in the equations describing subsampling.
* Revision 5 - Formatting changes for OpenML Specification.
* Revision 4 - Rewrite to use the <format> parameter, rather than a pixel storage mode, to specify subsampled data. Specify which format/type combinations are allowed for subsampled data, and define the representation of 10-bit component subsampled packed pixel data.
* Revision 3 - Removed support for YC component orders. Renamed CY and CYA enumerants more sensibly. Changed text descriptions of sampling to equations. Made enum values undefined until we've determined if this extension is backwards compatible with SGIX_subsample.
* Revision 2 - Corrected 4224 upsampling and downsampling figures. Moved discussion of errors for non-even image widths from the OML_resample specification.
* Revision 1 - Derived from SGIX_subsample.

GL_OML_resample Extension Specification

Name

OML_resample

Name Strings

GL_OML_resample

Contact

Jon Leech, Silicon Graphics (ljp 'at' sgi.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001
Author Revision: $Header: //depot/main/doc/registry/extensions/OML/resample.spec#10 $

Number

241

Dependencies

OML_subsample is required.
This extension is written against the OpenGL 1.2.1 Specification,

Overview

This extension enhances the resampling capabilities of the OML_subsample extension. It is loosely based on the SGIX_resample extension.

When converting data from subsampled to uniform sampling, upsampling may be performed by one of three methods: component replication, zero fill, or adjacent neighbor averaging.

When converting data from uniform sampling to subsampled form, downsampling may be performed only by component decimation (point sampling) or averaging.

Upsampling and downsampling filters other than those defined by this extension may be performed by appropriate use of convolution and other pixel transfer operations. The zero fill unpacking mode is included to assist applications wanting to define their own filters.

Issues

* Should RESAMPLE_xxx enums be renamed to PIXEL_RESAMPLE_xxx?

IP Status

No known issues.

New Procedures and Functions

None.

New Tokens

Accepted by the <pname> parameter of PixelStoref, PixelStorei, GetBooleanv, GetIntegerv, GetFloatv and GetDoublev:

PACK_RESAMPLE_OML	0x8984
UNPACK_RESAMPLE_OML	0x8985

Accepted by the <param> parameter of PixelStoref and PixelStorei when the <pname> parameter is UNPACK_RESAMPLE_OML:

RESAMPLE_REPLICATE_OML	0x8986
RESAMPLE_ZERO_FILL_OML	0x8987
RESAMPLE_AVERAGE_OML	0x8988

Accepted by the <param> parameter of PixelStoref and PixelStorei when the <pname> parameter is PACK_RESAMPLE_OML:

RESAMPLE_DECIMATE_OML	0x8989
RESAMPLE_AVERAGE_OML	0x8988

Additions to Chapter 2 of the OpenGL 1.2.1 Specification (OpenGL Operation)

None.

Additions to Chapter 3 of the OpenGL 1.2.1 Specification (Rasterization)

- (3.6.1, p. 75 "Pixel Storage Modes")

  Add to table 3.1 (p. 76):

Parameter Name	Type	Initial Value	Valid Range
UNPACK_RESAMPLE_OML	integer	RESAMPLE_REPLICATE_OML	RESAMPLE_REPLICATE_OML RESAMPLE_ZERO_FILL_OML RESAMPLE_AVERAGE_OML
PACK_RESAMPLE_OML	integer	RESAMPLE_DECIMATE_OML	RESAMPLE_DECIMATE_OML RESAMPLE_AVERAGE_OML

- (3.6.4, p. 88 "Rasterization of Pixel Rectangles")

- Modify the new subsection "Conversion to Uniform Sampling" (introduced by OML_subsample) to read:

  Conversion to Uniform Sampling

  This step is applied only to subsampled data. If <format> is FORMAT_SUBSAMPLE_24_24_OML, then the number of components per pixel

is increased from two to three. If <format> is FORMAT_SUBSAMPLE_244_244_OML. then the number of components per pixel is increased from three to four. The upsampling method used is determined by the value of the PixelStore parameter UNPACK_RESAMPLE_OML.

After conversion to uniform sampling (see figure 3.9). pixels are thereafter treated as though they were RGB (three component) or RGBA (four component) format.

In the remainder of this section, the j'th component of the i'th pixel in a row is denoted by S_i,j (for source pixels in client memory) and D_i,j (for destination pixels in the color buffer).

Replication

If the value of UNPACK_RESAMPLE_OML is RESAMPLE_REPLICATE_OML (see figure 3.9), destination component values are defined as:

For even pixels ((i mod 2) == 0):

```
D_i,0 = S_i,0
D_i,1 = S_i,1
D_i,2 = S_i+1,0
D_i,3 = S_i,2
```

For odd pixels ((i mod 2) == 1):

```
D_i,0 = S_i-1,0
D_i,1 = S_i,1
D_i,2 = S_i,0
D_i,3 = S_i,2
```

- (figure 3.9, introduced by OML_subsample, is unchanged)

Zero Fill

If the value of UNPACK_RESAMPLE_OML is RESAMPLE_ZERO_FILL_OML (see figure 3.10), destination component values are defined as:

For even pixels ((i mod 2) == 0):

```
D_i,0 = S_i,0
D_i,1 = S_i,1
D_i,2 = S_i+1,0
D_i,3 = S_i,2
```

For odd pixels ((i mod 2) == 1):

```
    D_i,0 = 0
    D_i,1 = S_i,1
    D_i,2 = 0
    D_i,3 = S_i,2
```

- Add new figure 3.10, following the new figure 3.9 defined in the OML_subsample extension:

```
FORMAT_SUBSAMPLE_24_24_OML:
<Cb0,Y0>     <Cr0,Y1>     <Cb2,Y2>    <Cr2, Y3>
  |  |         |   |        |   |         |   |
  |  |   ____/    |        |   |   ____/    |
  |  |  /         |        |   |  /         |
  |  |  |    0.0  | 0.0    |   |  |    0.0  | 0.0
  |  |  |     |   |  |     |   |  |     |   |  |
  V  V  V     V   V  V     V   V  V     V   V  V
<Cb0,Y0,Cr0> <Cb0,Y1,Cr0> <Cb2,Y2,Cr2> <Cb2,Y3,Cr2>
< R0,G0,B1 > < R0,G1,B1 > < R2,G2,B3 > < R2,G3,B3 >

FORMAT_SUBSAMPLE_244_244_OML:
<Cb0,Y0,A0>     <Cr0,Y1,A1>     <Cb2,Y2,A2>     <Cr2,Y3,A3>
  |  |   \        |   |   \        |   |   \        |   |   \
  |  |   _\_____/     |    \       |   |   _\_____/     |    \
  |  |  /  \          |     \      |   |  /  \          |     \
  |  |  |   \   0.0   | 0.0  \     |   |  |   \   0.0   | 0.0  \
  |  |  |   |    |    |  |   |     |   |  |   |    |    |  |   |
  V  V  V   V    V    V  V   V     V   V  V   V    V    V  V   V
<Cb0,Y0,Cr0,A0> <Cb0,Y1,Cr0,A1> <Cb2,Y2,Cr2,A2> <Cb2,Y3,Cr2,A3>
< R0,G0,B1,A0 > < R0,G1,B1,A1 > < R2,G2,B3,A2 > < R2,G3,B3,A3 >
```

Figure 3.10: Upsampling with zero fill of subsampled data from host memory to form RGB or RGBA pixels.

Averaging

If the value of UNPACK_RESAMPLE_OML is RESAMPLE_AVERAGE_OML (see figure 3.11), destination component values are defined as:

For even pixels:

```
    D_i,0 = S_i,0
    D_i,1 = S_i,1
    D_i,2 = S_i+1,0
    D_i,3 = S_i,2
```

(No special case for D_i,2 can arise when i is the last pixel,

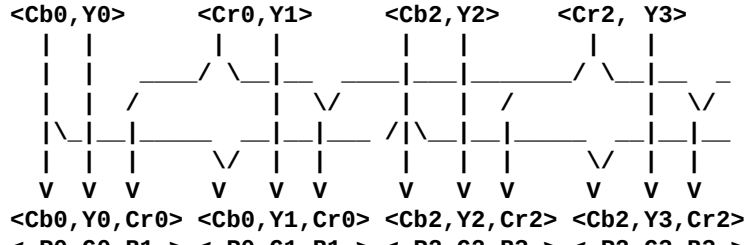
because of the restriction to even image widths).

