Using PDM Microphone to Record Sound

Example Code Introduction for 32-bit NuMicro® Family

Information

Application	This USB Audio Class example code records sound from PDM microphone connected on SPI or I²S when a microcontroller (MCU) has no dedicated interface for it. The example code includes a software converter to convert PDM to common PCM format.
BSP Version	M480 series BSP CMSIS v3.05.001
Hardware	NuMaker-PFM-M487 v3.0

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1 Overview

A PDM microphone has two wires, data wire and clock wire. When a microcontroller (MCU) does not have a dedicated interface for PDM microphone, SPI or I^{2}S can be used to capture the 1-bit data stream, called PDM format.

The example code uses SPI or I^{2}S on NuMicro M487 to capture PDM microphone data, and converts the PDM data to common PCM format through decimation, high and low band pass filters. Also, the example code can be used as a USB Audio Class device that can record the PCM data via USB.

The filter code is released by STMicroelectronics with Apache License on Mbed OS site[*1] for the MP45D or MP34D series MEMS microphone. The sample code has been tested with Adafruit 4346 module[*2] which has a MP34D MEMS microphone.

1.1 Demo Result

To see console message, please make sure the ISW1 switch are set as in Figure 1-1, then connect USB port on Nu-Link to PC.

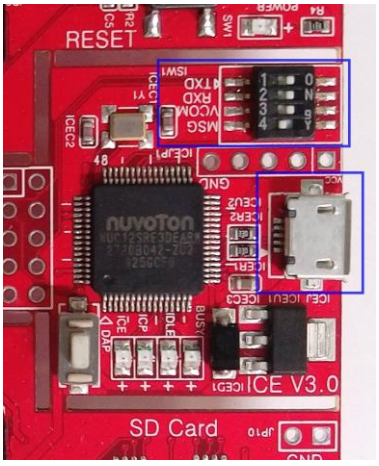

Figure 1-1 Nu-Link switches and USB port

Run a COM tool on PC. When NuMaker-PFM-M487 is powered up, the console will output following messages.

*1 https://os.mbed.com/teams/ST/code/X_NUCLEO_CCA02M1/file/53f8b511f2a1/Middlewares/OpenPDM2PCM/

