Freescale Semiconductor
Application Note

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ColdFire+ USB Audio Speakers

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1 Introduction

The USB audio class groups all functions that can interact with USB audio streams. All functions that convert between analog and digital audio domains can be part of this class, such as USB speakers that receive digital audio data from the host through the audio class, then reproduce it through an analog interface.

The Freescale ColdFire+ MCF51Jx portfolio offers integrated USB 2.0 Full-Speed OTG controller, 12-bit digital-to-analog Converter (DAC) to provide flexible and powerful mixed signal capabilities, and various timers that support general purpose control functions.

To fully understand this document, it is best to first read *Universal Serial Bus Device Class Definition for Audio Devices*, Release 1.0, at usb.org.

Contents

2 Functional description

Pulse-code modulation (PCM) is a standard method for digital audio used in computers to digitally represent sampled analog signals. PCM streams have two basic properties that determine their fidelity to the original analog signal:

1. Sampling rate: number of times per second that samples are taken (in other words, 8 kHz, 44.1 kHz, 48 kHz).
2. Bit depth: number of possible digital values that each sample can take (8, 16, 24 bits). 8-bit PCM uses unsigned data, whereas 16–24-bit PCM uses signed values.

To produce output from the digital audio sample data, after each sampling period has passed, the next digital value is read and the output signal is shifted to the recently obtained value. Digital-to-analog converters can be used to convert the digital audio into an accurate analog signal.

3 Firmware design

The software contained in this application note uses the Freescale USB stack, which supports audio class. This source code solution is downloadable from www.freescale.com/usb. The stack provides standardization, connectivity, and portability to the existing 8-bit and 32-bit Freescale microcontroller portfolio, and speeds up general purpose and medical product development.

3.1 Synchronization scheme

This application note configures the ColdFire+ MCF51JF to work like an audio streaming interface enabling PCM8 (8-bit depth at 8 kHz sample rate). This means that digital audio sample data needs to be converted to audible analog output through the DAC every 125 µs = 1/8 kHz.

The Modulo Timer (MTIM) module is a simple 16-bit timer with a programmable interrupt used to generate the 125 µs timely delay. Because isochronous transfers are used, it is necessary to synchronize the 125 µs delays with the USB SOF interrupt.

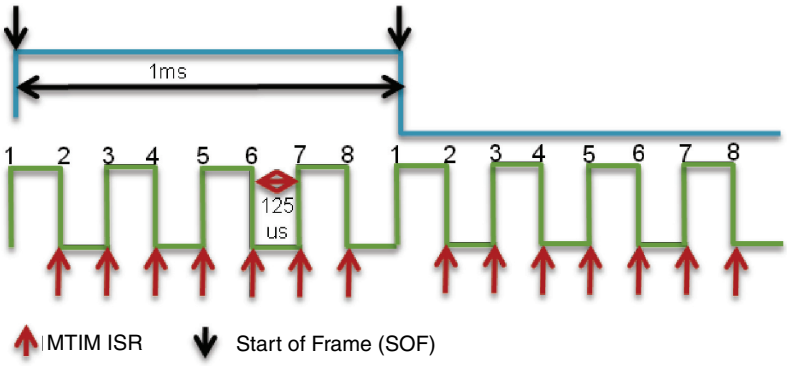

Figure 1. SOF and MTIM ratio

3.2 Main function

The main function flow chart is shown in Figure 2. At first the firmware initializes the system. The MTIM is configured to generate 125 µs interrupts and the counter is stopped for a moment. The DAC is enabled to work with software triggers, and the USB stack runs the software to enumerate the device as audio class.

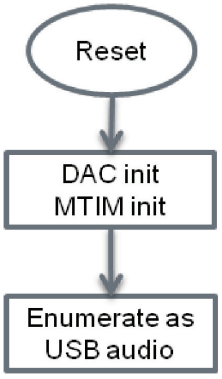

Figure 2. Main function flow chart

3.3 USB ISR

Inside the USB interrupt service routine (usb_dci.c), the start of frame flag is checked, in case an SOF event occurs. The MTIM counter, which is stopped from the initialization code, starts counting.

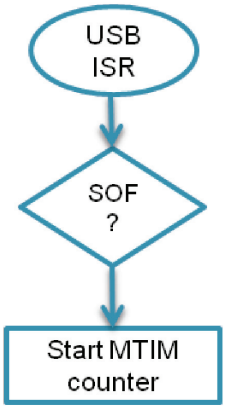

Figure 3. USB ISR flow chart

3.4 USB application callback

Whenever a reset occurs or the enumeration process is complete, the USB_App_Callback (audio_speakers.c) function is called from the class layer. This function sets a variable so that the application can start. It also receives data send/receive events.

The software is written in such a way that whenever data has been received, the USB application callback stores the samples in a global buffer. Because PCM8 format is used, this means that 8-byte samples are received at this moment.

Figure 4 shows that the first sample needs to be sent at the same time that it arrives in order to be synchronized with the sampling rate. Therefore, as soon as the global buffer finishes storing the samples, the first sample is sent to the DAC.

