

Steinberg

ASIO 2.0

Audio Streaming Input Output Development Kit

Documentation Release #1



Steinberg Audio Stream I/O API

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ASIO Interface Specification v 2.0

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I. Overview

1. Introduction

This document presents an overview of the design goals and implementation tradeoffs for an efficient personal computer based audio processing system. Due to technological advances in the computer industry in the recent years, and the ever-growing use of the Steinberg Virtual Studio Technology (VST) as a standard for Plug-in effects, it is clear that the personal computer will be a major target platform for a vast number of (previously impractical) audio-processing tasks.

2. The Goal

The personal computer platform really misses a relatively simple way of accessing multiple audio inputs and outputs. Today's operating system's audio support is designed for stereo input and stereo output only. There is no provision to extend this without creating major problems, i.e. synchronization issues between the different input and output channels.

With the Steinberg Audio Stream I/O (ASIO) Steinberg wants to help hardware and software manufacturers to create hardware and driver software which extends the personal computer's audio connectivity and meets the expectations of the customer (musician and audio engineer).

The Audio Stream I/O API addresses the areas of efficient audio processing, high data throughput, synchronization, low latency and extensibility on the audio hardware side. The interface is not bound to any fixed number of input and output channels (of course this numbers is limited by the processing power and data throughput of the computer system itself). It puts no limitation on the sample rate (32 kHz to 96 kHz or higher), sample format (16, 24, 32 bit or 32/64 bit floating point formats). It takes advantage of today's computer architectures for high data throughput (PCI, FireWire). It supports sophisticated hardware solutions for additional audio processing but it remains simple in comparison to other approaches.

3. The Design

The audio subsystem/hardware is treated as a software component (called audio driver). That is ASIO requires that the hardware manufacturers provide a driver, which abstracts the audio hardware in the way ASIO can deal with.

For efficient processing and great flexibility ASIO implements channels (input and output) as circular buffers with blocks of data. Actually a double buffer mechanism is used, which can be easily adapted to a great number of different buffer implementations. One buffer contains always data for one single channel only. This approach allows the host application to implement additional processing algorithms very effectively (opposed to an interleaved buffer model). The size of the data blocks is ascertained from the audio driver, to allow the best support for the audio hardware.

The audio driver allocates the memory for the actual data blocks. This allows the hardware manufacturer to select the best memory access method for their audio I/O solution. DMA or memory mapped I/O can be supported with equal efficiency. This way one of the keys to achieve



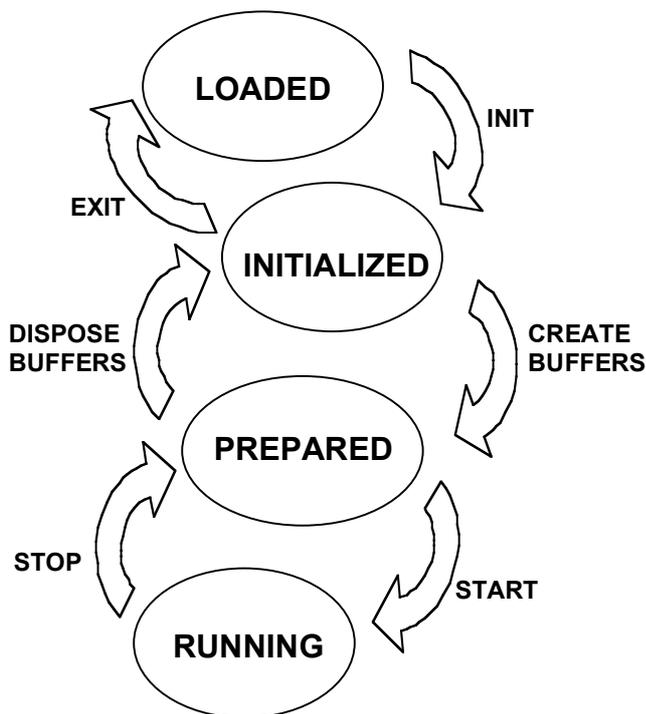
for low latency in the audio process. Since current operating systems are in transition towards multi-tasking, with all the advantages and tradeoffs, ASIO supports all features (Timestamped event notification and adaptive data pre-fetch/processing) necessary for asynchronous operation, usually occurring in preemptive multitasking operating systems such as MacOS X, Windows 95/NT, IRIX, BeOS. This will become also important for multi processor machines (SMP) or network distributed processing. (A direction in which personal computer systems will be heading to in the near future.)

II. Implementation Guide

1. Instantiation

The host application loads the driver and "links" it to itself. Depending on the Operating System, different methods are necessary. Please refer to the Chapter 4 "Host Utility API Reference" and the provided code.

2. Operation



The Finite State Machine diagram illustrates the states of the operation.

Loaded:	Driver code is accessible by the application
Initialized:	Driver is allocated by the application and inquiries from the application can be accepted. It is not necessary that the hardware be already allocated.
Prepared:	Audio buffers are allocated and the driver is prepared for running
Running:	The hardware is running and the Audio streaming takes place

The commands altering the states are:

<i>Init</i>	Initialize the driver for use by the application. Optionally acquire hardware or load additional driver components. ASIOInit()
<i>CreateBuffers</i>	Allocate memory for the audio buffers and allocate hardware resources for the audio channels. ASIOCreateBuffers()
<i>Start</i>	Starts the audio streaming process. ASIOStart()



<i>Stop</i>	Stops the streaming process. ASIOStop()
<i>DisposeBuffers</i>	Deallocates hardware resources for the used channels and disposes the memory for the audio buffers. ASIODisposeBuffers()
<i>Exit</i>	Deallocates any remaining resources and puts the driver back into the uninitialized state. ASIOExit()

3. Driver Query by the Host Application

The ASIO API provides several inquiry functions for the host application and the driver.

After the driver is initialized, the application will query for all or some of the following capabilities:

ASIOGetChannels()	query for the number of available audio channels
ASIOGetBufferSize()	get the supported audio buffer sizes
ASIOCanSampleRate()	ask whether a specific sample rate is supported by the driver/hardware
ASIOGetSampleRate()	get the current sample rate
ASIOGetClockSources()	get the possible clock source options of the audio hardware
ASIOGetChannelInfo()	get information about a specific channel (sample type, name, word clock group)
ASIOSetSampleRate()	Set a sample rate of the internal clock, should be used as base sample rate if an external clock source is selected.
ASIOSetClockSource()	set the clock source of the card.
ASIOGetLatencies()	query for the constant audio latencies relative to the bufferSwitch() callback.

Note: As **ASIOGetLatencies()** will also have to include the audio buffer size of the **ASIOCreateBuffers()** call, the application has to call this function after the buffer creation. In the case that the call occurs beforehand the driver should assume preferred buffer size.

Additional queries introduced with ASIO 2.0. These queries will occur via the **ASIOFuture()** call.

kAsioSupportsTimeInfo	query for support of the new bufferSwitchTimeInfo() callback
kAsioSupportsTimeCode	query for time code support of the audio hardware
kAsioSupportsInputMonitor	query for direct input monitoring support

4. Host Query by the Driver

After the *Prepared* state the driver can query the application for the following information via the asioMessage() callback:

kAsioSelectorSupported	query whether the asioMessage selector is supported by the application
kAsioEngineVersion	query the host application for the ASIO version it implements. The application will return the highest implemented version. The host application is expected to always support lower version implementations.