*2 https://www.adafruit.com/product/4346

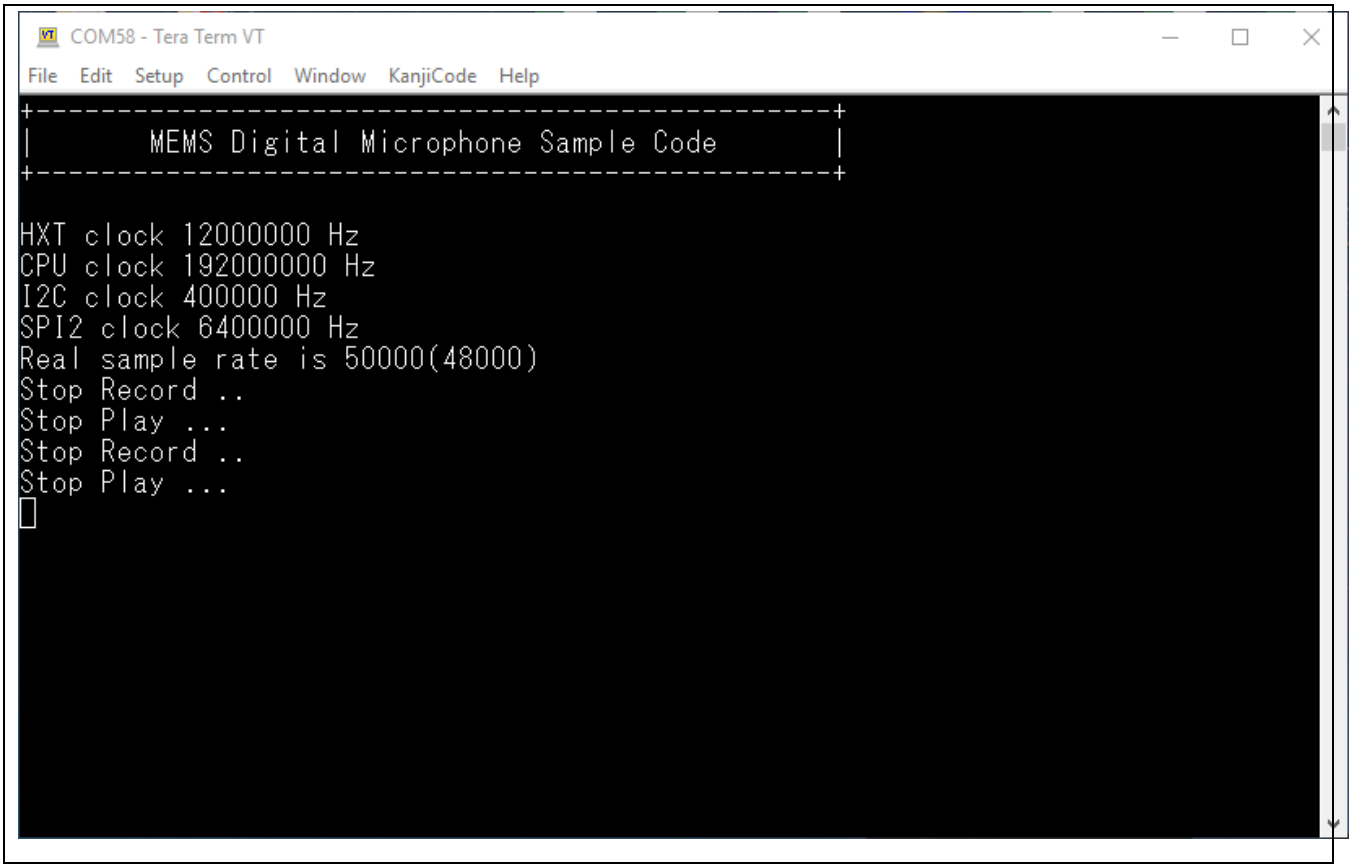

Figure 1-2 Console Output When Powered Up

Connect USB 2.0 port on NuMaker-PFM-M487 board to PC, which will recognize M487 as a USB audio device.

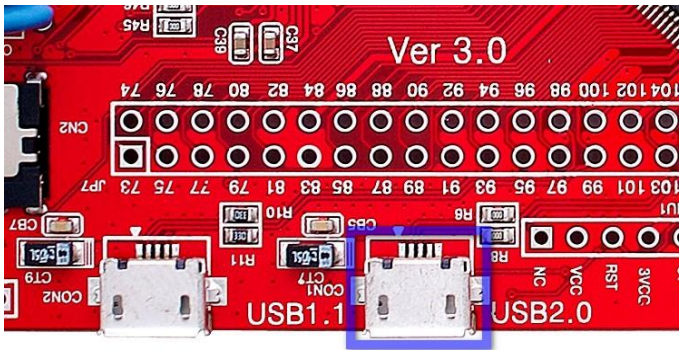

Figure 1-3 NuMaker-PFM-M487 USB 2.0 Port

Execute a recorder tool, such as Audacity, on PC and then start to record it.

2 Code Description

2.1 Initialization

Initialize the M487 in main.c, and initialize UART, I²C, I²S, SPI, NAU88L25, Timer, and HSUSBD. Then, a forever loop checks and sets USB Audio Class (UAC) status and process recorded data.

```
int main(void)
{
    uint32_t volatile i;

    /* Init System, peripheral clock and multi-function I/O */
    SYS_Init();
    /* Init UART for printf */
    UART_Init();

    printf("+-----------------------------------------------------+\n");
    printf("|       MEMS Digital Microphone Sample Code           |\n");
    printf("+-----------------------------------------------------+\n\n");
    printf("HXT clock %d Hz\n", CLK_GetHXTFreq());
    printf("CPU clock %d Hz\n", CLK_GetCPUFreq());

    /* Init I2C2 to access NAU88L25 */
    I2C2_Init();

#if ENABLE_PDM

  #if PDM_ON_SPI
    SPI2_Init();
  #else
    I2S0_Init();
  #endif
    PDM_MIC_Init();

#else
    I2S0_Init();
#endif

    /* Configure PDMA */
    PDMA_Init();

    HSUSBD_Open(&gsHSInfo, UAC_ClassRequest, UAC_SetInterface);

    /* Endpoint configuration */
    UAC_Init();
    NVIC_EnableIRQ(USBD20_IRQn);
    HSUSBD_Start();

    while(1)
    {
        if (g_usbd_rxflag)
        {
            UAC_GetPlayData();
        }
        else if(u8AudioPlaying && (u8TxDataCntInBuffer < 1))
        {
            UAC_DeviceDisable(1);
        }
```

```
        if ((g_usbd_UsbAudioState == UAC_START_AUDIO_RECORD) && g_usbd_txflag)
        {
            UAC_SendRecData();
        }

        if ((u8TxDataCntInBuffer != 0) && ((++i % 0x50000) == 0))
        {
            printf("%d <-> %d\n", u8TxDataCntInBuffer, u8RxDataCntInBuffer);
        }
#if ENABLE_PDM
        if ((g_usbd_UsbAudioState == UAC_START_AUDIO_RECORD) && (gu8SpiRxCnt > 0))
        {
            process_pdm_data();
        }
#endif
    }
}
```

