AN11115

USB Audio and USB CDC with FFT for LPC11U14

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Document information

Info	Content
Keywords	LPC11U14, LPC11U1X, LPCXpresso, ARM Cortex-M0, USB Audio, USB CDC, FFT, AN11115
Abstract	This document describes a sample project created to demonstrate the LPC11U14F for LPCXpresso. This project demonstrates USB audio and USB CDC with FFT capabilities on NXP ARM Cortex-M0 LPC11U family devices. The development platform used was LPCXpresso.

Revision history

Rev	Date	Description
1	20111001	Initial version.

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1. Introduction

The LPC11U14 is an ARM Cortex-M0 based, low-cost 32-bit MCU, designed for 8/16-bit microcontroller applications, offering performance, low power, simple instruction set and memory addressing together with reduced code size compared to existing 8/16-bit architectures.

The peripheral complement of the LPC11U14 includes 32 kB of flash memory, 6 kB of SRAM data memory, one Fast-mode Plus I^2C-bus interface, one RS-485/EIA-485 USART with support for synchronous mode and smart card interface, two SSP interfaces, four general purpose counter/timers, a 10-bit ADC, and up to 40 general purpose I/O pins.

This application note describes demonstration software that uses the hardware resources on the MCU such as the ARM core, IRQ handler, USB illustrating how it can handle complex processing like Fast Fourier Transforms (FFT) and events like Timer IRQ, and USB traffic, very efficiently.

This application note describes the following:

- System setup required to demonstrate the software
- Block diagram/overview of the setup
- Functional description of the system
- FFT algorithm
- System performance
- Applications
- A guide to setup the demonstration
- Conclusion

2. System setup

This demonstration requires an LPC11U14 LPCXpresso board. Fig 1 shows the system setup. Note that LPC11U14 Keil and IAR boards will also support the application.

