Technical Note TN1187
Digital CD Audio

CONTENTS

Starting with Mac OS 9.0 there is a new way of playing CD audio -- digitally. Pure digital data is read from the CD, played through the Sound Manager as a PCM (Pulse Code Modulation -- standard uncompressed audio) data stream, and then sent out to the speakers (where your ears require that it be converted back to an analog signal).

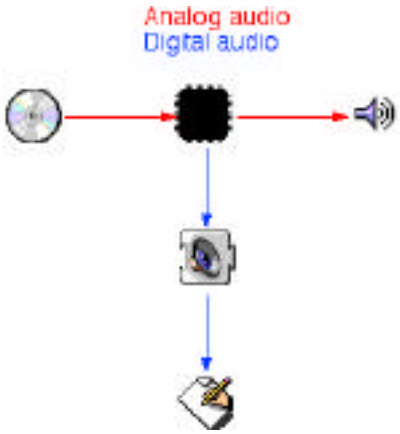
This Technote describes how an application uses the new digital CD audio support and what a CD or DVD driver needs to do to support playing audio digitally.

Updated: [Apr 3 2000]

The way it was

For as long as the Macintosh has had a built in CD-ROM, the audio has been played as an analog sound stream. The CD-ROM drive would output analog sound, just like a microphone, and the Mac would record that audio, optionally passing it through to the speakers (play through).

A diagram of the flow of audio data (from the CD-ROM only for simplification) looks like this:



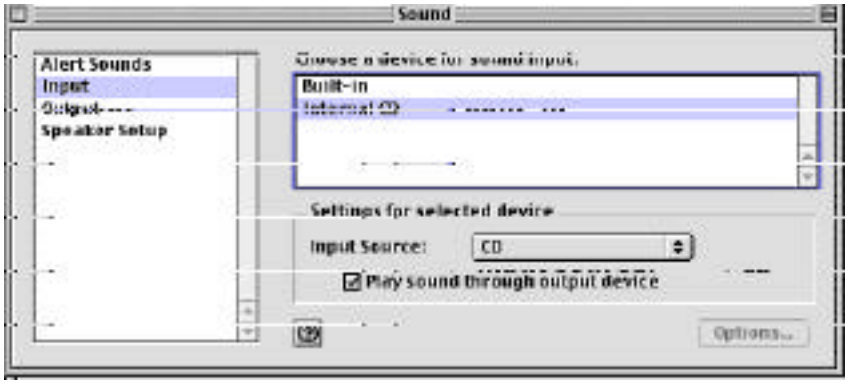
The audio data was read by the CD-ROM drive and converted to analog audio inside the CD-ROM drive. From there the analog audio would go to the sound hardware on the Macintosh. It would then be converted back to digital data and given to the Sound Manager. The Sound Manager would then pass the audio to any application that was recording the CD audio input source. If play through was turned on, the sound hardware would automatically route the analog sound back out to the speakers (or headphones), requiring no CPU intervention or overhead to hear the audio. The multiple conversions of the audio introduced the possibility of noise and reduced sound quality as well as making it difficult to precisely know, to a sample accuracy, what was being played.

That has all changed with Mac OS 9.0.

Back to top

The way it is now

Starting with Mac OS 9.0, on all ROM-in-RAM Macs (currently the iMac, iMac DV, iBook, Blue & White Power Macintosh G3, Power Macintosh G4, and Bronze Keyboard PowerBook G3 Series) there is a new sound input device called "Internal CD." When Internal CD is the selected input source, the Macintosh reads digital data directly from the CD and plays it as high-quality digital audio from CD using standard Sound Input Manager recording calls. However, the Internal CD input driver does not have to be selected to allow the user listen to the CD, it only has to be selected to record from.



Instead of using the digital to analog converters built into the CD-ROM drive (which may be of questionable quality to audio purists), the audio is read as digital data, much like a normal file would be read off of a CD. This digital audio is then passed to the Sound Manager which plays it, as it would play any sound.

This allows the sound to be played by the built-in sound hardware and the built-in speakers of the Macintosh, or out via some other hardware, such as USB speakers. Previously it was not possible for the internal audio CD to be played out via third-party hardware.