For odd pixels:

```
D_i,0 = S_i,0                        i == <width>-1 (last pixel)
      = 1/2 S_i-1,0 + 1/2 S_i+1,0    otherwise
D_i,1 = S_i,1
D_i,2 = S_i,0                        i == <width>-1 (last pixel)
      = 1/2 S_i,0 + 1/2 S_i+2,0      otherwise
D_i,3 = S_i,2
```

- Add new figure 3.11, following the new figure 3.10:

FORMAT_SUBSAMPLE_24_24_OML:



FORMAT_SUBSAMPLE_244_244_OML:

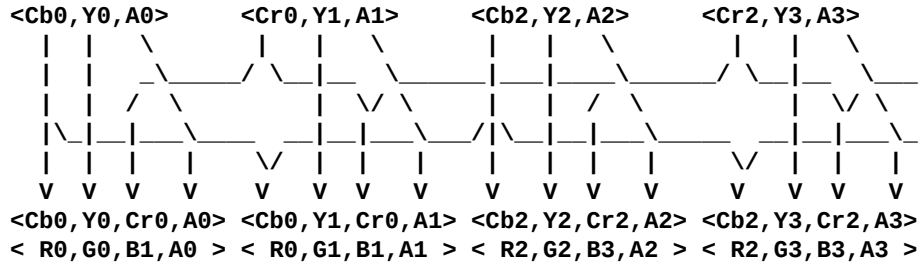


Figure 3.11: Upsampling with averaging of subsampled data from host memory to form RGB or RGBA pixels.

Additions to Chapter 4 of the OpenGL 1.2.1 Specification (Per-Fragment Operations and the Frame Buffer)

- Modify the new section "Conversion to Subsampled Form" (introduced by OML_subsample) to read:

Conversion to Subsampled Form

This step is applied only if <format> is FORMAT_SUBSAMPLE_24_24_OML or FORMAT_SUBSAMPLE_244_244_OML. A filter operation specified by the

value of PACK_RESAMPLE_OML is applied prior to the subsampling step.

In the remainder of this section, the j'th component of the i'th pixel in a row is denoted by S_i,j (for source pixels in the color buffer) and D_i,j (for destination pixels in client memory).

If <format> is FORMAT_SUBSAMPLE_24_24_OML, then the resulting pixels have 2 components (see figure 4.3); if <format> is FORMAT_SUBSAMPLE_244_244_OML, then the resulting pixels have 3 components (see figure 4.4).

Decimation

If the value of PACK_RESAMPLE_OML is RESAMPLE_DECIMATE_OML, then destination component values are defined as:

For even pixels ((i mod 2) == 0):

```
D_i,0 = S_i,0
D_i,1 = S_i,1
D_i,2 = S_i,3   (only for FORMAT_SUBSAMPLE_244_244_OML)
```

For odd pixels ((i mod 2) == 1):

```
D_i,0 = S_i-1,2
D_i,1 = S_i,1
D_i,2 = S_i,3   (only for FORMAT_SUBSAMPLE_244_244_OML)
```

- Add new figure 4.3 (renumber following figures):

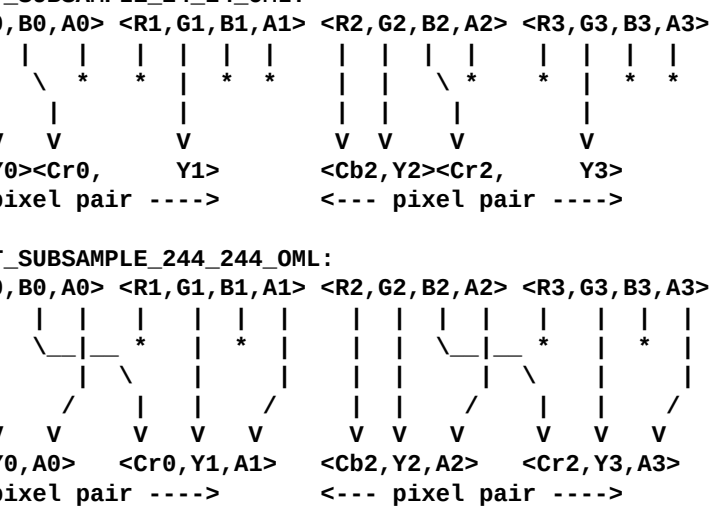


Figure 4.3: Downsampling with decimation of RGB or RGBA pixels to form subsampled data in host memory.

Averaging

If the value of PACK_RESAMPLE_OML is RESAMPLE_AVERAGE_OML, then destination component values are defined as:

For even pixels:

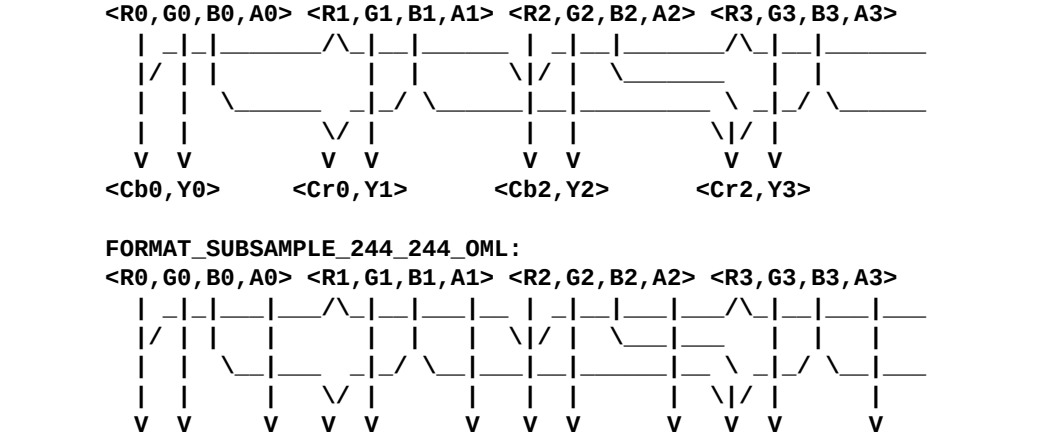
```
D_i,0 = 3/4 S_i,0 + 1/4 S_i+1,0     i == 0 (first pixel)
      = 1/4 S_i-1,0 + 3/4 S_i,0     i == <width>-1 (last pixel)
      = 1/4 S_i-1,0 +               otherwise
        1/2 S_i,0 +
        1/4 S_i+1,0
D_i,1 = S_i,1
D_i,2 = S_i,3
```

For odd pixels:

```
D_i,0 = 3/4 S_i-1,2 + 1/4 S_i,2     i == <width>-1 (last pixel)
      = 1/4 S_i-1,2 +               otherwise
        1/2 S_i,2 +
        1/4 S_i+1,2
D_i,1 = S_i,1
D_i,2 = S_i,3
```

XXX Note that the "last pixel" case is only needed for readbacks where
XXX <width> is not even, so may be removable.

- Add new figure 4.4 (renumber following figures):



<Cb0,Y0, A0><Cr0,Y1, A1><Cb2,Y2, A2><Cr2,Y3, A3>

Figure 4.4: Downsampling with averaging of RGB or RGBA pixels to form subsampled data in host memory.

Additions to Chapter 5 of the OpenGL 1.2.1 Specification (Special Functions)

None.

Additions to Chapter 6 of the OpenGL 1.2.1 Specification (State and State Requests)

None.

Additions to the GLX 1.3 Specification

None.

Errors

See above.

New State

(table 6.17, p. 207)

Get Value	Type	Get Command	Initial Value
UNPACK_RESAMPLE_OML	Z3	GetIntegerv	RESAMPLE_REPLICATE_OML
PACK_RESAMPLE_OML	Z2	GetIntegerv	RESAMPLE_DECIMATE_OML

(continued columns)

Get Value	Description	Sec	Attribute
UNPACK_RESAMPLE_OML	Pixel upsampling mode	3.6	pixel-store
PACK_RESAMPLE_OML	Pixel downsampling mode	4.3	pixel-store

New Implementation Dependent State

None.

Revision History

* Revision 10, 07/23/2001 - Finalized Status for OpenML 1.0.
* Revision 9, 07/16/2001 - Remove erroneous redefinition of RESAMPLE_AVERAGE enumerant value.
* Revisions 7-8, 07,11,2001 - Assign enum values and extension number for the registry.
* Revision 6 - Correct errors in the equations describing subsampling.
* Revision 5 - Formatting changes for OpenML Specification.