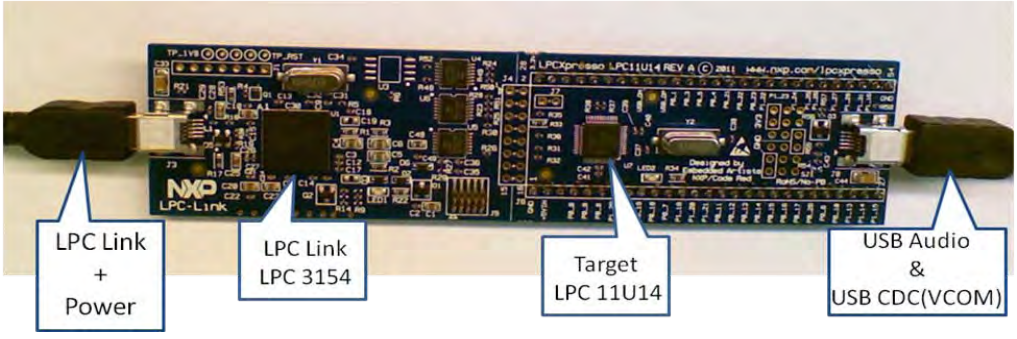

Fig 1. System setup

3. Block diagram

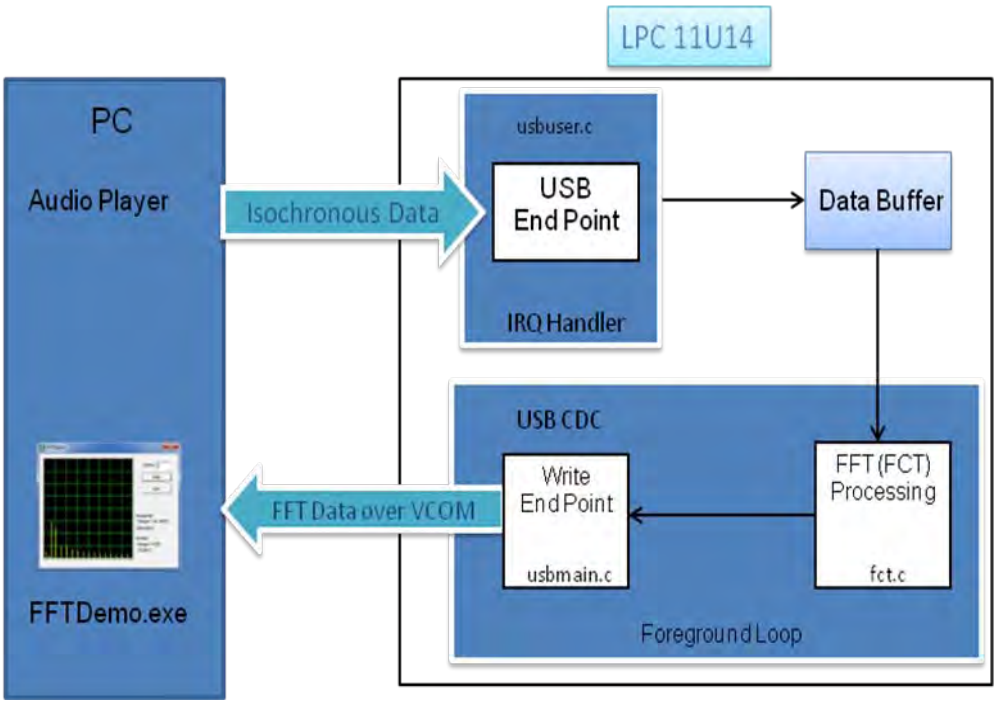

Fig 2. Block diagram

3.1 Functional description

- The target board receives 16-bit audio data from PC through USB Audio Class
- Performs Fast Cosine Transform (FCT) a derivative of Fast Fourier Transform (FFT) that transforms the audio data to its respective frequency components
- Sends the result to PC via USB CDC (VCOM)

3.2 Technical specification

- Audio : 16-bit 32 samples/s
- FFT Algorithm : 16-bit Fast Cosine Transform 64 points
- VCOM: 115.2 kbps

4. Functional description

4.1 Data flow

Fig 3 shows the data flow of the system back to the PC.

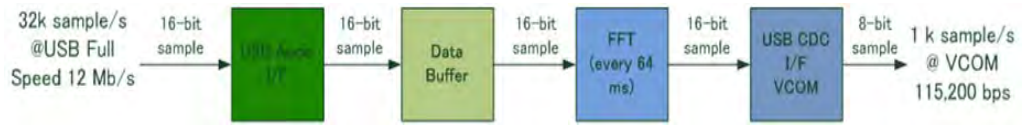

Fig 3. Data flow from USB (Audio) to VCOM (FFT)

The various steps involved in this process are:

- 16-bit Pulse Code Modulated (PCM) audio data is sent via USB Audio Class @32 samples/s
- FFT operation of 64 samples of audio data available in the buffer is performed every 64 ms

4.1.1 The 64 points FFT result (8-bit data) is sent via USB CDC (Bulk)

Fig 4 depicts the time frame in which the LPC11U14 performs FFT on the audio samples from the buffer and the resulting FFT data is sent back to the PC using Bulk data transfer mode.

The USB IRQ handler receives 32 samples of audio data every millisecond from the PC and interrupts each time. FFT is performed on the received audio data after 64ms or 64th USB IRQ (1st, 64th, 128th and so on).

Later, the 8-bit FFT data is sent back to the PC over USB CDC.