5. Audio Streaming

The audio streaming starts after the `ASIOStart()` call. Prior to starting the hardware streaming the driver will issue one or more `bufferSwitch()` or `bufferSwitchTimeInfo()` callbacks to fill its first output buffer(s). Since the hardware did not provide any input data yet the input channels' buffers should be filled with silence by the driver.

After the driver started the hardware streaming the `bufferSwitch()` or `bufferSwitchTimeInfo()` callbacks will always be called when the hardware requires more data. The driver passes the index of the double buffer half, which has to be processed, to the application. Upon return of the callback the application has read all input data and provided all output data.

Note: In order to reduce the amount of temporary buffers for a driver/hardware solution which has to further process the audio data, e.g. copy the data to the hardware, the ASIO API provides the `ASIOOutputReady()` method. `ASIOOutputReady()` is called immediately when the application has finished the processing of the buffers. This is a provision for drivers which require an immediate return of the `bufferSwitch()` or `bufferSwitchTimeInfo()` callback on interrupt driven systems like the Apple Macintosh, which cannot spend too long in the callback at a low level interrupt time. Instead the application will process the data at an interruptible execution level and inform the driver once it finished the processing. On a thread based system like Windows 95/98/NT or 2000 the callback can always process the data.

6. Media Synchronization (Sampleposition and System Time)

In order to provide proper media synchronization information to the host application a driver should fetch, at the occurrence of the `bufferSwitch()` or `bufferSwitchTimeInfo()` callback invocation event (interrupt or timed event), the current system time and sample position of the first sample of the audio buffer, which will be past to the callback. The host application retrieves this information during the `bufferSwitch()` callback with `ASIOGetSamplePosition()` or in the case of the `bufferSwitchTimeInfo()` callback this information is part of the parameters to the callback.

The following table shows the callback sequence and its values for the `bufferSwitchTimeInfo()` callback (1024 samples audio buffer size at 44100 Hz, System Time at Start is 2000 ms).

Callback No:	0	1	2	3	4	5	6
BufferIndex:	0	1	0	1	0	1	0
SystemTime(ms):	2000	2000	2023	2046	2069	2092	2116
SamplePosition:	0	1024	2048	3072	4096	5120	6144

Please note in the above table the same system time is used for the first two callbacks, as the hardware did not start yet. Since ASIO implements a constant streaming model, the time information of the first few `bufferSwitch` callbacks has to be ignored. The media synchronization process will start once the host application detects the constant streaming process. (It can be assumed that the streaming will be constant after the third `bufferSwitch` callback, more

sophisticated detection methods however are preferred as some driver/hardware combinations might retrieve more audio data for the hardware output processing.)

Note: The system time timestamp is a reference time of the operating system. Please see the Appendix D. "Platform / OS Differences" for the used system time information on the operating system.

7. Driver Notifications to the Host Application

The driver can notify the host application of the occurrence of some events which need special treatment by the host application. The following notification messages will be send via the `asioMessage()` callback.

kAsioResetRequest	the driver needs a reset, in case of an unexpected event or a reconfiguration
kAsioBufferSizeChange	the buffer sizes will change, issued by the user (however few applications support this yet, hence it is recommended to issue the kAsioResetRequest instead)
kAsioResyncRequest	the driver detected underruns and requires a resynchronization
kAsioLatenciesChanged	the driver detected a latency change

Note: A host application has to defer processing of these notification to a later "secure" time as the driver has finish its processing of the notification. Especially on the **kAsioResetRequest** it is a bad idea to unload the driver during the `asioMessage` callback since the callback has to return back into the driver, which is no longer present.

sampleRateDidChange()	informs the host application that the driver detected a sample rate change. Usually only used for an external clock source which changes its sample rate.
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III. Function Reference

Initialization/Termination

ASIOError ASIOInit(ASIODriverInfo *info);
ASIOError ASIOExit(void);

Start/Stop

ASIOError ASIOStart(void);
ASIOError ASIOStop(void);

Inquiry methods and sample rate

ASIOError ASIOGetChannels(long *numInputChannels, long *numOutputChannels);
ASIOError ASIOGetLatencies(long *inputLatency, long *outputLatency);
ASIOError ASIOGetBufferSize(long *minSize, long *maxSize, long *preferredSize, long *granularity);
ASIOError ASIOCanSampleRate(ASIOSampleRate sampleRate);
ASIOError ASIOGetSampleRate(ASIOSampleRate *currentRate);
ASIOError ASIOSetSampleRate(ASIOSampleRate sampleRate);
ASIOError ASIOGetClockSources(ASIOClockSource *clocks, long *numSources);
ASIOError ASIOSetClockSource(long reference);
ASIOError ASIOGetSamplePosition (ASIOSamples *sPos, ASIOTimeStamp *tStamp);
ASIOError ASIOGetChannelInfo(ASIOChannelInfo *info);

Buffer preparation

ASIOError ASIOCreateBuffers(ASIOBufferInfo *bufferInfos, long numChannels, long bufferSize, ASIOCallbacks *callbacks);
ASIOError ASIODisposeBuffers(void);
ASIOError ASIOOutputReady(void);

Miscellaneous

ASIOError ASIOControlPanel(void);
ASIOError ASIOFuture(long selector, void *params);

Callbacks

void (*bufferSwitch) (long doubleBufferIndex, ASIOBool directProcess);
ASIOTime* (*bufferSwitchTimeInfo) (ASIOTime* params, long doubleBufferIndex, ASIOBool directProcess);
void (*sampleRateDidChange) (ASIOSampleRate sRate);
long (*asioMessage) (long selector, long value, void* message, double* opt);

1. Initialization/Termination

ASIOError ASIOInit(ASIODriverInfo *info);

Purpose:

Initialize the AudioStreamIO.

Parameter:

info pointer to an **ASIODriverInfo** structure.

Returns:

If neither input nor output is present ASE_NotPresent will be returned. ASE_NoMemory, ASE_HWMalfunction are other possible error conditions

struct **ASIODriverInfo**

```
{
    long      asioVersion;      'on input' - the host version. This is 0 for earlier ASIO
                                implementations. The asioMessage callback is implemented
                                only if asioVersion is 2 or greater. (Sorry but due to a design
                                oversight the driver doesn't have access to the host version in
                                ASIOInit, see also Appendix E.).
                                Added selector for host (engine) version in the asioMessage
                                callback so we're ok from now on.

                                'on return', - ASIO implementation version. Older versions
                                are 1. If you support this version (namely,
                                ASIOOutputReady() ) this should be 2 or higher. also see the
                                note in ASIOGetSamplePosition() !

    long      driverVersion;    on return, the driver version (format is driver specific)

    char      name[32];         on return, a null-terminated string containing the driver's
                                name

    char      errorMessage[124]; on return, should contain a user message describing the type
                                of error that occurred during ASIOInit(), if any.

    void      *sysRef;         on input: system reference (Windows: application main
                                window handle, Mac & SGI: 0)
};
```



ASIOError ASIOExit(void);

Purpose:

Terminates the AudioStreamIO.

Parameter:

None.

Returns:

If neither input nor output is present ASE_NotPresent will be returned.