* Revision 4, 03/27/2001 - Rewrite to use the <format> parameter, rather than a pixel storage mode, to specify subsampled data.
* Revision 3 - Removed support for YC component orders. Renamed CY and CYA enumerants more sensibly. Added Discreet's RESAMPLE_AVERAGE resampling mode. Changed text descriptions of sampling to equations. Made enum values undefined until we've determined if this extension is backwards compatible with SGIX_resample.
* Revision 2 - Corrected 4224 upsampling and downsampling figures. Moved discussion of errors for non-even image widths to the OML_subsample specification.
* Revision 1 - Derived from SGIX_resample.

GL_OML_interlace Extension Specification

Name

OML_interlace

Name Strings

GL_OML_interlace

Contact

Jon Leech, Silicon Graphics (ljp 'at' sgi.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001
Author Revision: $Header: //depot/main/doc/registry/extensions/OML/interlace.spec#5 $

Number

239

Dependencies

None.

Overview

This extension provides a way to interlace rows of pixels when drawing, reading, or copying pixel rectangles or texture images. In this context, interlacing means skiping over rows of pixels or texels in the destination. This is useful for dealing with video data since a single frame of video is typically composed from two images or fields: one image specifying the data for even rows of the frame and the other image specifying the data for odd rows of the

frame.

The functionality provided by this extension is a combination of the older SGIX_interlace and INGR_interlace_read extensions, with changes applying interlacing to texture image queries.

Issues

* Should there be a single enumerant controlling both draw and read operations? For the moment, we continue using separate enums, for backwards compatibility with SGIX_interlace and INGR_interlace_read.

* Can we use the same enum values as the older extensions? Possibly, depending on the resolution of issues of exactly which operations interlacing is applied to. For the moment we assume the same values cannot be used.

* Are there any GLX protocol issues relating to the actual vs. specified size of the image being transferred? Probably not, since unlike the effects of convolution, the image being transferred over the wire is always the specified size; all that changes is where the pixels are positioned in the frame buffer.

* Discreet requested that INTERLACE_READ_OML apply to GetTexImage. The extension does not support this because there's no easy way to support it with any generality: with only the binary INTERLACE_READ_OML setting available, the implementation could return only the even rows, but would have no way of indicating that only the odd rows should be returned. This is non-orthogonal probably more frustrating than useful; a generic solution would require creation of a GetTexSubImage call.

* We may need to be more precise about exactly which operations interlacing is and is not applied to. Currently it must be inferred from other parts of the OpenGL Specification, and different implementations are likely to disagree on this. Some language has been added to section 6.1.4 to deal explicitly with GetTexImage, but may be needed elsewhere as well.

IP Status

No known issues.

New Procedures and Functions

None.

New Tokens

Accepted by the <cap> parameter of Enable, Disable, and IsEnabled, and by the <pname> parameter of GetBooleanv, GetIntegerv, GetFloatv, and GetDoublev:

INTERLACE_OML	0x8980
INTERLACE_READ_OML	0x8981

Additions to Chapter 2 of the OpenGL 1.2.1 Specification (OpenGL Operation)

None.

Additions to Chapter 3 of the OpenGL 1.2.1 Specification (Rasterization)

- **(3.6.4, p. 99) Insert the following subsection between "Pixel Transfer Operations" and "Final Conversion"**

  Interlacing

  This step applies only if INTERLACE_OML is enabled. All of the groups which belong to a row m in the source image are treated as if they belonged to the row 2 * m. If the source image has a height of h rows, this effectively expands the height of the image to 2 * h - 1 rows. After interlacing, only every other row of the image is defined. If the interlaced pixel rectangle is rasterized to the framebuffer, then only these rows are converted to fragments. If the interlaced pixel rectangle is a texture image, then only these rows are written to texure memory.

  In cases where errors can result from the specification of invalid image dimensions, it is the resulting dimensions that are tested, not the dimensions of the source image. (A specific example is TexImage2D, which specifies constraints for image dimensions. Even if TexImage2D is called with a null pixel pointer, the dimensions of the resulting texture image are those that would result from the effective expansion of the specified image due to interlacing.)

Additions to Chapter 4 of the OpenGL 1.2.1 Specification (Per-Fragment Operations and the Frame Buffer)

- **(4.3.2, p. 157) Modify the 5th paragraph of "Obtaining Pixels from the Framebuffer" to read**

  If INTERLACE_READ_OML is disabled, then ReadPixels obtains values from the selected buffer for each pixel with lower left hand corner at (x+i, y+j) for 0 <= i < width and 0 <= j < height; this pixel is said to be the ith pixel in the jth row.

  If INTERLACE_READ_OML is enabled, then ReadPixels obtains values from the selected buffer for each pixel with lower left hand corner at (x+i, y+(j*2)) for 0 <= i < width and 0 <= j < height; this pixel is said to be the ith pixel in the jth row.

  If any of these pixels lies outside of the window...

Additions to Chapter 5 of the OpenGL 1.2.1 Specification (Special Functions)

None.

Additions to Chapter 6 of the OpenGL 1.2.1 Specification (State and State Requests)

- **(6.1.4, p. 184) Insert in the second paragraph, following "... and from the first image to the last for three-dimensional textures."**

  The value of INTERLACE_READ_OML has no effect on the operation of GetTexImage.

Additions to the GLX 1.3 Specification

None.

```
Errors

    See above.

New State

    Get Value           Type Get Command Initial Value Attribute
    ---------           ---- ----------- ------------- ---------
    INTERLACE_OML       B    IsEnabled   False         pixel/enable
    INTERLACE_READ_OML  B    IsEnabled   False         pixel/enable

New Implementation Dependent State

    None.

Revision History

  * Revision 5, 07/23/2001 - Finalized Status for OpenML 1.0.
  * Revision 4, 07/11/2001 - Assign enum values and extension number
    for the registry.
  * Revision 3 - Formatting changes for OpenML Specification.
  * Revision 2 - Expanded description of why GetTexImage doesn't support
    interlaced readbacks.
  * Revision 1 - Derived from SGIX_interlace and INGR_interlace_read.
```

X Window System Requirements

GLX Requirements

GLX binds OpenGL to the X Window System. OpenML requires several GLX extensions in addition to core GLX 1.3. The complete set of GLX features required for OpenML is documented in the following table.

Where existing extensions have been adopted for OpenML, they are defined by reference to the *OpenGL Extension Registry*.

GLX extension specifications that were created by the Khronos SIG are included in their entirety following the list of features.

Requirement	Where Documented	Comments
GLX 1.3	GLX 1.3 Specification **http://www.opengl.org**	Baseline features. In addition, GLX protocol support is required for all core OpenGL extensions used in OpenML.
GLX_OML_swap_method	OpenML Specification	Buffer swap method control
GLX_OML_sync_control	OpenML Specification	UST/MSC/SBC synchronization

Table 25.2 GLX feature requirements

Identifying OpenML GLX Extensions

In addition to identifying all required GLX extensions individually in the GLX extension strings, an OpenML implementation must also include the symbol `GLX_OML_openml1_0` in the extension strings returned by **glXQueryExtensionsString**, **glXGetClientString**, and **glXQueryServerString**. This symbol does not correspond to a specific GLX extension, but rather identifies the presence of **all** required OpenML 1.0 GLX functionality as a group.

GLX_OML_swap_method Extension Specification

Name

GLX_OML_swap_method

Name Strings

GLX_OML_swap_method

Contact

Jon Leech, SGI (ljp 'at' sgi.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001
Revision: $Header: //depot/main/doc/registry/extensions/OML/glx_swap_method.spec#4 $

Number

237

Dependencies

GLX 1.3 is required.

Overview

This extension adds a new attribute, GLX_SWAP_METHOD, for a GLXFBConfig. The GLX_SWAP_METHOD indicates how front and back buffers are swapped when the GLXFBConfig is double-buffered.

IP Status

No known issues.

Issues and Notes

  * Some hardware supports different swap methods in full screen mode
    vs. windowed mode. How should this be handled? This is not handled
    by this extension. GLX does not support the notion of fullscreen vs.
    windowed mode. A separate extension is required to properly support
    fullscreen mode.

New Procedures and Functions

    None.