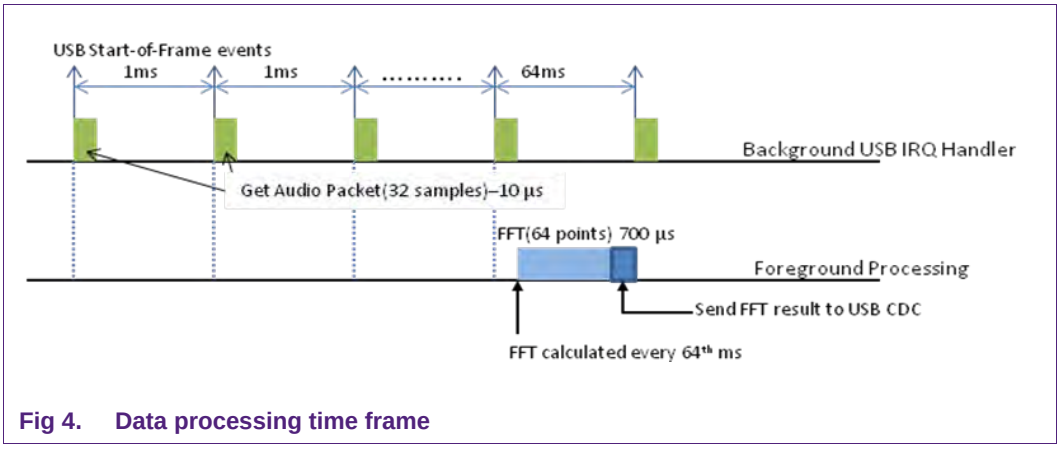

Fig 4. Data processing time frame

Processing time and workload:

- FFT calculation: The LPC11U14 MCU requires 700 µs to compute the FFT of the data from the buffer. Since the FFT is performed on the audio data every 64 ms, the load on the processor is *700 µs/64 ms = 1.09 %*
- USB data transfer: The USB receives audio data from PC @ 32 samples/s. It receives 32 samples every millisecond and requires 10 µs to handle the samples and generate a USB IRQ. Thus the USB Data transfer workload on the processor is *10 ms/s = 1.00 %*

Table 1 depicts that the processing time results in a very small CPU workload. This implies more complex applications are easily viable on the MCU.

Table 1. Processing time and workload

Function	Amount (times)	Processing time (us)	Total time (us)	Load
USB data transfer	64	10	640	1.00 %
FFT	1	700	700	1.09 %

Table 2 depicts the Code Size and memory requirements of the program when compiled without optimization.

Table 2. Code size

Category	Size (bytes)
Code	16,296
Data	532
Workspace	2,064
Total code	18,892

5. Fast Fourier Transform (FFT) algorithm

The LPC11U14 implements a 64 point Fast Cosine Transform (derivation of DCT) to perform the FFT. Fig 5 shows the FFT algorithm and Fig 6 depicts procedure of the algorithm used.

A more detailed explanation of the algorithm can be found in wikipedia: (http://en.wikipedia.org/wiki/Discrete_cosine_transform).

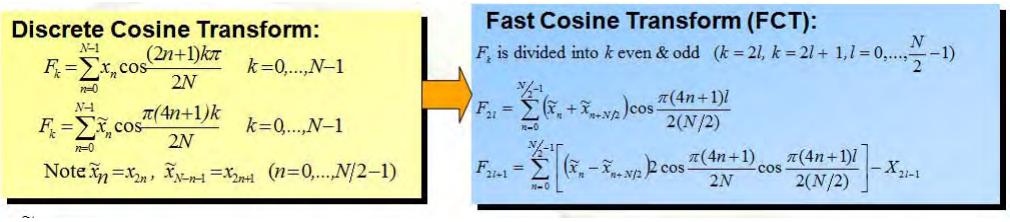

Fig 5. FFT algorithm

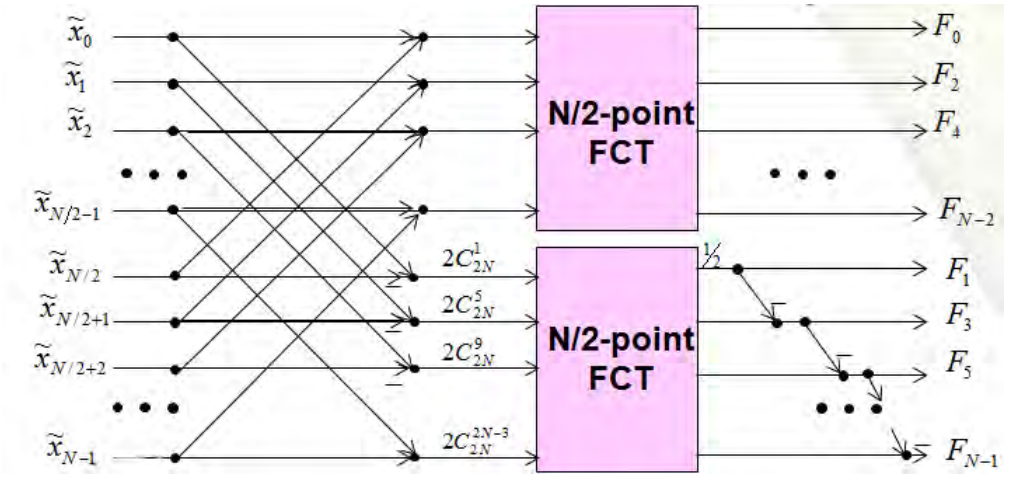

Fig 6. Procedure of the FFT algorithm

6. Applications

The strong computing capability of the LPC11U14 MCU provides the user with wide application choices. This demo software utilizes a few of such applications.