2.2 Compile Definitions

The example code derived from M480BSP HSUSBD_Audio10_Codec example supports to use NAU88L25 audio codec to play and record sound. Compile options are defined in *pdm_converter.h*

- *ENABLE_PDM*
  - 0 : The record source is NAU88L25
  - 1 : The record source is PDM microphone (Default)

- *PDM_ON_SPI*
  - 0 : PDM microphone connects to I2S0 interface
  - 1 : PDM microphone connects to SPI2 interface (PA10 / PA9) (Default)

- *PDM_ON_I2S_ALT*
  - 0 : PDM microphone connects to I2S0 PF10 / PF8. Conflict with NAU88L25.
  - 1 : PDM microphone connects to I2S0 PE1 / PH8 (Default)

The PDM microphone sample rate is controlled by output of SPI or I^{2}S clock. Since the filter and USB Audio Class code support limited sample rates, only 8K, 16K, 32K, and 48K sample rate are supported. To configure the microphone sample rate, set the *DEFAULT_FREQUENCY* in *pdm_converter.h* file to 8000, 16000, 32000, and 48000(default), respectively. SPI or I^{2}S will out proper clock to the PDM microphone according to the sample rate.

The USB Audio Class device reports the default 48K sample rate to PC. The example code includes a resample feature to adjust recorded audio to 48K sample rate and then feed to a USB buffer. It automatically sets proper resample parameters for different sample rates.

3 Software and Hardware Requirements

3.1 Software Requirements

- BSP version
  - M480 Series BSP CMSIS v3.05.001
- IDE version
  - Keil uVision 5.28

3.2 Hardware Requirements

- Circuit components
  - NuMaker-PFM-M487 v3.0
  - Adafruit 4346 module (with a STM MP34D MEMS microphone)

The L/R setting of the PDM microphone controls the output of data when the clock is low or high. SPI / I^2S is sampling at the raising edge of the clock. It is necessary to make sure that the L/R is set to low for SPI / I^2S interfaces. The default L/R setting on the Adafruit 4346 module is high. Please cut it according to the red line in Figure 3-1.

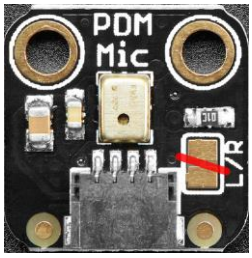

Figure 3-1 Cut the red line on Adafruit 4346 module

- Pin Connect

VDD	↔	VDD (3.3V)
GND	↔	GND
SPI2_MISO (PA.9 / Pin 15)	↔	DAT
SPI2_CLK (PA.10 / Pin 14)	↔	CLK
NuMaker-PFM-M487		Adafruit 4346 module

Figure 3-2 SPI pins connect to PDM microphone

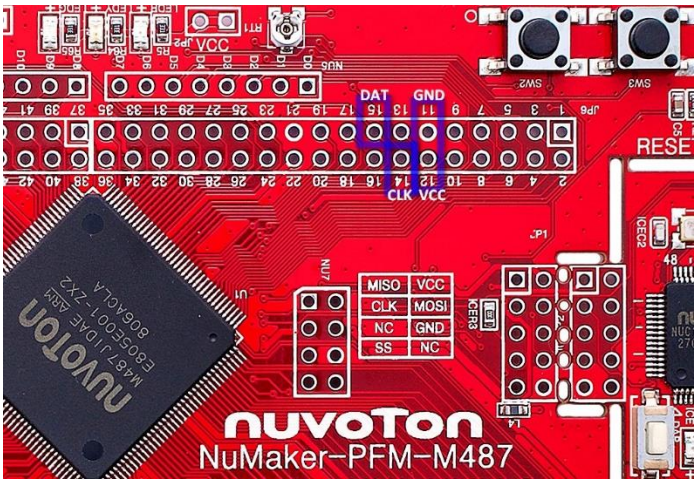

Figure 3-3 SPI pins on board

VDD	↔	VDD (3.3V)
GND	↔	GND
I2S0_DI (PH.8 / Pin 119)	↔	DAT
I2S0_BCLK (PE.1 / Pin 117)	↔	CLK
NuMaker-PFM-M487		Adafruit 4346 module