Notes:

This implies ASIOStop() and ASIODisposeBuffers(), meaning that no host callbacks must be accessed after ASIOExit().

2. Start/Stop

ASIOError ASIOStart(void);

Purpose:

Start input and output processing synchronously.

This will

- reset the sample counter to zero
- start the hardware (both input and output)

The first call to the hosts' bufferSwitch(index == 0) then tells the host to read from input buffer A (index 0), and start processing to output buffer A while output buffer B (which has been filled by the host prior to calling ASIOStart()) is possibly sounding (see also ASIOGetLatencies())

Parameter:

None.

Returns:

If neither input nor output is present, ASE_NotPresent will be returned. If the hardware fails to start, ASE_HWMalfunction will be returned.

Notes:

There is no restriction on the time that ASIOStart() takes to perform (that is, it is not considered a realtime trigger).

ASIOError ASIOStop(void);

Purpose:

Stops input and output processing altogether.

Parameter:

None.

Returns:

If neither input nor output is present ASE_NotPresent will be returned.

Notes:

On return from ASIOStop(), the driver must not call the hosts bufferSwitch() routine. On a pre-emptive multitasking OS you have to make sure that no pending events will call bufferSwitch() after the driver returned from this function.

3. Inquiry methods and sample rate

ASIOError ASIOGetChannels(long *numInputChannels, long *numOutputChannels);

Purpose:

Returns number of individual input/output channels.

Parameter:

numInputChannels will hold the number of available input channels.

numOutputChannels will hold the number of available output channels.

Returns:

If no input/output is present ASE_NotPresent will be returned. If only inputs, or only outputs are available, the according other parameter will be zero, and ASE_OK is returned.

ASIOError ASIOGetLatencies(long *inputLatency, long *outputLatency);

Purpose:

Returns the input and output latencies. This includes device specific delays, like FIFOs etc.

Parameter:

inputLatency on return will hold the 'age' of the first sample frame in the input buffer when the hosts reads it in bufferSwitch() (this is theoretical, meaning it does not include the overhead and delay between the actual physical switch, and the time when bufferSwitch() enters). This will usually be the size of one block in sample frames, plus device specific latencies.

outputLatency on return will specify the time between the buffer switch, and the time when the next play buffer will start to sound. The next play buffer is defined as the one the host starts processing after (or at) bufferSwitch(), indicated by the index parameter (0 for buffer A, 1 for buffer B).

It will usually be either one block, if the host writes directly to a DMA buffer or two or more blocks if the buffer is 'latched' by the driver. As an example, on ASIOStart(), the host will have filled the play buffer at index 1 already; when it gets the callback (with the parameter index == 0), this tells it to read from the input buffer 0, and start to fill the play buffer 0 (assuming that now play buffer 1 is already sounding). In this case, the output latency is one block. If the driver decides to copy buffer 1 at that time, and pass it to the hardware at the next slot (which is most commonly done, but should be avoided), the output latency becomes two blocks instead, resulting in a total i/o latency of at least 3 blocks. As memory access is the main bottleneck in native DSP processing, and to achieve lower latency, it is highly recommended to try to avoid copying (this is also why the driver is the owner

of the buffers). To summarize, the minimum i/o latency can be achieved if the input buffer is processed by the host into the output buffer which will physically start to sound on the next time slice. Also note that the host expects the `bufferSwitch()` callback to be accessed for each time slice in order to retain sync, possibly recursively; if it fails to process a block in time, it will suspend its operation for some time in order to recover.

Returns:

If no input/output is present `ASE_NotPresent` will be returned.

ASIOError ASIOGetBufferSize(long *minSize, long *maxSize, long *preferredSize, long *granularity);

Purpose:

Returns min, max, and preferred buffer sizes for input/output

Parameter:

<i>minSize</i>	on return will hold the minimum buffer size
<i>maxSize</i>	on return will hold the maximum possible buffer size
<i>preferredSize</i>	on return will hold the preferred buffer size (a size which best fits performance and hardware requirements)
<i>granularity</i>	on return will hold the granularity at which buffer sizes may differ. Usually, the buffer size will be a power of 2; in this case, granularity will hold -1 on return, signaling possible buffer sizes starting from minSize, increased in powers of 2 up to maxSize.

Returns:

If no input/output is present `ASE_NotPresent` will be returned.

Notes:

When minimum and maximum buffer size are equal, the preferred buffer size has to be the same value as well; granularity should be 0 in this case.



ASIOError ASIOCanSampleRate(ASIOSampleRate sampleRate);

Purpose:

Inquires of the hardware if a specific available sample rate is available.

Parameter:

sampleRate is the rate in question.

Returns:

If the stated sample rate is not supported, ASE_NoClock will be returned. If no input/output is present ASE_NotPresent will be returned.

ASIOError ASIOGetSampleRate(ASIOSampleRate *currentRate);

Purpose:

Get the current sample Rate.

Parameter:

currentRate on return will hold the current sample rate on return.

Returns:

If sample rate is unknown, sampleRate will be 0 and ASE_NoClock will be returned.

If no input/output is present ASE_NotPresent will be returned.

ASIOError ASIOSetSampleRate(ASIOSampleRate sampleRate);

Purpose:

Set the hardware to the requested sample Rate. If sampleRate == 0, enable external sync.

Parameter:

sampleRate the requested rate

Returns:

If sampleRate is unknown ASE_NoClock will be returned. If the current clock is external, and sampleRate is != 0, ASE_InvalidMode will be returned. If no input/output is present ASE_NotPresent will be returned.

```
ASIOError ASIOGetClockSources(ASIOClockSource *clocks, long *numSources);
```

Purpose:

Get the available external audio clock sources

Parameter:

clocks points to an array of **ASIOClockSource** structures.

numSources on input: the number of allocated array members
on output: the number of available clock sources, at least 1 (internal clock generator).

Returns:

If no input/output is present ASE_NotPresent will be returned.

```
struct ASIOClockSource {
    long        index;                      this is used to identify the clock source when
ASIOSetClockSource() is accessed, should be an index
counting from zero

    long        associatedChannel;        the first channel of an associated input group, if any.

    long        associatedGroup;        the group index of that channel. Groups of channels are
defined to separate, for instance analog, S/PDIF, AES/EBU,
ADAT connectors etc, when present simultaneously. Note
that associated channel is enumerated according to
numInputs/numOutputs, meaning it is independent from a
group (see also ASIOGetChannelInfo()) inputs are associated
to a clock if the physical connection transfers both data and
clock (like S/PDIF, AES/EBU, or ADAT inputs). If there is
no input channel associated with the clock source (like Word
Clock, or internal oscillator), both associatedChannel and
associatedGroup should be set to -1.

    ASIOBool   isCurrentSource;        on exit, ASIOTrue if this is the current clock source,
ASIOFalse else

    char        name[32];                a null-terminated string for user selection of the available
sources.
};
```



ASIOError ASIOSetClockSource(long index);**Purpose:**

Set the audio clock source

Parameter:

index as obtained from an inquiry to ASIOGetClockSources()

Returns:

If no input/output is present ASE_NotPresent will be returned. If the clock can not be selected because an input channel which carries the current clock source is active, ASE_InvalidMode *may* be returned (this depends on the properties of the driver and/or hardware).