The possible applications of this demo software could be:

- Spectrum analyzer
- Frequency based audio data compression
- High frequency component detection

The LPC11U14 MCU as a USB Audio class and USB CDC could be used for similar applications as mentioned above, such as utilizing the USB CDC as a speaker.

7. Application demonstration

7.1 Requirements

7.1.1 Hardware

LPCXpresso LPC11U14

7.1.2 Software

LPCXpresso IDE Version 4.0 or later.

The download link for the software can be found at:

http://lpcxpresso.code-red-tech.com/LPCXpresso/ (registration is required for download).

A detailed description on how to get started, importing, and compiling projects in the LPCXpresso IDE can be found at:
http://ics.nxp.com/support/documents/microcontrollers/pdf/lpcxpresso.getting.started.pdf

7.2 Compile and flashing

1. Copy project files LPCXpresso11U14F_usbaudiowithFFT_usbdc and CMSISv2p00_LPC11xx to your workspace directory.
(CD://USB Audio FFT/LPC11DemoSoftware-LPCXpresso/)
2. Import the project file using LPCXpresso (as shown in Fig 7)
3. Connect LPCXpresso LPC11U14 Target board J3 and J8 to PC's USB port using two separate USB cables
4. Compile and flash to board
   a. Select the project LPCXpresso11U14_usbaudiowithFFT_usbdc at the Project Explorer Panel
   b. Compile :Project → Build Project
   c. Program flash: Click 
   d. Select file: LPCXpresso1114_usbaudiowithFFT_usbdc\Debug\ LPCXpresso1114_usbaudiowithFFT_usbdc.axf (as shown in Fig 8)
   e. Click OK
   f. Recycle power to J3 (LPC-Link)