The flow of audio data now looks like this:

However, this also means that the CPU is now running code that plays the audio. A very minor performance penalty is extracted for this new functionality. The measured statistics are about 0.5% CPU usage on a PowerBook G3 300MHz when the sound output setting is set to 44.1 kHz. This number doesn't include the cost of the Sound Manager sound channel which is needed for the sound output.

Back to top

How your application needs to change

There is no longer an option of selecting the internal CD from the Built-in input driver. If the user's CPU is able to support digital CD audio the option of doing it the old analog way has been removed for a consistent user interface between different Macintoshes.

If you would like to give the users of your application the ability to record digital CD audio using the new Internal CD input source, you will have to choose it as the recording source. It is a completely different sound input driver, not a different input source of the Built-in sound input device. You will need some method of selecting different input sources because you cannot assume that it will be the default input device.

Apple **does not** recommend that you have the user use the Sound control panel to change the default input source unless the user wants a global change. Typically this is the not the case, as only one application wants to record from the Internal CD input source -- most applications will want to record from the microphone or sound in input. Therefore having the user change the system wide behavior is the wrong thing to do.

Having your own interface element for this is the preferred method for changing all sound settings in your application. The proper way to choose the Internal CD input source is to construct a list of all sound input drivers (using repeated calls to `SPBGetIndexedDevice`) to populate a menu or a list. The application should store these settings in its preferences and configure the sound input driver and sound output component accordingly each time the application starts. **Do not** have the user set these settings in the Sound control and rely on them always being the default sound settings.

There are a few key points that should be pointed out regarding the Internal CD input source:

- Because it is a separate input device, the user can record from the microphone in one application (for instance, Speech Recognition), and listen to CD audio at the same time.
- The Internal CD input device will be busy when an application is recording from the CD. Be prepared to deal with this gracefully. It will **not** be busy when it is just playing a CD.
- Play through is always on. It is hoped that once most applications are updated to be able to deal with not having the `siPlayThruOnOff` selector supported that it will be removed. For now you should update your code to be able to deal with not being able to check or set the play through setting of an input source. Remember, the `siPlayThruOnOff` selector is optional, so not all input devices support it.

Back to top

How your CD/DVD driver needs to change

Developers of CD or DVD drivers may wish to support the new Internal CD input driver. To do this the driver needs to be updated to call some functions in the Internal CD PPC code fragment. Calling these functions from 68K code is not supported. If you wish to do that, you are squarely in unsupported territory - watch your step.

These functions are called by the CD/DVD driver and are how digital audio is passed from the driver to the Internal CD driver when the CD/DVD driver gets an `AudioPlay` control call.

The exported functions of the DigitalCDSoundLib are:

```
typedef void (*ReadMoreCDAudioProcPtr)(SInt32 refCon);
typedef STACK_UPP_TYPE(ReadMoreCDAudioProcPtr) ReadMoreCDAudioUPP;

void    CDSoundMain( CDSoundInfoTable *infoTable, SInt32 drvrRef );

OSErr   SetupSound( UInt32 bytesInRingBuffer,
                    ReadMoreCDAudioUPP readMoreCDUPP,
                    SInt32 refCon,
                    Component outputDevice,
                    UInt32 numMarkers );
OSErr   TeardownSound( void );
void    CDSoundTerminate ( void );

void    StartSound( void );
void    StopSound( void );

void    PlayRing( void );
void    PauseRing( void );

SInt32  RingBytesAvailable( void );
void    WriteAudioToRing( SInt16 *newData, UInt32 numFrames );
void    StitchAudioIntoRing( Ptr wholeBuff,
                             UInt32 buffFrames,
                             UInt32 overlapFrames );
void    InvalidateRingBuffer( void );

SInt32  GetVolume( void );
OSErr   SetVolume( SInt32 volume );

OSErr   Set3DSoundOn( void );
OSErr   Set3DSoundOff( void );

void    SetTrackMarker( UInt32 marker );
void    GetCurrentTrackMarker( UInt32 *marker,
                               UInt32 *framesBeyondMarker );
```