Notes:

Should *not* return ASE_NoClock if there is no clock signal present at the selected source; this will be inquired via ASIOGetSampleRate().

It should call the host callback procedure sampleRateHasChanged(), if the switch causes a sample rate change, or if no external clock is present at the selected source.

ASIOError ASIOGetSamplePosition (ASIOSamples *sPos, ASIOTimeStamp *tStamp);**Purpose:**

Inquires the sample position/time stamp pair.

Parameter:

sPos on return will hold the sample position on return. The sample position is reset to zero when ASIOStart() gets called.

tStamp on return will hold the system time when the sample position was latched.

Returns:

If no input/output is present, ASE_NotPresent will be returned. If there is no clock, ASE_SPNotAdvancing will be returned.

Notes:

In order to be able to synchronize properly, the sample position / time stamp pair must refer to the *current block*, that is, the engine will call ASIOGetSamplePosition() in its bufferSwitch() callback and expect the time for the first sample of the current block. Thus, when requested in the very first bufferSwitch after ASIOStart(), the sample position should be zero, and the time stamp should refer to the very time where the stream was started. It also means that the sample position must be block aligned. The driver must ensure proper interpolation if the system time can not be determined for the block position. The driver is responsible for precise time stamps as it usually has most direct access to lower level resources. Proper behavior of ASIOGetSamplePosition() and ASIOGetLatencies() are essential for precise media synchronization!



ASIOError ASIOGetChannelInfo(ASIOChannelInfo *info);

Purpose:

Retrieve information about the nature of a channel.

Parameter:

info is a pointer to one **ASIOChannelInfo** structure.

Returns:

If no input/output is present ASE_NotPresent will be returned.

Notes:

If possible, the string should be organized such that the first characters are most significantly describing the nature of the port, to allow for identification even if the view showing the port name is too small to display more than 8 characters, for instance.

struct **ASIOChannelInfo**

```
{
    long          channel;          on input: the channel index of the channel in question.

    ASIOBool     isInput;          on input: ASIOTrue if info for an input channel is
                                   requested, else an output channel is addressed

    ASIOBool     isActive;         on output: ASIOTrue if channel is active as it was
                                   installed by ASIOCreateBuffers(), otherwise it is set to
                                   ASIOFalse

    long         channelGroup;     on output: the channel group that the channel belongs to.
                                   For drivers which support different types of channels, like
                                   analog, S/PDIF, AES/EBU, ADAT etc interfaces, there
                                   should be a reasonable grouping of these types. Groups
                                   are always independent from a channel index, that is, a
                                   channel index always counts from 0 to
                                   numInputs/numOutputs regardless of the group it may
                                   belong to. There will always be at least one group (group
                                   0). Please also note that by default, the host may decide to
                                   activate channels 0 and 1; thus, these should belong to the
                                   most useful type (analog i/o, if present).

    ASIOSampleType type;           on output: contains the sample type of the channel

    char         name[32];         on output: describing the type of channel in question.
                                   Used to allow for user selection, and enabling of specific
                                   channels. Examples: "Analog In", "SPDIF Out" etc.
};
```

4. Buffer preparation

ASIOError ASIOCreateBuffers(ASIOBufferInfo *bufferInfos, long numChannels, long bufferSize, ASIOCallbacks *callbacks);

Purpose:

Allocates input/output buffers for all input and output channels to be activated.

Parameter:

bufferInfos is a pointer to an array of **ASIOBufferInfo** structures.

numChannels is the sum of all input and output channels to be created; thus *bufferInfos* is a pointer to an array of *numChannels* **ASIOBufferInfo** structures.

bufferSize selects one of the possible buffer sizes as obtained from **ASIOGetBufferSizes()**.

callbacks is a pointer to an **ASIOCallbacks** structure.

Returns:

If not enough memory is available **ASE_NoMemory** will be returned. If no input/output is present **ASE_NotPresent** will be returned. If *bufferSize* is not supported, or one or more of the *bufferInfos* elements contain invalid settings, **ASE_InvalidMode** will be returned.

Notes:

If individual channel selection is not possible but requested, the driver has to handle this. Namely, **bufferSwitch()** will only fill buffers of enabled outputs. If possible, processing and buss activities overhead should be avoided for channels that were not enabled here.

struct **ASIOBufferInfo**

```
{
    ASIOBool    isInput;        on input: set to ASIOTrue if it describes an input buffer.
                                Otherwise it is an output buffer

    long        channelNum;     on input: the index of the channel in question (counting from
                                0)

    void        *buffers[2];    on output: 2 pointers to the two halves of the channels'
                                double-buffer. The sizes of the buffer(s) of course depend on
                                both the bufferSize and the ASIOSampleType of the device
                                for the channel. See also ASIOGetChannelInfo().
};
```

ASIOError ASIODisposeBuffers(void);**Purpose:**

Releases all buffers for the device.

Parameter:

None.

Returns:

If no buffer were ever prepared, ASE_InvalidMode will be returned. If no input/output is present ASE_NotPresent will be returned.

ASIOError ASIOOutputReady(void);**Purpose:**

This tells the driver that the host has completed processing the output buffers. If sample data format required by the hardware differs from the supported ASIO sample formats, but the hardware buffers are DMA buffers, the driver will have to convert the audio stream data. As the bufferSwitch callback is usually issued at DMA block switch time, the driver will have to convert the *previous* host buffer, which increases the output latency by one block.

When the host finds out that ASIOOutputReady() returns true, it will issue this call whenever it completed output processing. Then the driver can convert the host data directly to the DMA buffer to be played next, reducing output latency by one block.

Another way to look at it is, that the buffer switch is called in order to pass the *input* stream to the host, so that it can process the input into the output, and the output stream is passed to the driver when the host has completed its process.

Parameter:

None

Returns:

Only if the above mentioned scenario is given, and a reduction of output latency can be achieved by this mechanism, should ASE_OK be returned. Otherwise (and usually) ASE_NotPresent should be returned in order to prevent further calls to this function. Note that the host may want to determine if it can use this when the system is not yet fully initialized, so ASE_OK should always be returned if the mechanism makes sense.

Notes: Please remember to adjust ASIOGetLatencies() according to whether ASIOOutputReady() was ever called or not, if your driver supports this scenario. Also note that the engine may fail to call ASIOOutputReady() in time in overload cases. As already mentioned, bufferSwitch should be called for every block regardless of whether a block could be processed in time.



5. Miscellaneous

ASIOError ASIOControlPanel(void);

Purpose:

Request the driver to start a control panel component for device specific user settings. This might not be accessible on all platforms.

Parameter:

None.

Returns:

If no panel is available ASE_NotPresent will be returned. Actually, the return code is ignored.

Notes:

If the user applied settings which require a re-configuration of parts or all of the engine and/or driver (such as a change of the block size), the asioMessage callback can be used (see ASIOCallbacks).

ASIOError ASIOFuture(long selector, void *params);

Purpose:

various

Parameter:

selector operation Code as to be defined. Zero is reserved for testing purposes.

params depends on the selector; usually pointer to a structure for passing and retrieving any type and amount of parameters.

Returns:

The return value is also selector dependent. If the selector is unknown, ASE_InvalidParameter should be returned to prevent further calls with this selector. On success, ASE_SUCCESS must be returned

Notes:

See selectors defined below.