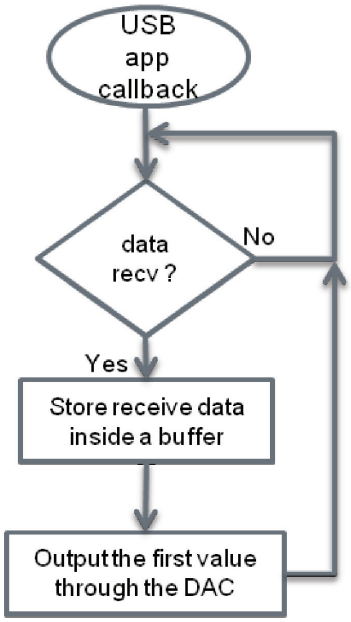

Figure 4. Application callback flow chart

3.5 MTIM ISR

The MTIM interrupt (audio_mtim.c) provides timely delays to play the received digital audio data through the DAC. Inside the MTIM ISR the software needs to:

1. Check if there is new data to be sent.
2. Convert the current digital audio data into an analog output.
3. Check if the current sample equals bit depth (8 samples); if it does then the MTIM counter is stopped.

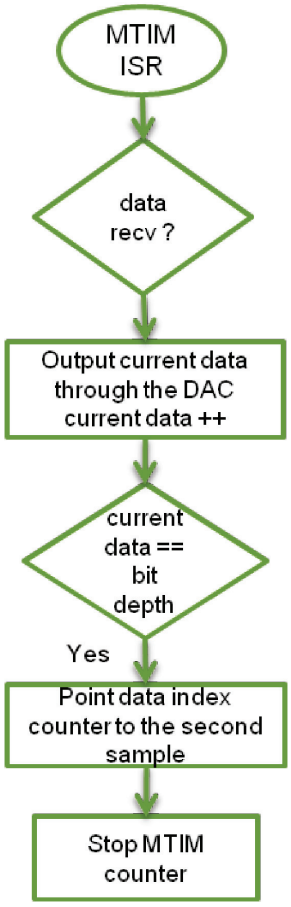

Figure 5. MTIM ISR

4 Running the software

This section explains how to use the USB audio speaker software which receives audio streams data from a host and plays it through the DAC. Such software also supports specific requests from the audio control interface (from host) such as mute control, volume control, and many more.

4.1 Setting up the demo

The TWR-MCF51JF is connected to a PC (host) using two USB cables and one speaker through an audio jack output. The PC uses one USB cable to supply power to the board and to flash the software to the ColdFire+ device. The second USB cable connects the PC host and the TWR-MCF51JF device.

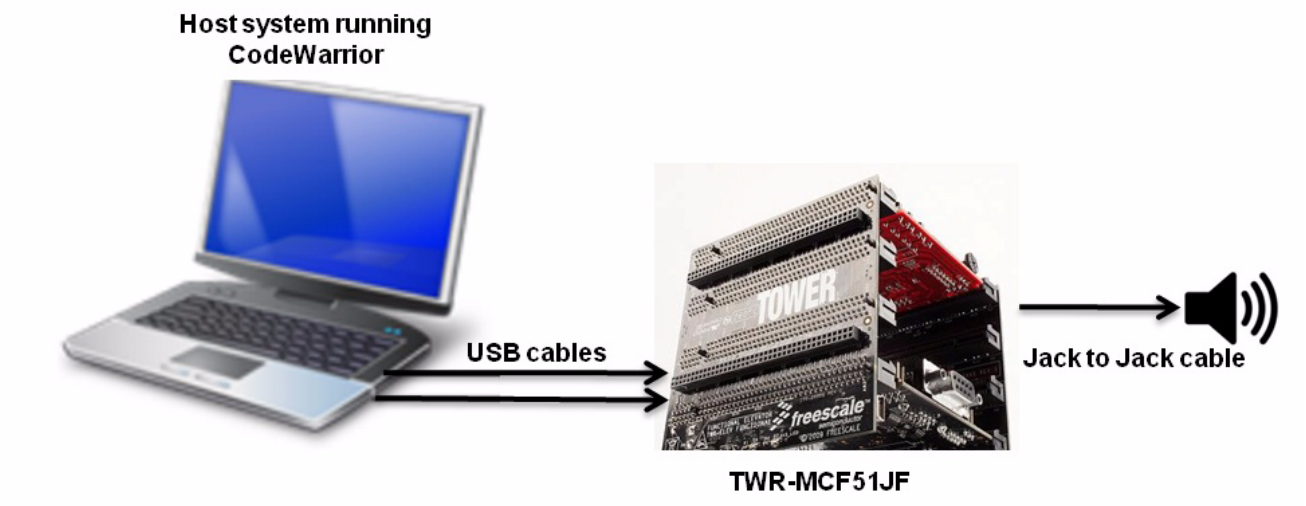

Figure 6. Audio speaker demo setup

4.2 Running the demo

After the system has been set and flashed, use these steps to run the demo.

1. Plug USB audio device into the PC. As soon as you turn on the device, it is recognized by the host and installed automatically. Callout shown in Figure 9 should appear on the right bottom corner of your screen.