New Tokens

    Accepted in the <attrib_list> parameter array of glXChooseFBConfig
    and as the <attribute> parameter for glXGetFBConfigAttrib:

        GLX_SWAP_METHOD_OML   0x8060

Accepted as a value in the <attrib_list> parameter of glXChooseFBConfig
and returned in the <value> parameter of glXGetFBConfig:

        GLX_SWAP_EXCHANGE_OML   0x8061
        GLX_SWAP_COPY_OML   0x8062
        GLX_SWAP_UNDEFINED_OML   0x8063

Additions to the OpenGL 1.2.1 Specification

    None

Additions to the GLX 1.3 Specification

  - (3.3.3, p. ?? "Configuration Management")

    Add to table 3.1:

    Attribute   Type Notes
    ---------   ---- -----
    GLX_SWAP_METHOD_OML enum method used to swap front and back color buffers

    The GLX_SWAP_METHOD_OML attribute may be set to one of the following
    values: GLX_SWAP_EXCHANGE_OML, GLX_SWAP_COPY_OML or
    GLX_SWAP_UNDEFINED_OML. If this attribute is set to
    GLX_SWAP_EXCHANGE_OML then swapping exchanges the front and back
    buffer contents; if the attribute is set to GLX_SWAP_COPY_OML then
    swapping copies the back buffer contents to the front buffer,
    preserving the back buffer contents; if it is set to
    GLX_SWAP_UNDEFINED_OML then the back buffer contents are copied to

the front buffer but the back buffer contents are undefined after the operation. If the GLXFBConfig does not support a back buffer, then the value of GLX_SWAP_METHOD_OML is set to GLX_SWAP_UNDEFINED_OML.

Add to table 3.4:

Attribute	Default	Selection and Sorting Criteria	Sort Priority
GLX_SWAP_METHOD_OML	GLX_DONT_CARE	Exact	???

New State

None

New Implementation Dependent State

None

Revision History

* Revision 4, 07/23/2001 - Finalized Status for OpenML 1.0.
* Revision 3, 07/11/2001 - Assign enum values.
* Revision 2, 07/11/2001 - Assign extension numbers for the registry.
* Revision 1 - Change Paula's draft to use OML affix.

GLX_OML_sync_control Extension Specification

Name

OML_sync_control

Name Strings

GLX_OML_sync_control

Contact

Randi Rost, 3Dlabs (rost 'at' 3dlabs.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001 Revision: 6.0

Based on WGL_OML_sync_control Revision 17.0

Number

238

Dependencies

The extension is written against the OpenGL 1.2.1 Specification and the GLX 1.3 Specification, although it should work on previous versions of these specifications.

Overview

This extension provides the control necessary to ensure synchronization between events on the graphics card (such as vertical retrace) and other parts of the system. It provides support for applications with real-time rendering requirements by providing precise synchronization between graphics and streaming video or audio.

This extension incorporates the use of three counters that provide the necessary synchronization. The Unadjusted System Time (or UST) is a 64-bit monotonically increasing counter that is available throughout the system. UST is not a resource that is controlled by OpenGL, so it is not defined further as part of this extension. The graphics Media Stream Counter (or graphics MSC) is a counter that is unique to the graphics subsystem and increments for each vertical retrace that occurs. The Swap Buffer Counter (SBC) is an attribute of a GLXDrawable and is incremented each time a swap buffer action is performed on the associated drawable.

The use of these three counters allows the application to synchronize graphics rendering to vertical retraces and/or swap buffer actions, and to synchronize other activities in the system (such as streaming video or audio) to vertical retraces and/or swap buffer actions.

Functions are provided to allow an application to detect when an MSC or SBC has reached a certain value. This function will block until the specified value has been reached. Applications that want to continue other processing while waiting are expected to call these blocking functions from a thread that is separate from the main processing thread(s) of the application.

This extension carefully defines the observable order in which things occur in order to allow implementations to perform optimizations and avoid artifacts such as tearing, while at the same time providing a framework for consistent behavior from the point of view of an application.

Issues

None.

IP Status

No known issues.

New Procedures and Functions

```
Bool glXGetSyncValuesOML(Display* dpy,
                         GLXDrawable drawable,
```

```
                              int64_t* ust,
                              int64_t* msc,
                              int64_t* sbc)

    Bool glXGetMscRateOML(Display* dpy,
                          GLXDrawable drawable,
                          int32_t* numerator,
                          int32_t* denominator)

    int64_t glXSwapBuffersMscOML(Display* dpy,
                                 GLXDrawable drawable,
                                 int64_t target_msc,
                                 int64_t divisor,
                                 int64_t remainder)

    Bool glXWaitForMscOML(Display* dpy,
                          GLXDrawable drawable,
                          int64_t target_msc,
                          int64_t divisor,
                          int64_t remainder,
                          int64_t* ust,
                          int64_t* msc,
                          int64_t* sbc)

    Bool glXWaitForSbcOML(Display* dpy,
                          GLXDrawable drawable,
                          int64_t target_sbc,
                          int64_t* ust,
                          int64_t* msc,
                          int64_t* sbc)
```

New Tokens

None

Additions to Chapter 2 of the OpenGL 1.2.1 Specification (OpenGL Operation)

None

Additions to Chapter 3 of the OpenGL 1.2.1 Specification (Rasterization)

None

Additions to Chapter 4 of the OpenGL 1.2.1 Specification (Per-Fragment Operations and the Framebuffer)

None

Additions to Chapter 5 of the OpenGL 1.2.1 Specification (Special Functions)

None

Additions to Chapter 6 of the OpenGL 1.2.1 Specification (State and State Requests)

None

Additions to the GLX 1.3 Specification

glXGetSyncValuesOML returns the current UST/MSC/SBC triple. A UST

timestamp is obtained each time the graphics MSC is incremented. If this value does not reflect the value of the UST at the time the first scan line of the display begins passing through the video output port, it will be adjusted by the graphics driver to do so prior to being returned by any of the functions defined by this extension.

This UST timestamp, together with the current graphics MSC and the current SBC, comprise the current UST/MSC/SBC triple. The UST, graphics MSC, and SBC values are not part of the render context state. These values cannot be pushed or popped. The graphics MSC value is initialized to 0 when the graphics device is initialized. The SBC is per-window state and is initialized to 0 when the GLXDrawable data structure is initialized.

The SBC value is incremented by the graphics driver at the completion of each buffer swap (e.g., the pixel copy has been completed or the hardware register that swaps memory banks has been written). For pixel formats that do not contain a back buffer, the SBC will always be returned as 0.

The graphics MSC value is incremented once for each screen refresh. For a non-interlaced display, this means that the graphics MSC value is incremented for each frame. For an interlaced display, it means that it will be incremented for each field. For a multi-monitor system, the monitor used to determine MSC is screen 0 of <display>.

glXGetMscRateOML returns the rate at which the MSC will be incremented for the display associated with <hdc>. The rate is expressed in Hertz as <numerator> / <denominator>. If the MSC rate in Hertz is an integer, then <denominator> will be 1 and <numerator> will be the MSC rate.

glXSwapBuffersMscOML has the same functionality as glXSwapBuffers, except for the following. The swap indicated by a call to glXSwapBuffersMscOML does not perform an implicit glFlush. The indicated swap will not occur until all prior rendering commands affecting the buffer have been completed. Once prior rendering commands have been completed, if the current MSC is less than <target_msc>, the buffer swap will occur when the MSC value becomes equal to <target_msc>. Once prior rendering commands have completed, if the current MSC is greater than or equal to <target_msc>, the buffer swap will occur the next time the MSC value is incremented to a value such that MSC % <divisor> = <remainder>. If <divisor> = 0, the swap will occur when MSC becomes greater than or equal to <target_msc>.

Once glXSwapBuffersMscOML has been called, subsequent OpenGL commands can be issued immediately. If the thread's current context is made current to another drawable, or if the thread makes another context current on another drawable, rendering can proceed immediately.

If there are multiple outstanding swaps for the same window, at most one such swap can be satisfied per increment of MSC. The order of satisfying outstanding swaps of a window must be the order they were issued. Each window that has an outstanding swap satisfied by the same current MSC should have one swap done.

If a thread issues a glXSwapBuffersMscOML call on a window, then issues OpenGL commands while still current to this window (which now

has a pending glXSwapBuffersMscOML call), the commands will be executed in the order they were received, subject to implementation resource constraints. Furthermore, subsequent commands that would affect the back buffer will only affect the new back buffer (that is, the back buffer after the swap completes). Such commands do not affect the current front buffer.