ASIOFuture() *selectors*:

kAsioEnableTimeCodeRead
kAsioDisableTimeCodeRead

Purpose:

Enable or Disable the time code reader if the hardware device supports time code.

Parameter:

None.

Returns:

ASE_SUCCESS if request is accepted or *ASE_NotPresent* otherwise

Note:

If the hardware/driver does not support time code reader facilities *ASE_NotPresent* should be returned.

kAsioSetInputMonitor

Purpose:

Set the direct input monitoring state.

Parameter:

params pointer to **ASIOInputMonitor** structure.

Returns:

ASE_SUCCESS if request is accepted or otherwise *ASE_NotPresent*

Note:

If the hardware does not support patching and mixing a straight 1 to 1 routing is suggested. The driver should ignore all the information of **ASIOInputMonitor** it cannot deal with, usually these might be either or all of *output*, *gain*, *pan*.

Output is the base channel of a stereo channel pair, i.e. *output* is always an even channel (0,2,4...). If an odd input channel should be monitored and no panning or output routing can be applied, the driver has to use the next higher output (imply a hard right pan).

```
struct ASIOInputMonitor
{
    long    input;        this input was set to monitor (or off), -1: all
    long    output;       suggested output for monitoring the input (if so)
    long    gain;         suggested gain, ranging 0 - 0x7fffffffL (-inf to +12
                          dB, 0x20000000 equals 0 dB)
    ASIOBool state;     ASIOTrue => on, ASIOFalse => off
    long    pan;         suggested pan, 0 => left, 0x7fffffff => right
};
```

6. Callbacks

void (*bufferSwitch) (long doubleBufferIndex, ASIOBool directProcess);

Purpose:

bufferSwitch indicates that both input and output are to be processed.

Parameter:

doubleBufferIndex The current buffer half index (0 or 1) determines the output buffer that the host should start to fill. The other buffer will be passed to output hardware regardless of whether it got filled in time or not. The addressed input buffer is now filled with incoming data. Note that because of the synchronicity of i/o, the input always has at least one buffer latency in relation to the output.

directProcess suggests to the host whether it should immediately start processing (*directProcess* == ASIOTrue), or whether its process should be deferred because the call comes from a very low level (for instance, a high level priority interrupt), and direct processing would cause timing instabilities for the rest of the system. If in doubt, *directProcess* should be set to ASIOFalse.

Returns:

No return value.

Notes:

bufferSwitch() may be called at interrupt time for highest efficiency.

ASIOTime* (*bufferSwitchTimeInfo) (ASIOTime* params, long doubleBufferIndex, ASIOBool directProcess);

Purpose:

bufferSwitchTimeInfo indicates that both input and output are to be processed. It also passes extended time information (time code for synchronization purposes) to the host application and back to the driver.

Parameter:

params pointer to ASIOTime structure

doubleBufferIndex The current buffer half index (0 or 1) determines the output buffer that the host should start to fill. The other buffer will be passed to output hardware regardless of whether it got filled in time or not. The addressed input buffer is now filled with incoming data. Note that because of the synchronicity of i/o, the input always has at least one buffer latency in relation to the output.



directProcess suggests to the host whether it should immediately start processing (*directProcess* == ASIOTrue), or whether its process should be deferred because the call comes from a very low level (for instance, a high level priority interrupt), and direct processing would cause timing instabilities for the rest of the system. If in doubt, *directProcess* should be set to ASIOFalse.

Returns:

Pointer to ASIOTime structure with "output" time code information.

Notes:

bufferSwitchTimeInfo() may be called at interrupt time for highest efficiency.

This new callback with time info makes ASIOGetSamplePosition() and various calls to ASIOGetSampleRate obsolete, and allows for timecode sync etc. Therefore it is the preferred callback; it will be used if the driver successfully calls asioMessage with selector kAsioSupportsTimeInfo.

```
struct ASIOTime
{
    long          reserved[4];      must be 0

    AsioTimeInfo timeInfo;         required

    ASIOTimeCode timeCode;         optional, evaluated if (timeCode.flags & kTcValid)
};
```

```
struct AsioTimeInfo
{
    double        speed;           absolute speed (1. = nominal)

    ASIOTimeStamp systemTime;      system time related to samplePosition, in nanoseconds
                                   On MacOS, must be derived from Microseconds() (not
                                   UpTime(!)).
                                   On Windows, must be derived from timeGetTime()

    ASIOSamples  samplePosition;   sample position since ASIOStart()

    ASIOSampleRate sampleRate;     current rate

    unsigned long flags;           see AsioTimeInfoFlags

    char         reserved[12];     must be 0
};
```

AsioTimeInfoFlags

kSystemTimeValid	set if system time field is valid - must always be valid
kSamplePositionValid	set if sample position valid - must always be valid
kSampleRateValid	set if sample rate field is valid
kSpeedValid	set if speed field is valid
kSampleRateChanged	set if sample rate changed in between callbacks
kClockSourceChanged	set if clock source changed in between callbacks

struct **ASIOTimeCode**

```
{
    double          speed;          speed relation (fraction of nominal speed) optional; set to
                                0. or 1. if not supported

    ASIOSamples     timeCodeSamples; time in samples

    unsigned long   flags;          see ASIOTimeCodeFlags

    char            future[64];     set to 0
};
```

ASIOTimeCodeFlags

kTcValid	set if time code data is valid
kTcRunning	set if time code is running
kTcReverse	set if reverse time code is detected
kTcOnspeed	set if time code is on speed (optional)
kTcStill	set if still frame time code is received
kTcSpeedValid	set if speed field is valid

void (*sampleRateDidChange) (ASIOSampleRate sRate);

Purpose:

This callback will inform the host application that a sample rate change was detected (e.g. sample rate status bit in an incoming S/PDIF or AES/EBU signal changes).

Parameter:

sRate The detected sample rate. 0 when sample rate is not known (for instance, clock loss when externally synchronized).

Returns:

No return value.

Notes:

The host application usually will just store the information. Actual action of the host application is not specified.

long (*asioMessage) (long selector, long value, void* message, double* opt);

Purpose:

Generic callback use for various purposes, see selectors below.

Parameter:

selector what kind of message is send.

value single value. Specific to each *selector* as defined below.

message message parameter. Specific to each *selector* as defined below.

opt optional parameter. Specific to each *selector* as defined below.

Returns:

Specific to the *selector*, undefined selectors will return 0.

Notes:

This callback was not implemented in the first ASIO host implementation of Cubase VST 3.0 for Macintosh, all other ASIO host application will have this callback.



asioMessage selectors

kAsioSelectorSupported

Purpose:

Test whether the host application supports a specific selector.

Parameter:

value selector to be test for.

Host Application Returns:

1L if selector is supported or 0 otherwise

kAsioEngineVersion

Purpose:

Ask the host application for its ASIO implementation.

Parameter:

None.

Host Application Returns:

Host ASIO implementation version, 2 or higher

kAsioResetRequest

Purpose:

Requests a driver reset. If accepted, this will close the driver (ASIOExit()) and re-open it again (ASIOInit() etc.) at the next "safe" time (usually during the application IDLE time). Some drivers need to reconfigure for instance when the sample rate changes, or some basic changes have been made in ASIOControlPanel().

Parameter:

None.

Host Application Returns:

Return value is always 1L.