The usage, and general ordering, of these routines is as follows:

1. Call `CDSoundMain` which will install the "Internal CD" sound input driver and create other needed internal structures.Pass a valid `CDSoundInfoTable` with the `versionNumber` field set to 1. For `drvrRef`, pass in the reference number of the driver that will be reading the digital audio. Ignore the values of the fields in `CDSoundInfoTable` when `CDSoundMain` returns. You cannot call this function at interrupt time, call it only at task time.
2. Call `SetupSound`. This allocates all necessary data structures. Pass this function the size in bytes of the ring buffer you want to use. Also pass a pointer to the `UPP` for the `ReadMoreCDAudio` function, and an optional `refCon` that will be passed to the `ReadMoreCDAudio` function. The second to the last parameter contains the component reference of an output device to use. Set it to `nil` to use the default output device. The last parameter contains the number of track markers to allocate. This must be called at task level, and will return `controlErr` if the current execution level is not task level.

Note:
`SetupSound` can return any of a number of errors due to conditions such as being out of memory, incorrect hardware, etc. Be prepared to deal with errors.

1. Start reading audio CD data.
2. Call `StartSound`. This will start the output running. Don't worry, the user won't hear anything until you put some data into the ring buffer. This function cannot be called at interrupt time, it must be called at task time.
3. Once a CD read completes, call `WriteAudioToRing` or `StitchAudioIntoRing` - use `WriteAudioToRing` if you are writing the first data, or if the CD drive in use does not require stitching. Use `StitchAudioIntoRing` if the CD drive requires stitching, and this is not the first bit of data to play (in other words, there should be overlap from a previous read). You can call this function at interrupt time.

Note:
If stitching is required by the CD drive, you must read overlapping data from the drive. For instance, if one read you get 75 blocks starting at address 01:15:50 (one minute, 15 seconds, 50 blocks), the next read should overlap by some amount. I have found that an overlap of 7 blocks gives good results. Thus the next read would read 75 blocks starting at address 01:16:43 (7 blocks shy of a full second). You need to pass the `StitchAudioIntoRing` the number of frames of overlap that you're using.

1. `PlayRing` and `PauseRing` can be used to start and stop the audio at any time. `PlayRing` will start the sound as soon as possible. `PauseRing` will stop the sound from playing as soon as possible. These functions can be called at interrupt time.
2. Call `RingBytesAvailable` to determine if you should queue another read of CD data. If there is enough space in the ring buffer, queue another read. Otherwise, stop reading. See `ReadMoreCDAudio` below for how to get the data reads started again. This function can be called at interrupt time.
3. `ReadMoreCDAudio` is a function that is called by the sound interrupt code every time an audio interrupt happens. The call is made at interrupt time. This is the way that the audio task will alert you that you should read more data from the CD. Because the CD drive will be able to read data faster than the sound plays it, eventually the function getting the CD audio will no longer have room to insert more audio data into the ring buffer. Using `RingBytesAvailable`, determine the amount of available space in the ring buffer. If there's enough to get more data from the CD, and if data is not currently being read off the CD, queue another read.
4. Call `InvalidateRingBuffer` whenever you are playing some user-specified different data, such as a mid-track switch. Call this function to instantly invalidate any existing audio data in the ring buffer. This call also **removes** all previously set track marker information. This function can be called at interrupt time.
5. Call `StopSound` to stop the sound output from happening. All sound will immediately stop. Use this when there's no more data to play. This function can be called at interrupt time.
6. Call `TeardownSound` to deallocate all data structures, including the ring buffer. Don't call any ring buffer manipulation routines after calling this before calling `SetupSound` again. This function must be called at task level, and will return `controlErr` if the current execution level is not task level.
7. Call `CDSoundTerminate` to remove the sound driver if your device will no longer be offering digital CD audio, for instance, if your USB or FireWire CD drive has been disconnected. This function cannot be called at interrupt time and must be called at task time.

These functions are used to control how the audio plays or give you feedback about where in the audio stream you are.