If the graphics driver utilizes an extra thread to perform the wait, it is expected that this thread will have a high priority so that the swap will occur at the earliest possible moment once all the conditions for swapping have been satisfied.

glXSwapBuffersMscOML will return the value that will correspond to the value of the SBC when the buffer swap actually occurs (in other words, the return value will be the current value of the SBC + the number of pending buffer swaps + 1). It will return a value of -1 if the function failed because of errors detected in the input parameters. glXSwapBuffersMscOML is a no-op and will always return 0 if the specified drawable was created with a non-double-buffered GLXFBConfig or if the specified drawable is a GLXPixmap.

glXWaitForMscOML can be used to cause the calling thread to wait until a specific graphics MSC value has been reached. If the current MSC is less than the <target_msc> parameter for glXWaitForMscOML, glXWaitForMscOML will block until the MSC value becomes equal to <target_msc> and then will return the current values for UST, MSC, and SBC. Otherwise, the function will block until the MSC value is incremented to a value such that MSC % <divisor> = <remainder> and then will return the current values for UST, MSC, and SBC. If <divisor> = 0, then the wait will return as soon as MSC >= <target_msc>.

glXWaitForSbcOML can be used to cause the calling thread to wait until a specific SBC value has been reached. This function will block until the SBC value for <hdc> becomes equal to <target_sbc> and then will return the current values for UST, MSC, and SBC. If the SBC value is already greater than or equal to <target_sbc>, the function will return immediately with the current values for UST, MSC, and SBC. If <target_sbc> = 0, the function will block until all previous swaps requested with glXSwapBuffersMscOML for that window have completed. It will then return the current values for UST, MSC, and SBC.

When glXSwapBuffersMscOML has been called to cause a swap at a particular MSC, an application process would observe the following order of execution for that MSC:

1. The window for which a glXSwapBuffersMscOML call has been issued has been completely scanned out to the display for the previous MSC
2. The swap buffer action for that window begins
3. All the swap buffer actions for all the windows for the application process are completed
4. SBC and MSC values are atomically incremented
5. Any calls to glXWaitForMscOML or glXWaitForSbcOML that are satisfied by the new values for SBC and graphics MSC are released

The functions glXGetSyncValuesOML, glXGetMscRateOML, glXWaitForMscOML, and glXWaitForSbcOML will each return TRUE if the function completed successfully, FALSE otherwise.

The following Attribute/Type/Notes triple is added to Table 3.1, GLXFBConfig attributes:

GLX_SBC	integer	Swap buffer count

Errors

Each of the functions defined by this extension will generate a GLX_BAD_CONTEXT error if there is no current GLXContext.

glXWaitForMscOML and glXWaitForSbcOML will each generate a GLX_BAD_CONTEXT error if the current context is not direct.

glXSwapBuffersMscOML and glXWaitForMscOML will each generate a GLX_BAD_VALUE error if <divisor> is less than zero, or if <remainder> is less than zero, or if <remainder> is greater than or equal to a non-zero <divisor>, or if <target_msc> is less than zero.

glXWaitForSbcOML will generate a GLX_BAD_VALUE error if <target_sbc> is less than zero.

GLX Protocol

TBD

New State

Get Value	Get Command	Type	Initial Value
[UST]	glXGetSyncValuesOML	Z	unspecified
[MSC]	glXGetSyncValuesOML	Z	0
[SBC]	glXGetSyncValuesOML	Z	0

New Implementation Dependent State

None

Microsoft Windows Requirements

WGL Requirements

WGL binds OpenGL to Microsoft Windows. OpenML requires several WGL extensions in addition to core WGL. The complete set of WGL features required for OpenML is documented in the following table.

Where existing extensions have been adopted for OpenML, they are defined by reference to the *OpenGL Extension Registry*.

WGL extension specifications that were created by the Khronos SIG are included in their entirety following the list of features.

Requirement	Where Documented	Comments
WGL	Microsoft Developer's Network Help Files	Baseline features. No formal WGL Specification exists
WGL_ARB_extensions_string	Registry	WGL extension query mechanism
WGL_ARB_pixel_format	Registry	Extended pixel format attribute specification
WGL_ARB_pbuffer	Registry	Accelerated rendering to offscreen pixel buffers
WGL_ARB_make_current_read	Registry	Separate read and draw drawables
WGL_OML_sync_control	OpenML Specification	UST/MSC/SBC synchronization

Table 25.3 WGL Feature Requirements

Identifying OpenML WGL Extensions

In addition to identifying all required WGL extensions individually in the WGL extension string, an OpenML implementation must also include the symbol `WGL_OML_openml1_0` in the extension string returned by **wglGetExtensionsStringARB**. This symbol does not correspond to a specific WGL extension, but rather identifies the presence of **all** required OpenML 1.0 WGL functionality as a group.

WGL_OML_sync_control Extension Specification

Name

OML_sync_control

Name Strings

WGL_OML_sync_control

Contact

Randi Rost, 3Dlabs (rost 'at' 3dlabs.com)

Status

Complete. Approved by the Khronos SIG on July 19, 2001.

Version

Last Modified Date: 07/23/2001 Revision: 17.0

Number

242

Dependencies

The extension is written against the OpenGL 1.2.1 Specification although it should work on any previous OpenGL specification.

WGL_ARB_extensions_string is required.

Overview

This extension provides the control necessary to ensure synchronization between events on the graphics card (such as vertical retrace) and other parts of the system. It provides support for applications with real-time rendering requirements by providing precise synchronization between graphics and streaming video or audio.

This extension incorporates the use of three counters that provide the necessary synchronization. The Unadjusted System Time (or UST) is a 64-bit monotonically increasing counter that is available throughout the system. UST is not a resource that is controlled by OpenGL, so it is not defined further as part of this extension. The graphics Media Stream Counter (or graphics MSC) is a counter that is unique to the graphics subsystem and increments for each vertical retrace that occurs. The Swap Buffer Counter (SBC) is a per-window value that is incremented each time a swap buffer action is performed on the window.

The use of these three counters allows the application to synchronize graphics rendering to vertical retraces and/or swap buffer actions, and to synchronize other activities in the system (such as streaming video or audio) to vertical retraces and/or swap buffer actions.

Functions are provided to allow an application to detect when an MSC or SBC has reached a certain value. This function will block until the specified value has been reached. Applications that want to continue other processing while waiting are expected to call these blocking functions from a thread that is separate from the main processing thread(s) of the application.

This extension carefully defines the observable order in which things occur in order to allow implementations to perform optimizations and avoid artifacts such as tearing, while at the same time providing a framework for consistent behavior from the point of view of an application.

Issues

None.

IP Status

No known issues.

New Procedures and Functions

```
BOOL wglGetSyncValuesOML(HDC hdc, INT64 *ust, INT64 *msc, INT64 *sbc)

BOOL wglGetMscRateOML(HDC hdc, INT32 *numerator, INT32 *denominator)

INT64 wglSwapBuffersMscOML(HDC hdc, INT64 target_msc, INT64 divisor,
                           INT64 remainder)

INT64 wglSwapLayerBuffersMscOML(HDC hdc, INT fuPlanes, INT64 target_msc,
                                INT64 divisor, INT64 remainder)

BOOL wglWaitForMscOML(HDC hdc, INT64 target_msc, INT64 divisor,
                      INT64 remainder, INT64 *ust, INT64 *msc,
                      INT64 *sbc)

BOOL wglWaitForSbcOML(HDC hdc, INT64 target_sbc, INT64 *ust, INT64 *msc,
                      INT64 *sbc)
```

New Tokens

None

Additions to Chapter 2 of the OpenGL 1.2.1 Specification (OpenGL Operation)

None

Additions to Chapter 3 of the OpenGL 1.2.1 Specification (Rasterization)

None

Additions to Chapter 4 of the OpenGL 1.2.1 Specification (Per-Fragment Operations and the Framebuffer)

None

Additions to Chapter 5 of the OpenGL 1.2.1 Specification (Special Functions)

None

Additions to Chapter 6 of the OpenGL 1.2.1 Specification (State and

State Requests)

None

Additions to the WGL Specification

wglGetSyncValuesOML returns the current UST/MSC/SBC triple. A UST timestamp is obtained each time the graphics MSC is incremented. If this value does not reflect the value of the UST at the time the first scan line of the display begins passing through the video output port, it will be adjusted by the graphics driver to do so prior to being returned by any of the functions defined by this extension.