Note:

The request is merely passed to the application, there is no way to determine if it gets accepted at this time (but it usually will be).



kAsioBufferSizeChange

Purpose:

Informs the application that the driver has a new preferred buffer size.

Parameter:

value new buffer size.

Host Application Returns:

1L if request is accepted or 0 otherwise

Note:

If request is not accepted but the bufer size changed, the driver should send kAsioResetRequest.

kAsioResyncRequest

Purpose:

The driver went out of sync, such that the timestamp is no longer valid. This is a request to re-start the engine and slave devices (sequencer).

Parameter:

None.

Host Application Returns:

1L if request is accepted or 0 otherwise

kAsioLatenciesChanged

Purpose:

Informs the application that the driver's latencies have changed. The engine will re-fetch the latencies.

Parameter:

None.

Host Application Returns:

Returns always 1L if the selector is supported is accepted or 0 otherwise



kAsioSupportsTimeInfo

Purpose:

Ask the application whether it supports the `bufferSwitchTimeInfo()` callback.

Parameter:

None.

Host Application Returns:

1L if `bufferSwitchTimeInfo()` is supported or 0 otherwise

kAsioSupportsTimeCode

Purpose:

Ask the application whether it supports time code reading in the `bufferSwitchTimeInfo()` callback.

Parameter:

None.

Host Application Returns:

1L if time code reading is supported or 0 otherwise

Note:

This requires that the `bufferSwitchTimeInfo()` callback is supported by the host application.

7. Type definitions

Sample Types

1. Big Endian formats

The basic types, sample data is left aligned in the data word. The most significant Byte of the data word is stored first in memory.

ASIOSTInt16MSB 16 bit data word (fewer than 16 bits are not supported)

ASIOSTInt24MSB This is the packed 24 bit format. 2 data words will spawn consecutive 6 bytes in memory. (Used for 18 and 20 bits as well, if they use this packed format)

ASIOSTInt32MSB This format should also be used for 24 bit data, if the sample data is left aligned. Lowest 8 bit should be reset or dithered whatever the hardware/software provides.

ASIOSTFloat32MSB IEEE 754 32 bit float, as found on PowerPC implementation

ASIOSTFloat64MSB IEEE 754 64 bit double float, as found on PowerPC implementation

Right aligned variations of the *ASIOSTInt32MSB* data type.

These are used for 32 bit data transfers with different alignment of the sample data inside the 32 bit data word. This supports right aligned sample data in the 32-bit data word, most significant bits should be sign extended. (32 bit PCI bus systems can be more easily used with these)

ASIOSTInt32MSB16 sample data fills the least significant 16 bits, the other bits are sign extended

ASIOSTInt32MSB18 sample data fills the least significant 18 bits, the other bits are sign extended

ASIOSTInt32MSB20 sample data fills the least significant 20 bits, the other bits are sign extended

ASIOSTInt32MSB24 sample data fills the least significant 24 bits, the other bits are sign extended



2. Little Endian formats

The basic types, sample data is left aligned in the container. The least significant Byte of the data word is stored first in memory.

ASIOSTInt16LSB 16 bit data word

ASIOSTInt24LSB This is the packed 24 bit format. 2 data words will spawn consecutive 6 bytes in memory. (Used for 18 and 20 bits as well, if they use this packed format)

ASIOSTInt32LSB This format should also be used for 24 bit data, if the sample data is left aligned. Lowest 8 bit should be reset or dithered whatever the hardware/software provides.

ASIOSTFloat32LSB IEEE 754 32 bit float, as found on Intel x86 architecture

ASIOSTFloat64LSB IEEE 754 64 bit double float, as found on Intel x86 architecture

Right aligned variations of the *ASIOSTInt32LSB* data type.

These are used for 32 bit data transfers with different alignment of the sample data inside the 32 bit data word. This supports right aligned sample data in the 32-bit data word, most significant bits should be sign extended. (32 bit PCI bus systems can be more easily used with these)

ASIOSTInt32LSB16 32 bit data with 16 bit sample data right aligned

ASIOSTInt32LSB18 32 bit data with 18 bit sample data right aligned

ASIOSTInt32LSB20 32 bit data with 20 bit sample data right aligned

ASIOSTInt32LSB24 32 bit data with 24 bit sample data right aligned

ASIOSamples

ASIOTimeStamp

Number of samples - data type is 64-bit integer

Timestamp data type is 64-bit integer. The Time format is Nanoseconds.

Note:

The 64 bit data is passed via a structure with two 32-bit values.

```
struct {
    unsigned long hi; // most significant bits (Bits 32..63)
    unsigned long lo; // least significant bits (Bits 0..31)
};
```

Unfortunately the ASIO API was implemented it before compiler supported consistently 64 bit integer types. By using the structure the data layout on a little-endian system like the Intel x86 architecture will result in a "non native" storage of the 64 bit data. The most significant 32 bit are stored first in memory, the least significant bits are stored in the higher memory space. However each 32 bit is stored in the native little-endian fashion.

ASIOSampleRate

Sample rates are expressed in IEEE 754 64 bit double float, native format as host computer

ASIOBool

ASIOFalse	indicates a false value
ASIOTrue	indicates a true value

Error codes

<i>ASE_OK</i>	This value will be returned whenever the call succeeded
<i>ASE_SUCCESS</i>	unique success return value for ASIOFuture calls
<i>ASE_NotPresent</i>	hardware input or output is not present or available
<i>ASE_HWMalfunction</i>	hardware is malfunctioning (can be returned by any ASIO function)
<i>ASE_InvalidParameter</i>	input parameter invalid
<i>ASE_InvalidMode</i>	hardware is in a bad mode or used in a bad mode
<i>ASE_SPNotAdvancing</i>	hardware is not running when sample position is inquired
<i>ASE_NoClock</i>	sample clock or rate cannot be determined or is not present
<i>ASE_NoMemory</i>	not enough memory for completing the request

IV. Host Utility API Reference

1. AsioDrivers Class

The AsioDrivers class implements the unified driver enumeration and instantiation on the different OS platforms. However the implementation is currently limited to one active driver. Also it implies that a driver names will have max. 32 characters including the terminating '\0'.

AsioDrivers();

~AsioDrivers();

Constructor/Destructor for the driver manager class

bool loadDriver(char *name);

Purpose:

Instanciates an ASIO driver. Loads the driver executable into memory and resolves any OS specific linkage between the host application executable and the driver executable. The driver will be accessed via the global pointer *theAsioDriver* from inside "asio.cpp".

Parameter:

name name of the driver to load, *name* is to be obtained from getDriverNames().

Returns:

Returns true if the driver was instantiated successfully, false otherwise.

long getDriverNames(char **names, long maxDrivers);

Purpose:

Retrieves the names of the available drivers for the host application.

Parameter:

names an array of strings with upto 32 character each.

maxDrivers number of entries in the *names* array.

Returns:

Returns the number of filled entries of the *names* array. The value 0 described the fact that no driver is available.

bool getCurrentDriverName(char *name);**Purpose:**

Retrieves the name of the currently instantiated driver.

Parameter:

name an array with space for 32 characters.

Returns:

Returns *true* if a driver is currently instantiated, *false* if no driver is instantiated.

long getCurrentDriverIndex();**Purpose:**

Retrieves the index into the *names* array of the currently instantiated driver. See *getDriverNames()*.