- Use `GetVolume` to get the volume for the CD audio stream (only). The volume is passed back as a long in the format `0x0RRR0LLL` where `RRR` is the right volume and `LLL` is the left volume. The value of `RRR` and `LLL` ranges from `0x000` to `0x100`. Do not call this function at interrupt time as it may be made interrupt unsafe at some point in the future.
- Use `SetVolume` to get and set the volume for the CD audio stream (only). The volume is passed in as a long in the format `0x0RRR0LLL` where `RRR` is the right volume and `LLL` is the left volume. The value of `RRR` and `LLL` must be in the range of `0x000` to `0x100`. Do not call this function at interrupt time as it may be made interrupt unsafe at some point in the future.
- Use `Set3DSoundOn` to turn on 3D spatial enhancement. Do not call this function at interrupt time as it may be made interrupt unsafe at some point in the future.
- Use `Set3DSoundOff` to turn off 3D spatial enhancement. Do not call this function at interrupt time as it may be made interrupt unsafe at some point in the future.

Note:
`Set3DSoundOn` and `Set3DSoundOff` will return an error if 3D sound enhancement is not supported by the hardware.

- Use `SetTrackMarker` to mark the next data being written to the ring. You can pass any arbitrary 4 byte value. This value will be passed back if that data is currently being played when a `GetCurrentTrackMarker` call is made. This function can be called at interrupt time.
- Use `GetCurrentTrackMarker` to retrieve the marker that was last passed as audio data is being played. Along with the marker that was passed, a frame count is returned that tells how far beyond the marker has been played. This function can be called at interrupt time.

There are a significant number of data structures and memory allocations associated with digital CD audio. To minimize the use of system resources that are not needed, your driver should not call `SetupSound` until it is actually going to play a CD. Likewise, it should call `TeardownSound` as soon as it is done playing the CD so that system resources can be freed for other applications.

Back to top

Additional Notes & Comments

The Only Way

The only way that users will be able to hear their CDs through USB speakers is for the CD/DVD driver to support digital audio. If you are the author of a CD or DVD driver, you should work to add this functionality to your driver as quickly as possible.

The Apple CD/DVD driver allows for digital CD audio only on Macintoshes which have ATAPI CD or DVD drives. It does not support SCSI CD drives. Macintoshes with SCSI CD drives using the Apple CD/DVD driver will behave as they always have.

The iBook *only* does digital CD audio, as its sound chip does not have an analog to digital converter (remember, it doesn't have a built in microphone either). All iBooks will play audio CD using the above API. If a user installs a third-party CD driver on the iBook, it is imperative that it supports digital CD audio or the user will loose the ability to hear their audio

CDs.

The Power Macintosh G4 (AGP Graphics) only does digital CD audio as there is no internal CD audio analog connection on the motherboard. Though the computer does support analog recording via an external microphone, it does not have an internal analog connection.

3D Sound

The 3D sound enhancement that is offered is a simple filter. It is one of a class of filters called "stereo spreaders." This type of enhancement works well with some types of music, and not so well with others, so make sure you allow the user to choose their personal preference of on or off.

Because of the additional signal from the stereo spreader is being added back into the original signal, the overall signal is reduced to avoid the possibility of clipping. This has the effect of reducing the overall volume level of the sound when the 3D effect is turned on (and a raising of the volume when it is turned off). The user can compensate for this by turning up the volume on the Mac, the CD, or their speakers.

The current implementation of the 3D-Stereo component takes about 1.4% of the CPU on a 300MHz PowerBook G3.

Back to top

Summary

As you can see, applications do not have to do anything special and will just continue to work -- assuming that they were properly coded with the correct error handling and user interface. If you do not have a user interface for sound preferences, but instead rely on the Sound control panel, please remedy this as soon as possible.

Drivers have a bit more work to allow for digital CD audio, but the benefit of allowing the user to play their CDs through their USB speakers definitely makes this effort worthwhile.

References

TN1124: New Sound Input Driver Features

TN1108: Unknown Sound Features

Back to top

Downloadables

	Acrobat version of this Note (K).	Download
	DigitalCDSound.h (13K).	Download
	DigitalCDSoundLib.stub (1K)	Download

Back to top