This UST timestamp, together with the current graphics MSC and the current SBC, comprise the current UST/MSC/SBC triple. The UST, graphics MSC, and SBC values are not part of the render context state. These values cannot be pushed or popped. The graphics MSC value is initialized to 0 when the graphics device is initialized. The SBC is per-window state and is initialized to 0 when the window is initialized.

The SBC value is incremented by the graphics driver at the completion of each buffer swap (e.g., the pixel copy has been completed or the hardware register that swaps memory banks has been written). For pixel formats that do not contain a back buffer, the SBC will always be returned as 0.

The graphics MSC value is incremented once for each screen refresh. For a non-interlaced display, this means that the graphics MSC value is incremented for each frame. For an interlaced display, it means that it will be incremented for each field. For a multi-monitor system, the monitor used to determine MSC is the one Windows associates with <hdc> (i.e., the primary monitor).

wglGetMscRateOML returns the rate at which the MSC will be incremented for the display associated with <hdc>. The rate is expressed in Hertz as <numerator> / <denominator>. If the MSC rate in Hertz is an integer, then <denominator> will be 1 and <numerator> will be the MSC rate.

wglSwapBuffersMscOML has the same functionality as SwapBuffers, except for the following. The swap indicated by a call to wglSwapBuffersMscOML does not perform an implicit glFlush. The indicated swap will not occur until all prior rendering commands affecting the buffer have been completed. Once prior rendering commands have been completed, if the current MSC is less than <target_msc>, the buffer swap will occur when the MSC value becomes equal to <target_msc>. Once prior rendering commands have completed,

if the current MSC is greater than or equal to <target_msc>, the buffer swap will occur the next time the MSC value is incremented to a value such that MSC % <divisor> = <remainder>. If <divisor> = 0, the swap will occur when MSC becomes greater than or equal to <target_msc>.

Once wglSwapBuffersMscOML has been called, subsequent OpenGL commands can be issued immediately. If the thread's current context is made current to another drawable, or if the thread makes another context current on another drawable, rendering can proceed immediately.

If there are multiple outstanding swaps for the same window, at most one such swap can be satisfied per increment of MSC. The order of satisfying outstanding swaps of a window must be the order they were issued. Each window that has an outstanding swap satisfied by the same current MSC should have one swap done.

If a thread issues a wglSwapBuffersMscOML call on a window, then issues OpenGL commands while still current to this window (which now has a pending wglSwapBuffersMscOML call), the commands will be executed in the order they were received, subject to implementation resource constraints. Furthermore, subsequent commands that would affect the back buffer will only affect the new back buffer (that is, the back buffer after the swap completes). Such commands do not affect the current front buffer.

If the graphics driver utilizes an extra thread to perform the wait, it is expected that this thread will have a high priority so that the swap will occur at the earliest possible moment once all the conditions for swapping have been satisfied.

wglSwapLayerBuffersMscOML works identically to wglSwapBuffersMscOML, except that the specified layers of a window are swapped when the buffer swap occurs, as defined in wglSwapLayerBuffers. The <planes> parameter has the same definition as it has in the wglSwapLayerBuffers function, and it indicates whether to swap buffers for the overlay, underlay, or main planes of the window.

Both wglSwapBuffersMscOML and wglSwapLayerBuffersMscOML return the value that will correspond to the value of the SBC when the buffer swap actually occurs (in other words, the return value will be the current value of the SBC + the number of pending buffer swaps + 1). Both functions will return a value of -1 if the function failed because of errors detected in the input parameters. Both functions are no-ops if the current pixel format for <hdc> does not include a back buffer.

wglWaitForMscOML can be used to cause the calling thread to wait until a specific graphics MSC value has been reached. If the current

MSC is less than the <target_msc> parameter for wglWaitForMscOML, wglWaitForMscOML will block until the MSC value becomes equal to <target_msc> and then will return the current values for UST, MSC, and SBC. Otherwise, the function will block until the MSC value is incremented to a value such that MSC % <divisor> = <remainder> and then will return the current values for UST, MSC, and SBC. If <divisor> = 0, then the wait will return as soon as MSC >= <target_msc>.

wglWaitForSbcOML can be used to cause the calling thread to wait until a specific SBC value has been reached. This function will block until the SBC value for <hdc> becomes equal to <target_sbc> and then will return the current values for UST, MSC, and SBC. If the SBC value is already greater than or equal to <target_sbc>, the function will return immediately with the current values for UST, MSC, and SBC. If <target_sbc> = 0, the function will block until all previous swaps requested with wglSwapBuffersMscOML or wglSwapLayerBuffersMscOML for that window have completed. It will then return the current values for UST, MSC, and SBC.

When wglSwapBuffersMscOML or wglSwapLayerBuffersMscOML has been called to cause a swap at a particular MSC, an application process would observe the following order of execution for that MSC:

1. The window for which a wglSwapBuffersMscOML call has been issued has been completely scanned out to the display for the previous MSC
2. The swap buffer action for that window begins
3. All the swap buffer actions for all the windows for the application process are completed
4. SBC and MSC values are atomically incremented
5. Any calls to wglWaitForMscOML or wglWaitForSbcOML that are satisfied by the new values for SBC and graphics MSC are released

The functions wglGetSyncValuesOML, wglGetMscRateOML, wglWaitForMscOML, and wglWaitForSbcOML will each return TRUE if the function completed successfully, FALSE otherwise.

Dependencies on WGL_ARB_extensions_string

Because there is no way to extend wgl, these calls are defined in the ICD and can be called by obtaining the address with wglGetProcAddress. Because this is not a GL extension, it is not included in the GL_EXTENSIONS string. If this extension is supported by the implementation, its name will be returned in the extension string returned by wglGetExtensionString.

Errors

To get extended error information, call GetLastError. Each of the functions defined by this extension may generate the following error:

ERROR_DC_NOT_FOUND	The <hDC> parameter was not valid.

The following error will be generated for the functions wglSwapBuffersMscOML, wglSwapLayerBuffersMscOML, and wglWaitForMscOML, if <divisor> is less than zero, or if <remainder> is less than zero, or if <remainder> is greater than or equal to a non-zero <divisor>, or if <target_msc> is less than zero; and for the function wglWaitForSbcOML if <target_sbc> is less than zero:

ERROR_INVALID_DATA	A parameter is incorrect.

New State

Get Value	Get Command	Type	Initial Value
[UST]	wglGetSyncValuesOML	Z	unspecified
[MSC]	wglGetSyncValuesOML	Z	0
[SBC]	wglGetSyncValuesOML	Z	0

New Implementation Dependent State

None

APPENDIX

B

RECOMMENDED PRACTICES

This section identifies functional areas where good performance is considered to be particularly important.

Pixel Array Color Formats

This section discusses some issues relating to pixel color formats and how these can affect the performance of an OpenML compliant system, and in particular how pixels can be efficiently transferred between ML video devices, transcoders and OpenGL graphics adapters.

Image Orientation

The natural scanline orientation for video devices is from top to bottom, left to right, which corresponds to the order in which scanlines are displayed on a CRT display device. On the other hand, the default scanline order in OpenGL is from bottom to top, left to right. By setting the **ML_IMAGE_ORIENTATION_INT32** image buffer parameter to **ML_ORIENTATION_BOTTOM_TO_TOP**, it is possible to tell ML video devices to accept/produce pixels in OpenGL-compatible orientation. Similarly, it is possible to get OpenGL to accept images in top to bottom scanline orientation by specifying a negative value for the Y zoom factor of **glPixelZoom**: for instance, a call to glPixelZoom(1.0,-1.0). But since **glPixelZoom** only applies to calls to **glDrawPixels** and **glCopyPixels**, this approach can only be used when sending pixels from an ML device to an OpenGL graphics device: if the application needs to read pixels from OpenGL using **glReadPixels** to send to an ML video device, it would have to do an additional **glCopyPixels** to first flip the image.

Whether done by the ML video device or the OpenGL graphics device, this scanline flipping should be supported efficiently and not require host CPU copying of pixel scanlines. Also, if CPU-based processing of the data stream between the video and graphics devices is required, this may impose scanline orientation requirements, making it desirable for image flipping to be efficiently supported by both the video and graphics devices.