Parameter:

None.

Returns:

Returns index into the *names* array. If no driver is instantiated -1 will be returned.

void removeCurrentDriver();**Purpose:**

Removes the currently instantiated driver from memory any further access to the driver will be denied.

Parameter:

None.

Returns:

None.

Note:

Successful removal of the driver is implied, even if no driver was instantiated.

V. Appendix

A. Using the `bufferSwitchTimeInfo()` callback

It is recommended to use the new method with time info even if the ASIO device does not support timecode; continuous calls to `ASIOGetSamplePosition()` and `ASIOGetSampleRate()` are avoided, and there is a defined relationship between callback time and the time info.

See the example code for a driver on the next page.

To initiate time info mode, after you have received the callbacks pointer in `ASIOCreateBuffers()`, you will call the `asioMessage()` callback with `kAsioSupportsTimeInfo` as the argument. If this returns 1, the host has accepted time info mode. Now the host expects the new callback `bufferSwitchTimeInfo` to be used instead of the old `bufferSwitch` method. The `ASIOTime` structure is assumed to be valid and accessible until the callback returns.

Using time code:

If the device supports reading time code, it will call the host's `asioMessage()` callback with `kAsioSupportsTimeCode` as the selector. It may then fill the according fields and set the `kTcValid` flag.

The host will call the future method with the `kAsioEnableTimeCodeRead` selector when it wants to enable or disable time-code reading by the device.

Note:

The `AsioTimeInfo/ASIOTimeCode` pair is supposed to work in both directions. As a matter of convention, the relationship between the sample position counter and the time code at buffer switch time is (ignoring offset between time-code and sample position when time-code is running):

on input: sample 0 -> input buffer sample 0 -> time code 0

on output: sample 0 -> output buffer sample 0 -> time code 0

This means that for 'real' calculations, one has to take into account the according latencies.

Example:

```
ASIOTime asioTime;

in createBuffers()
{
    memset(&asioTime, 0, sizeof(ASIOTime));
    AsioTimeInfo* ti = &asioTime.timeInfo;
    ti->sampleRate = theSampleRate;
    ASIOTimeCode* tc = &asioTime.timeCode;
    tc->speed = 1.;
    tc->frameRate = AsioFPS_30;           // frame rate
    timeInfoMode = false;
    canTimeCode = false;
    if(callbacks->asioMessage(kAsioSupportsTimeInfo, 0, 0, 0) == 1)
    {
        timeInfoMode = true;
#ifdef kCanTimeCode
        if(callbacks->asioMessage(kAsioSupportsTimeCode, 0, 0, 0) == 1)
            canTimeCode = true;
#endif
    }
}

void switchBuffers(long doubleBufferIndex, bool processNow)
{
    if(timeInfoMode)
    {
        AsioTimeInfo* ti = &asioTime.timeInfo;
        ti->flags = kSystemTimeValid | kSamplePositionValid | kSampleRateValid;
        ti->systemTime = theNanoSeconds;
        ti->samplePosition = theSamplePosition;
        if(ti->sampleRate != theSampleRate)
            ti->flags |= kSampleRateChanged;
        ti->sampleRate = theSampleRate;

#ifdef kCanTimeCode
        if(canTimeCode && timeCodeEnabled)
        {
            ASIOTimeCode* tc = &asioTime.timeCode;
            tc->timeCodeSamples = tcSamples;
            tc->flags = kTcValid | kTcRunning;           // if so...
        }
        ASIOTime* bb = callbacks->bufferSwitchTimeInfo(&asioTime, doubleBufferIndex,
processNow ? ASIOTrue : ASIOFalse);
#else
        callbacks->bufferSwitchTimeInfo(&asioTime, doubleBufferIndex, processNow ?
ASIOTrue : ASIOFalse);
#endif
    }
    else
        callbacks->bufferSwitch(doubleBufferIndex, ASIOFalse);
}
```

```
ASIOError ASIOFuture(long selector, void *params)
{
    switch(selector)
    {
        case kAsioEnableTimeCodeRead:
            timeCodeEnabled = true;
            return ASE_SUCCESS;
        case kAsioDisableTimeCodeRead:
            timeCodeEnabled = false;
            return ASE_SUCCESS;
    }
    return ASE_NotPresent;
};
```

B. ASIOGetLatencies() vs. Sample Placement

This appendix covers the actual meaning of the latency values for ASIOGetLatencies(). To ease the understanding of these latencies the first sample inside the audio data buffer of the bufferSwitch() callback is used as reference into the continuous stream of audio samples.

The latency is required by the application to align the incoming audio data to the outgoing audio data to the outside world. The application considers the audio data as continuous stream of samples. It has to send the output data ahead of time to the driver in order to have the right samples at the output at the right time. The incoming audio data needs to be placed at the appropriate position during recording.

Below is a sample situation when a sample at sample position 256 is examined. The audio driver/hardware reports an output latency of 230 samples and an input latency of 239 samples.

```

Output      -----*
buffers    | 128 | 256 | 384 | 512 | ....
Input      *-----| will occur at position 495 in the stream

```

The output sample will appear at the output with a delay of 230 samples. Therefore it needs to be placed by the application into the audio buffer at position 26.

Input signal at sample position 256 will appear at sample position 495 inside the audio buffers. Since the driver informed the application about this delay it can place the input signal in relation to its internal time line (time reference).

Output latency:

The output latency specifies the time in number sample frames a sample will reach the output after it was passed from the application to the driver in an audio data buffer during a buffer switch. In order to provide the correct latency value for ASIOGetLatencies() you have to perform the following calculation:

$(\text{number of queued audio buffers} * \text{size of buffer}) + \text{hardware dependent latency}$

In case the hardware implements a double buffer and accesses the same memory as the application/driver data buffer usually one audio buffer is queued up, only the hardware dependent latency as found in digital transmitter or DAC's needs to be added to the audio buffer size.

If the hardware has to copy the data from the ASIO data buffers to another buffer you should look at ASIOOutputReady() whether you can use this notification mechanism to keep one audio data buffer as fixed latency.

**Input latency:**

The input latency specifies the number of sample frames an incoming audio sample is passed to the application during a buffer switch callback.

(number of queued audio buffers * size of buffer) + hardware dependent latency

In case the hardware implements a double buffer and accesses the same memory as the application/driver data buffer usually one audio buffer is queued up, only the hardware dependent latency as found in digital receivers or ADC's needs to be added to the audio buffer size.

In order to reduce the input latency if the driver needs to copy the audio data to the ASIO data buffer, the copy operation should be executed immediately before the `bufferSwitch()` callback.

Note: The latency is always constant for a specific driver/hardware combination and audio data buffer size. It is not affected by the time the buffer switch callback is actually issued and it does not reflect the time the samples of the current `bufferSwitch()` callback will require to pass through the system. This is due to the fact that the audio stream is continuously processed and the audio data buffer of each buffer switch is adjacently joined to audio data from the previous buffer switch.