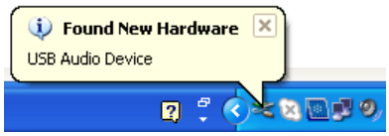

Figure 7. Find new hardware callout

2. After successful installation, the host indicates that the device is ready to use as shown in Figure 8.

Figure 8. Installation of USB audio device

3. To verify whether the USB audio device has been installed properly, look at the device manager dialog.

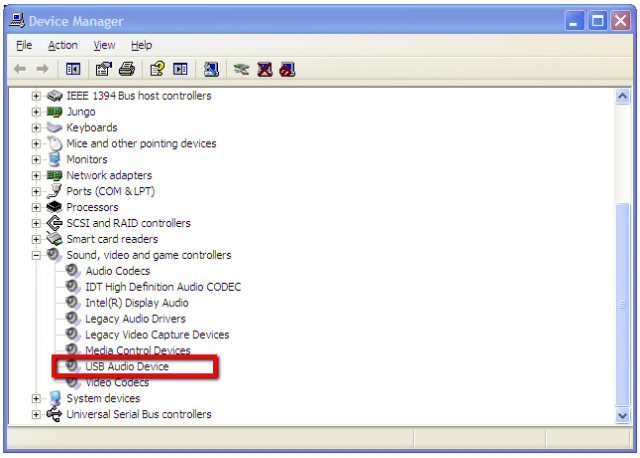

Figure 9. Device manager dialog

4. Double-click on the USB Audio Device icon, and the device properties dialog appears as shown in Figure 10.

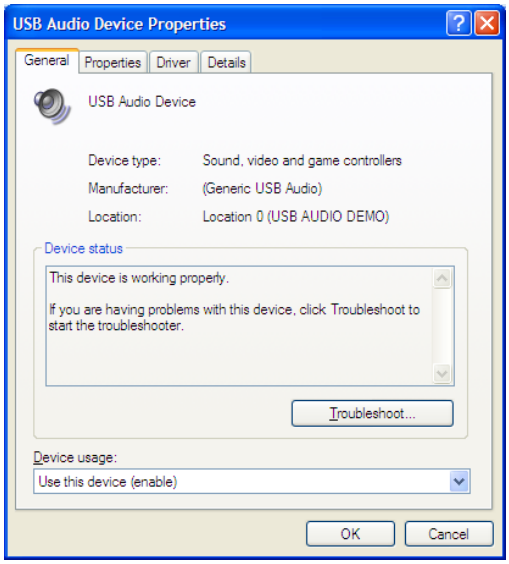

Figure 10. USB Audio Device properties dialog

5. To verify whether the USB Audio Device has been selected as the default device or not, you must right-click on master volume icon.

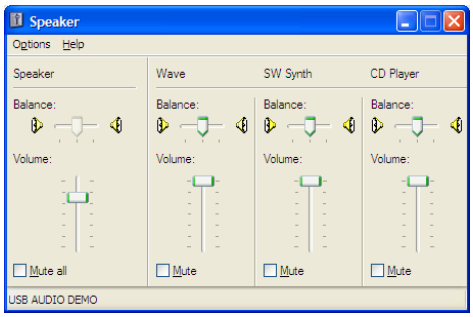

Figure 11. Master volume

6. After installation, the device works as a sound driver and the PC is able to control it. To show that the control functions are received by the device, the software sends command control echoes through the UART.
   a) Open a HyperTerminal with the following properties (baud rate: 11520, parity: none, stop bits: 1, flow control: none).

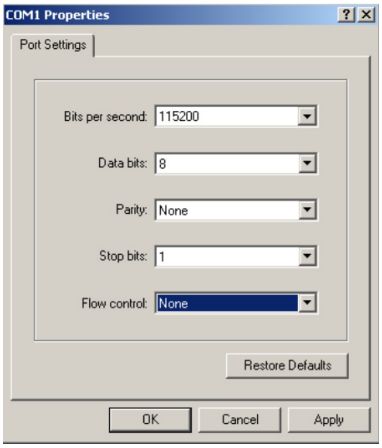

Figure 12. HyperTerminal properties

   b) With the PC, send audio control interface commands such as adjusting the volume (volume, on/off mute). The changed values are displayed on the HyperTerminal screen.

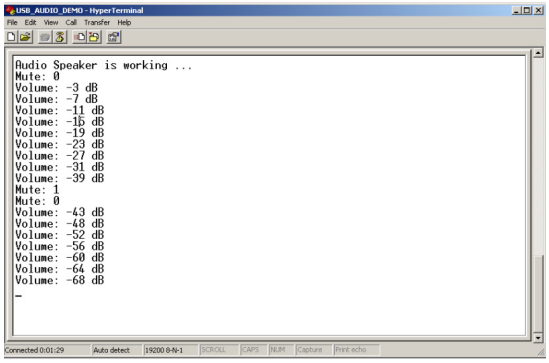

Figure 13. Volume and mute control

   c) Open the Windows Media Player and then select and listen to your favorite audio.

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