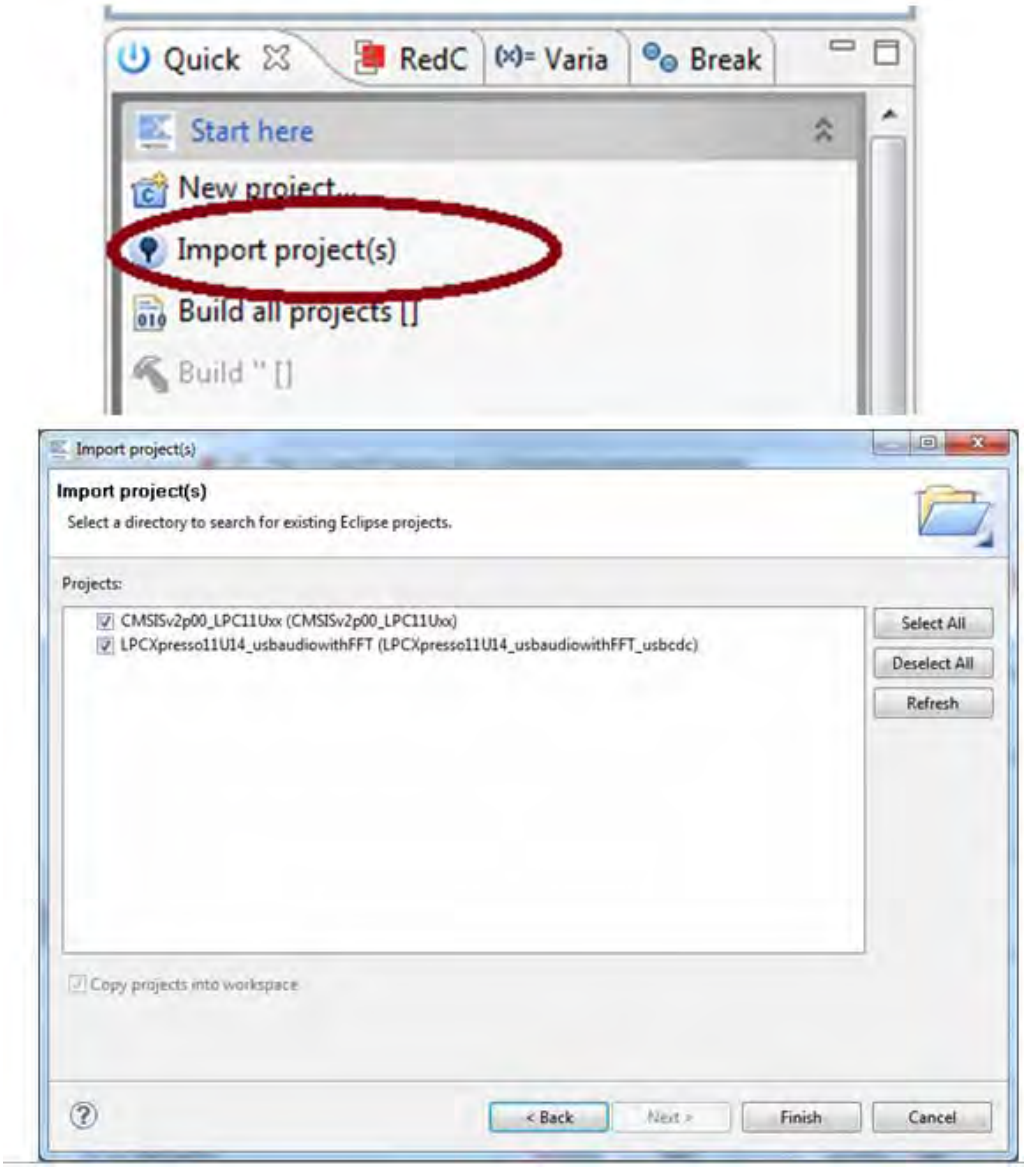

Fig 7. Importing project

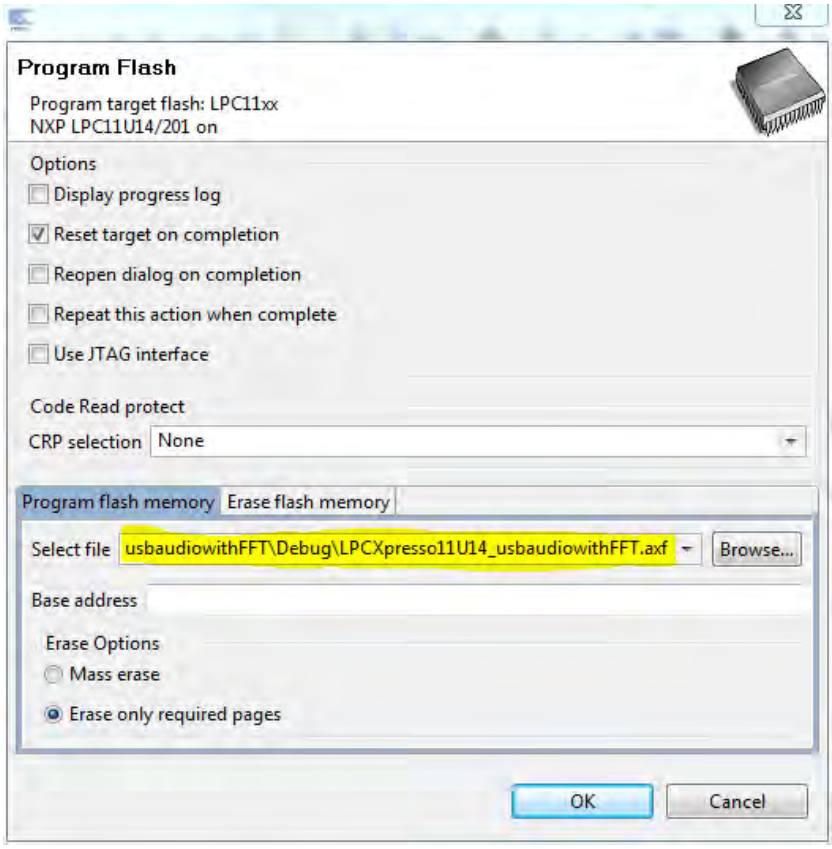

Fig 8. Program flash

7.3 Install USB drivers

1. Make sure the USB cable between PC and LPC11U14F Target Board J8 is connected

Note: Jumpers SJ1 & J7 must be closed for the Target Board to be powered by USB connector J8 alone (as shown in Fig 9). Otherwise, the target must be powered by connecting J3 to the PC.