C. Driver Test Methods

1. Audio input to output placement (bounce)

Recording audio output to input should be placed on time (+/- 1 ms)

1. Make sure that the output is routed back to the input. (outboard connection or patchbay)
2. In Cubase VST place a test signal (preferably a single impulse) 1 bar right to the left locator.
3. Move the song position 1 bar before the left locator.
4. Activate Auto-Punch In record
5. Start playback, when the song position reaches the left locator recording will start.
6. Stop after some time
7. Check that the recorded signal is placed at the same time as the source signal

Whenever the recorded signal is not aligned with the source signal, the input and/or output latency has to be refined.

2. Audio to MIDI sync (Audio click/MIDI click and output latency)

Similar test as above, however a MIDI tone generator created signal should be recorded, too. We suggest a stereo recording of left channel returned audio playback and right channel from the MIDI tone generator. As audio source the audio click and for the MIDI tone generator the MIDI click can be used (both can be found in the Metronome setting window of Cubase VST).

If MIDI and audio are not aligned, please check the ASIOGetLatency results. Please note that common tone generators like Yamaha MU-80 or Roland Sound Canvas have an inherent 5 ms delay between the computer sending a MIDI event and the sound appearing at the tone modules output. Therefore it is sufficient if the audio and MIDI signal are aligned with a deviation of 5 ms. If the deviation looks more like a multiple of the audio buffer size, an incorrect result of ASIOGetLatency is likely.

3. MIDI timing stability

Same test as above. Use Audio click as signal for the audio hardware (Metronome Dialog)

MIDI sound generator created audio events should deviate within +/- 2 ms from the audio click. If MIDI notes are out of range, please check the results of ASIOGetSamplePosition(), also check that the driver does not influence the systems reference timer or blocks the system for too long in other ways.

4. MIDI/Audio drift

Same test as above. Use Audio click as signal for the audio hardware (Metronome Dialog)
MIDI notes and audio clicks should not move apart. If they do, the timestamp/sample-position
result from ASIOGetSamplePos() needs to be checked.

1. MIDI/Audio offset
2. Stereo recording left channel audio click/right MIDI click
3. Bus assignment
4. Open last and first output/input bus and check for the right routing

D. Platform/OS Differences

MacOS

1. The ASIO `bufferSwitch()/bufferSwitchTimeInfo()` are called from interrupt. You cannot call any Macintosh Toolbox routines, except the ones that are interrupt safe. Please refer to Apple's MacOS documentation.
2. Primary/Secondary Interrupt service routine should call ASIO `bufferSwitch ()` with `processNow` set to true only if the buffer is small enough. Too large buffer can stall the execution of other important tasks in the system. Though this also depends on the time spend for audio processing, if the buffer can be calculated in less than 1 ms, the system will not be affected. An adaptive method can be implemented in the driver in case the audio processing requires more time.
3. `DeferredTaskManager` used for the ASIO `bufferSwitch` callback can create drop out situation based on lengthy tasks already in the DT-queue.
4. The timing stability of the MIDI processing should never be compromised. A 1 ms accuracy for MIDI processing is required and should not be delayed by the audio driver processing. (ASIO `bufferSwitch ()` with `processNow` set to false, might be the best solution, because the application can provide the mechanics for accurate MIDI and audio processing.)
5. Future host implementation might exploit the MP-Library of MacOS 8.6 and up. The application might then not take the value of `processNow` into account.
6. The time reference for the timestamp is the `Microseconds()` call. It can be accessed at interrupt and application time.

Windows

1. ASIO `bufferSwitch()` is usually implemented in its own thread, created by the driver. Thread execution is either invoked by event notification from the kernel driver or by issuing an APC in the thread context. The driver should set an appropriate high priority for the thread.
2. It is advised that the driver provide enough audio buffer size choices to avoid audio dropouts on a busy system. Due to the implementation of the thread scheduler in Windows 95/98 low priority threads can block the high priority callback thread. The time quantum is between 15 and 19 ms. We observed that a buffer size of around 50 ms (2048 samples at 48 kHz sample rate) will provide enough head room to avoid drop outs on a heavy loaded system. Though higher buffer sizes might be required depending on the constraints of the driver. The driver can implement smaller audio buffer sizes if the user can select them.
3. Win16Mutex contention should be avoided. Please keep in mind that calling the Win16 sub system can block thread execution for a long time. Several Windows 95/98 sub-systems like GDI and the window management are implemented in the Win16 sub-system which is secured against re-entrancy by the Win16Mutex. Graphic animations like the "fading" Tool Tips will execute for their entire duration in the Win16 sub system and can halt the Win16Mutex for a very long time



(we observed durations of up to 1.5 s). Therefore it is necessary to avoid Win16 sub system calls in the driver threads.

4. On Windows the time reference for the timestamp is the multimedia timer, `timeGetTime()`, with a resolution of 1 ms. The time base for this timer can be obtained at the kernel level with the `VMMCall GetSystemTime` or `GetUpdatedSystemTimeAddress`.

5. The **`asioMessage()`** callback will be present for all Windows ASIO host applications. The initial Macintosh ASIO host application, Cubase VST 3.0 for Macintosh, did not provide this callback.

E. AsioDriver class for the driver implementation

```
class AsioDriver
{
public:
    AsioDriver();
    ~AsioDriver();

    ASIOBool init(void *);
    void getDriverName(char *name);
    long getDriverVersion();
    void getErrorMessage(char *string);
    ASIOError start();
    ASIOError stop();
    ASIOError getChannels(long *numInputChannels, long *numOutputChannels);
    ASIOError getLatencies(long *inputLatency, long *outputLatency);
    ASIOError getBufferSize(long *minSize, long *maxSize, long *preferredSize, long *granularity);
    ASIOError canSampleRate(ASIOSampleRate sampleRate);
    ASIOError getSampleRate(ASIOSampleRate *sampleRate);
    ASIOError setSampleRate(ASIOSampleRate sampleRate);
    ASIOError getClockSources(ASIOClockSource *clocks, long *numSources);
    ASIOError setClockSource(long reference);
    ASIOError getSamplePosition(ASIOSamples *sPos, ASIOTimeStamp *tStamp);
    ASIOError getChannelInfo(ASIOChannelInfo *info);
    ASIOError createBuffers(ASIOBufferInfo *bufferInfos, long numChannels,
                           long bufferSize, ASIOCallbacks *callbacks);
    ASIOError disposeBuffers();
    ASIOError controlPanel();
    ASIOError future(long selector, void *opt);
    ASIOError outputReady();
};
```



Differences to the ASIO C interface

Nearly all member functions match the ASIO-API name with the ASIO-prefix removed. The exceptions are:

AsioDriver()

The constructor will actually just perform any system dependent tasks. On Windows it is actually the constructor for the COM object of the driver. See the separate documentation about the COM specific details on the Windows platform.

init(), getDriverName(), getDriverVersion()

These three member functions are a split up version of the ASIOInit() call. However not all parameter of the ASIOInit() call are provided.

Missing are asioVersion and driverVersion from the ASIODriverInfo.

init(void *sysRef) receives on Windows the applications frame window handle. On the Macintosh the pointer will be set to 0.

Since the driver can not determine the host applications ASIO version until it receives the ASIOCallbacks structure via the createBuffers() method, it has to assume ASIO 1.0 compliance. During the createBuffers() call the driver can query the host for its version via asioMessage with the **kAsioEngineVersion** selector.

~AsioDriver()

The destructor implies ASIOExit(). The driver will not receive the ASIOExit() call, instead the destructor will be invoked.