Scan Line Alignment

ML specifies that there should be no alignment restrictions on scanlines of images stored in memory: the end of a scanline should be adjacent to the beginning of the next scanline, without the need for

padding at the end of each scanline. On the other hand, the default values for the **GL_PACK_ALIGNMENT** and **GL_UNPACK_ALIGNMENT** parameters to the **glPixelStorei** function is 4, which means that by default, OpenGL expects the beginning of pixel scanlines to be aligned on 4 byte boundaries. For some combinations of pixel and scanline size, this might not be the case, so it might be necessary for the application to call **glPixelStorei** to remove this restriction by setting these parameters to 1, allowing arbitrary alignment of pixel scanlines. Preferably, this should not affect performance of pixel transfers to and from the OpenGL graphics device.

Correspondence Between ML and OpenGL Pixel Formats

In ML, the format of pixels in a memory buffer is specified by a combination of the **ML_IMAGE_PACKING_INT32**, **ML_IMAGE_COLORSPACE_INT32** and **ML_IMAGE_SAMPLING_INT32** image buffer parameters. When pixels are to be transferred between ML and OpenGL devices, it will be preferable for an application to use ML image buffer formats which directly correspond to OpenGL pixel formats to avoid having to reformat image buffers in software. Some of the more common pixel formats which have direct counterparts in ML and OpenGL are:

ML	OpenGL
ML_IMAGE_PACKING_INT32, **ML_IMAGE_PACKING_RGB,** **ML_IMAGE_COLORSPACE_INT32,** **ML_REPRESENTATION_RGB |** **ML_STANDARD_601 |** **ML_RANGE_FULL,** **ML_IMAGE_SAMPLING_INT32,** **ML_SAMPLING_444**	**GL_RGB,** **GL_UNSIGNED_BYTE**
ML_IMAGE_PACKING_INT32, **ML_IMAGE_PACKING_RGB(A),** **ML_IMAGE_COLORSPACE_INT32,** **ML_REPRESENTATION_RGB |** **ML_STANDARD_601 |** **ML_RANGE_FULL,** **ML_IMAGE_SAMPLING_INT32,** **ML_SAMPLING_444**	**GL_RGBA,** **GL_UNSIGNED_BYTE,** (alpha channel contains 0)
ML_IMAGE_PACKING_INT32, **ML_IMAGE_PACKING_RGBA,** **ML_IMAGE_COLORSPACE_INT32,** **ML_REPRESENTATION_RGB |** **ML_STANDARD_601 |** **ML_RANGE_FULL,** **ML_IMAGE_SAMPLING_INT32,** **ML_SAMPLING_4444**	**GL_RGBA,** **GL_UNSIGNED_BYTE,** (alpha channel contains valid data)

Table 25.4 Correspondance Between ML and OpenGL Pixel Formats

ML	OpenGL
ML_IMAGE_PACKING_INT32, **ML_IMAGE_PACKING_RGB_10_10_10_2,** **ML_IMAGE_COLORSPACE_INT32,** **ML_REPRESENTATION_RGB |** **ML_STANDARD_601 |** **ML_RANGE_FULL,** **ML_IMAGE_SAMPLING_INT32,** **ML_SAMPLING_444**	**GL_RGBA,** **GL_UNSIGNED_INT_10_10_10_2,** (alpha channel contains 0)
ML_IMAGE_PACKING_INT32, **ML_IMAGE_PACKING_RGB_12_in_16_L,** **ML_IMAGE_COLORSPACE_INT32,** **ML_REPRESENTATION_RGB |** **ML_STANDARD_601 |** **ML_RANGE_FULL,** **ML_IMAGE_SAMPLING_INT32,** **ML_SAMPLING_444**	**GL_RGB,** **GL_UNSIGNED_SHORT**

Table 25.4 Correspondance Between ML and OpenGL Pixel Formats

RGB and RGBA Pixel Formats

ML and OpenGL specify both RGB and RGBA pixel formats. With 8 bits per component formats, RGBA pixels will line up naturally with 4-byte or 32-bit boundaries, whereas RGB pixels will take up 3 bytes, which can create alignment issues as discussed above. To simplify hardware design, it might be tempting to only support RGBA formats in hardware and fallback to a slower software path when dealing with RGB formats. For applications where there is no use for the alpha channel, this additional overhead can be unacceptable. For instance, if video data is to be stored on hard drives, it will be difficult to justify storing an additional 33% of useless data: instead of storing four hours of video, a storage subsystem might only be able to store three hours. If the video has to be sent over a network, it will take 33% longer to send a clip of RGBA rather than RGB pixels. And even internally to a system, a stream of 1920x1080 HDTV video at 30 frames per second requires 180MB/sec of bandwidth with RGB pixels and 240MB/sec with RGBA pixels, which can make the difference between realtime and non-realtime operation.

RGB vs BGR component ordering

ML and OpenGL specify both RGB/RGBA and BGR/ABGR/BGRA component orderings. When integrating video and graphics devices from different vendors, it is important that color component orderings should be compatible. As much as possible, devices should support these orderings without a performance penalty, and be able to swizzle components on the fly during image transfers. This is especially important when connecting multiple computer systems through networks or shared storage: a common storage format for images will typically be required, and it would be problematic if some of the devices were penalized by being unable to efficiently deal with this common component ordering.

Greater Than 8 Bits Per Component Pixel Formats

Digital media applications often have to deal with pixel formats which have more than 8 bits per color component. For instance, digital video often uses 10 bits of luma and chroma components in YCrCb color space, digital film applications often require 12 or 16 bits per RGB color coefficient to capture the dynamic range of film. It is desirable for ML video devices and OpenGL graphics devices to support pixel formats

with more than 8 bits per color component for such applications. ML image buffer parameters can be used to specify pixel formats with 10 or 12 bits per color component. OpenGL pixel types such as **GL_UNSIGNED_INT_10_10_10_2** or **GL_UNSIGNED_SHORT** can be used to transfer these pixels to and from graphics devices. Even if the device does not support processing all of the bits of precision in these formats, they should still be supported efficiently for pixel transfer operations in order to maintain compatibility with the other devices in the system.

Pixel Format/Visual Selection Criteria

An OpenML compliant system must support a baseline of OpenGL functionality, including a number of OpenGL extensions. Yet the functionality offered by an OpenGL implementation greatly depends on the supported visuals/pixel formats. This is especially true for a digital media application which expects to use an OpenGL implementation to preview or even completely render result images. Such an application will most likely need to query OpenGL for supported visuals/pixel formats, pick the ones which most closely match its requirements, and perhaps have to fall back to software algorithms in the absence of required functionality.

It is expected that most digital media applications will work with RGBA rather than color index visuals; integrating true-color images with 2D and 3D geometry usually cannot be done in color index mode. An exception to this is hardware overlay bitplanes. It is usually sufficient to have only a few different colors in color index mode to support things like grids, crosshair cursors, and masks.

To provide smooth animation, double-buffering is usually preferred. To avoid tearing artifacts, it is desirable that buffer swaps occur during the vertical blanking interval. This also allows video applications to synchronize buffer swaps and screen refreshes to an external synchronization signal (a process known as genlocking or framelocking).

8 bits per color component is usually considered a minimum for rendering high quality images, with higher bit depths (10, 12 or even 16 bits per component) being desirable for applications requiring a larger dynamic range (for instance, more than 8 bits per component is required to capture the dynamic range of print film in a linear color space). Blending and masking techniques can take advantage of destination alpha bitplanes. So a double-buffered RGB or RGBA visual/pixel format with at least 8 bits per component is likely to be a minimum requirement for digital media applications.

A Z buffer is often useful, but in many cases not required for 2D-only applications. If a hardware implementation places an upper limit on the memory size of a pixel, it might be useful to offer double-buffered visuals/pixel formats without a Z buffer which can be used in those cases where a Z buffer is not required, but where the application can take advantage of the greater bit depth. The application might be able to manage several different visuals/pixel formats depending on its current needs. Similarly, stencil bitplanes can be useful, but the application might decide to use a visual/pixel format without stencil bitplanes, but with some additional functionality depending on its priorities.