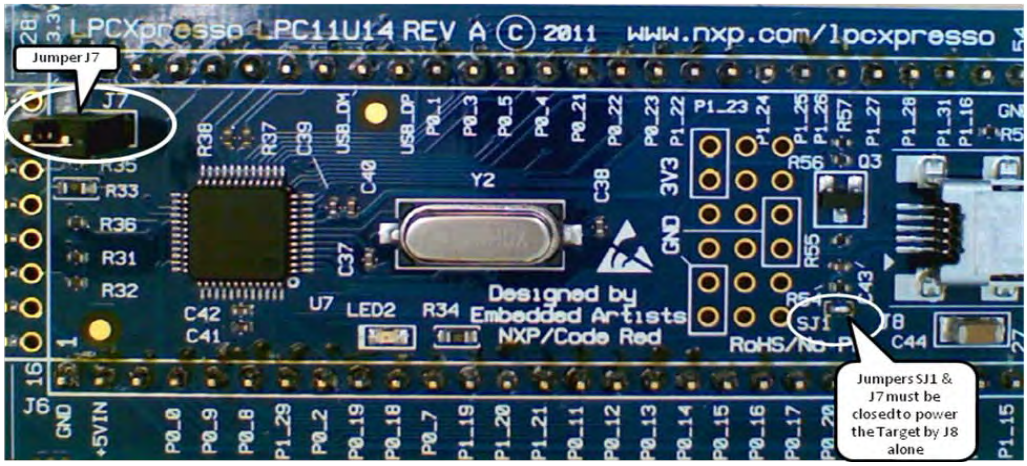

Fig 9. SJ1 Jumper settings

2. A pop-up notifies that two USB devices were recognized:
   a. NXP LPC VCOM device
      - Select Install from a list or specific location (Advanced)
      - Browse to directory which contains file LPC11xx_vcom.win32

(CD://USB Audio FFT/LPC11DemoSoftware-LPCXpresso/WinXP_Win7-32bit_usb_driver)

      - Click Next
   b. NXP Speaker will be automatically detected as USB audio class
3. Check the VCOM number
   a. Open Control Panel → System → Hardware → Device Manager
   b. Check Port: e.g., NXP LPC Vcom Device (COM3) → COM3 (as shown in Fig 10).

Fig 10. Selecting COM port

7.4 FFT Demo

Run the USB Audio FFT Demo.

1. Open the FFTDemo.exe by clicking on the FFTDemo icon (The GUI program has been included in the Application Note zip file)
2. Run the demo by setting the COM # of VCOM and click Start to open the serial communication

Note:

1. Click Stop to stop the communication
2. Click Exit to exit the FFT demo

Fig 11 shows the FFTDemo.exe screenshot

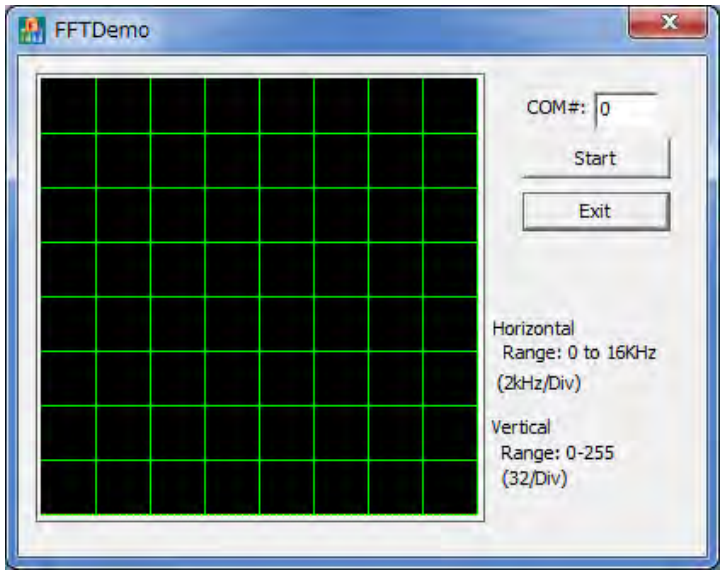

Fig 11. FFTDemo.exe

7.5 Play audio on a player

1. Run the audio player and play some music or a sound file
2. Observe the spectrum shown in the FFT Demo's display when the audio is played on the music player, as shown in Fig 12.
3. Example of sound (dir: DemoSound/)

   - sweeplin.wav: run the sound from low to high frequency

   - sin500.wav: run sine wave 500 Hz

   - sin300_2000.wav: run sine wave 300&2000 Hz and observe the frequency spectrum on the GUI.
4. Audacity (http://audacity.sourceforge.net/) also lets the user generate various types of tones. This video http://youtu.be/8GgGyOqgbyE shows how to generate various audio tones using Audacity.

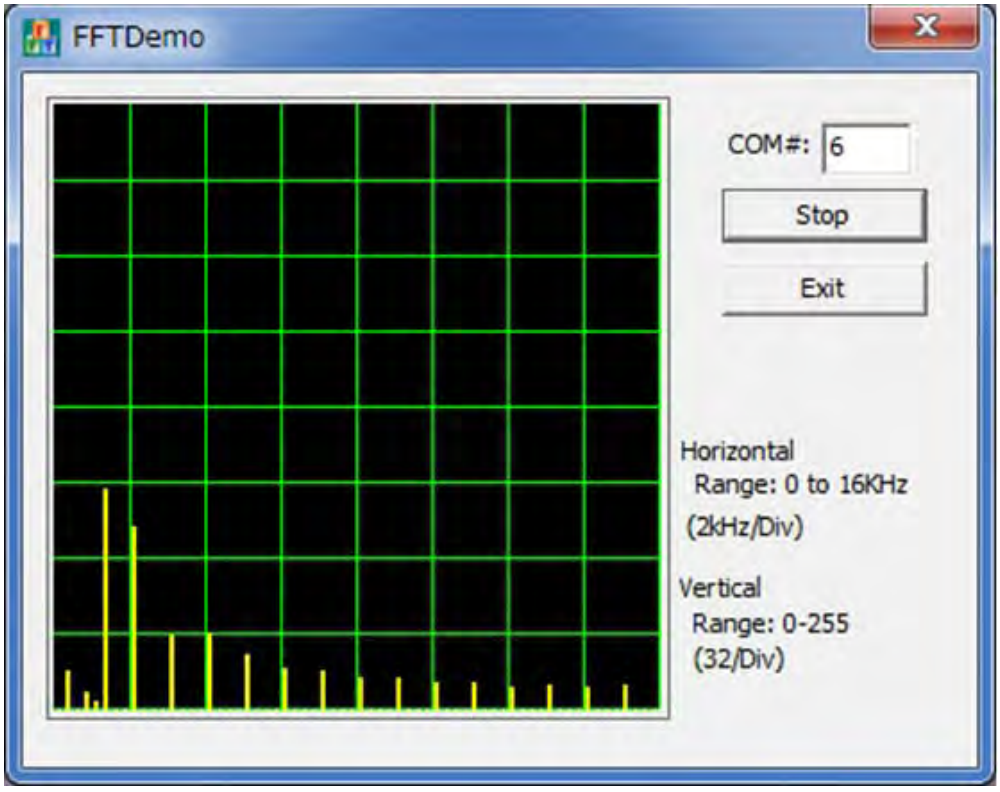

Fig 12. Observed Spectrum of the Audio as seen on FFTDemo.exe

8. Conclusion

This application note described demonstration software that was developed to highlight the capabilities of the NXP LPC11U14 MCU. The USB audio and USB CDC sample software with FFT demonstrates the processing capability of the ARM Cortex-M0 powered NXP LPC11U14 MCU.

The successful demonstration of the sample software shows that the LPC11U14 MCU can handle quite complex processing like FFT requiring very little memory with only a very small burden on the CPU.

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