OpenGL implementations are required to support visuals/pixel formats with an accumulation buffer. The accumulation buffer is useful for a number of digital media operations, including 2D operations such as averaging and temporal filtering, and for 3D rendering techniques such as anti-aliasing, motion blur and depth of field. Yet in many cases this functionality is implemented in software, and the application can often get better performance by implementing this functionality on its own, either by providing a parallelized implementation which takes advantage of multiple CPUs, or by using different rendering algorithms. Although there is no generalized mechanism for determining whether specific OpenGL functionality is implemented in hardware or software, the application will probably try to determine this based on the number of bits per component supported by the accumulation or by benchmarking the performance of accumulation buffer operations.

Finally, if the OpenGL implementation supports it, hardware anti-aliasing mechanisms such as multi-sampling require that the application select a visual/pixel format which supports this capability. Although multi-sampling may not provide sufficient anti-aliasing quality for a final image render, it can be used to provide fast interactive previews, and can be combined with other anti-aliasing techniques to shorten final render times.

Color Space Conversion with OpenGL Extensions

The OpenGL pipeline usually deals with pixels in the RGB colorspace. Yet in most cases digital video devices expect pixels to be in the Y'CrCb colorspace. Furthermore, although luma (the Y' component) is usually provided on a per-pixel basis, the chroma components (the Cr, Cb components) are usually subsampled. 4:2:2 sampling is one of the most frequent sampling patterns found in professional video applications: each horizontal pair of adjacent pixels share a set of Cr, Cb components, which means that the chroma signals have half the horizontal bandwidth of the luma signal.

Chroma subsampling is a form of data compression, and is based on the observation that the human eye tends to be less sensitive to variations in color than to variations in intensity. Such an observation does not apply to pixels in the RGB colorspace, so it makes no sense to attempt to decimate one of the R,G,B components. Thus if a digital media application obtains 4:2:2 Y'CrCb images from a digital video source, it will have to convert these to 4:4:4 RGB (where a 4:4:4 sampling pattern means that all of the color components are provided for each pixel). This is a two-step process involving an upsampling of the chroma coefficients to obtain a 4:4:4 Y'CrCb signal, followed by a color space conversion from Y'CrCb to RGB colorspace.

Chroma Upsampling

In an OpenML-compliant system, the OML_resample OpenGL extension can be used to implement the chroma upsampling step. This extension defines three different ways in which this chroma resampling can be performed.

glPixelStorei(GL_UNPACK_RESAMPLE_OML, GL_RESAMPLE_REPLICATE_OML)

specifies that the shared chroma values should simply be replicated for the two adjacent pixels. This is equivalent to a zero order hold filter, which can generate reconstruction artefacts (it is equivalent to zooming up an image by a factor of two by simply replicating pixels). It may be sufficient for preview applications.

The second method is enabled with:

glPixelStorei(GL_UNPACK_RESAMPLE_OML, GL_RESAMPLE_AVERAGE_OML)

In this case, even pixels inherit the chroma values from the corresponding pixel pair, and odd pixels get chroma values which are computed from a simple average of adjacent chroma values. This is equivalent to applying a simple box filter, which yields a much better result than simple replication, but still falls far short of the requirements for studio applications, as per the ITU-R BT.601-5 standard.

The third upsampling method specified by the OML_resample extension is enabled with:

glPixelStorei(GL_UNPACK_RESAMPLE_OML, GL_RESAMPLE_ZERO_FILL_OML)

With this method, the even pixels are assigned the corresponding chroma coefficients from the pixel pairs, and the odd pixels get 0 as chroma coefficients. This is used in conjunction with the one-dimensional convolution filter capabilities of the OpenGL imaging extensions (also mandated by OpenML compliance). The application specifies the desired FIR filter coefficients using glConvolutionFilter1D() and enables horizontal convolution with **glEnable(GL_CONVOLUTION_1D)**. The quality of the FIR interpolation filter will depend upon the maximum 1D convolution size supported by the OpenGL implementation, as returned by:

glGetConvolutionParameteriv(GL_CONVOLUTION_1D, GL_MAX_CONVOLUTION_WIDTH, &width)

Since only the chroma components need to be interpolated while leaving the luma component unchanged, the application will need to provide a 3-component "RGB" convolution filter kernel which implements a dirac filter for the luma component and the desired interpolation filter for the chroma components.

Color Space Conversion

Once the chroma coefficients have been upsampled using the OML_resample extension, the image pixels are now in a 4:4:4 Y'CrCb colorspace, ready to be converted to 4:4:4 RGB using the color matrix section of the OpenGL imaging pipeline. The first consideration is that Y'CrCb values usually do not use the full range of values: digital video standards specify that headroom needs to be preserved at both ends of the range.

For 8-bit values, Y' coefficients are specified to range between 16 and 235, and Cr, Cb coefficients are specified to range between 16 and 240 (actually, Cr,Cb coefficients are interpreted as ranging between -112 and +112, with an offset of +128). When converting to RGB values, it is typically desirable to expand to the full 0-255 range when dealing with 8-bit, `GL_UNSIGNED_BYTE` components. In the OpenGL imaging pipeline, values are normalized between 0 and 1, which has to be taken into consideration.

Pixels in Y'CrCb are typically encoded in one of three different colorspaces, which are defined by the equation which computes the Y' luma value based on the R,G,B primaries. For standard-definition video, this standard is defined in ITU-R BT.601-5 as:

$$Y' = 0.299\ R + 0.587\ G + 0.114\ B$$

from which the following transformation can be derived, where Y'CrCb and RGB are in the range 0 to 1:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \frac{1}{219} & 0 & \frac{1-0.299}{224*0.5} \\ \frac{1}{219} & \frac{-0.114*(1-0.114)}{0.587*224*0.5} & \frac{-0.299*(1-0.299)}{0.587*224*0.5} \\ \frac{1}{219} & \frac{1-0.114}{224*0.5} & 0 \end{bmatrix} \cdot \begin{bmatrix} 255Y' - 16 \\ 255Cb - 128 \\ 255Cr - 128 \end{bmatrix}$$

which can be rewritten as:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \frac{255}{219} & 0 & \frac{255*(1-0.299)}{224*0.5} \\ \frac{255}{219} & \frac{-255*0.114*(1-0.114)}{0.587*224*0.5} & \frac{-255*0.299*(1-0.299)}{0.587*224*0.5} \\ \frac{255}{219} & \frac{255*(1-0.114)}{224*0.5} & 0 \end{bmatrix} * \begin{bmatrix} Y' \\ Cb \\ Cr \end{bmatrix} +$$

$$\begin{bmatrix} \frac{-16}{219} & 0 & \frac{-128*(1-0.299)}{224*0.5} \\ \frac{-16}{219} & \frac{-128*0.114*(1-0.114)}{0.587*224*0.5} & \frac{-128*0.299*(1-0.299)}{0.587*224*0.5} \\ \frac{-16}{219} & \frac{-128*(1-0.114)}{224*0.5} & 0 \end{bmatrix}$$

which can be summarized as:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = M_{33} \begin{bmatrix} Y' \\ Cr \\ Cb \end{bmatrix} + \begin{bmatrix} V0 \\ V1 \\ V2 \end{bmatrix}$$

This equation can be implemented using the color matrix and post-color matrix bias functionality of the OpenGL imaging pipeline in a straightforward manner:

```
load M33 into the upper 3x3 section of an OpenGL matrix
glMatrixMode(GL_COLOR);
glLoadMatrix(conversion_matrix);
glPixelTransferf(GL_POST_COLOR_MATRIX_RED_SCALE,  V0);
glPixelTransferf(GL_POST_COLOR_MATRIX_GREEN_SCALE,V1);
glPixelTransferf(GL_POST_COLOR_MATRIX_BLUE_SCALE, V2);
```

The second colorspace which is often used in digital video is the SMPTE-240M colorspace, which defines the luma equation as:

$$Y' = 0.212\ R + 0.701\ G + 0.087\ B$$

This colorspace is used for the SMPTE-240M 1920x1035 HDTV standard. By replacing the R, G and B luma coefficients in the above equations, a similar transformation can be implemented.

The third colorspace which is used frequently in digital video applications is defined by ITU-R BT.709-4, and is used by the more recent SMPTE-274M (1920x1080) and SMPTE-296M (1280x720) HDTV standards. This standard defines the luma equation as:

$$Y' = 0.2126\ R + 0.7152\ G + 0.0722\ B$$

Again, the required color space conversion can be derived by simply replacing the corresponding coefficients.