Figure 3-4 I^{2}S pins connect to PDM microphone

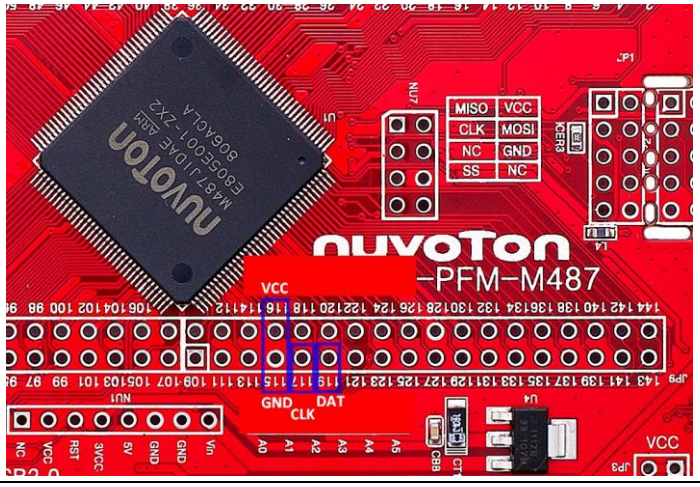

Figure 3-5 I²S pins on board

4 Directory Information

The directory structure is shown below.

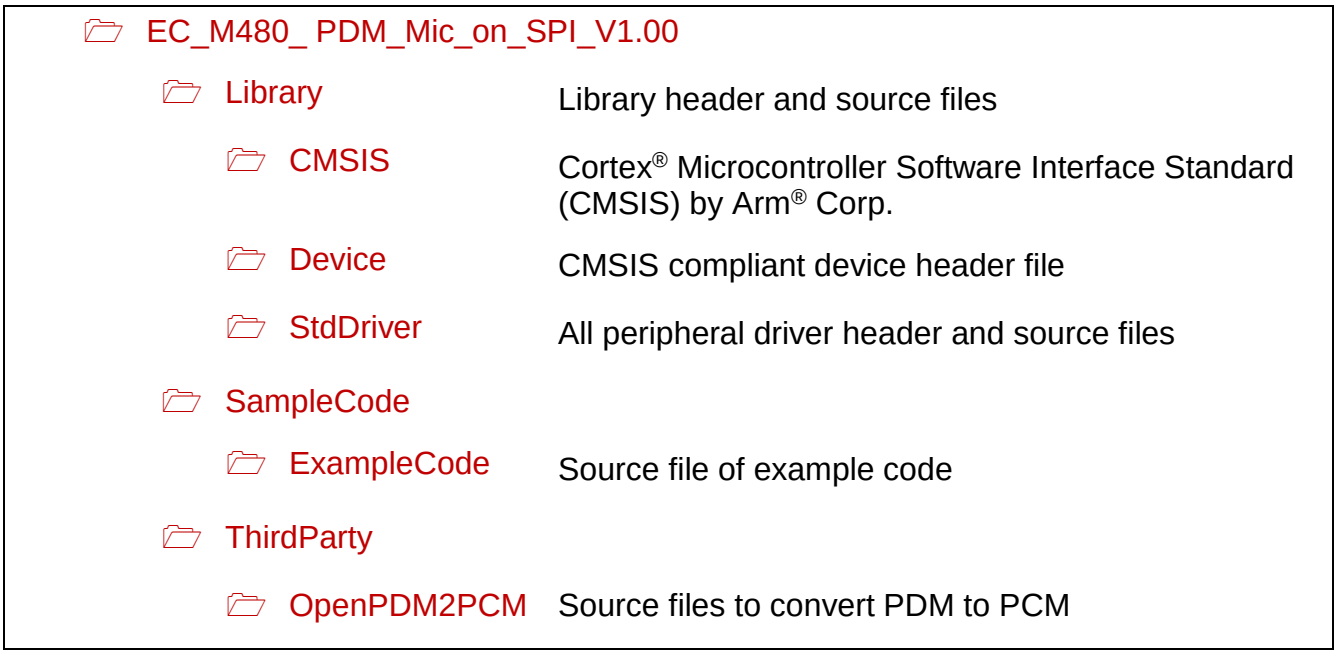

Figure 4-1 Directory Structure

5 Example Code Execution

1. Connect to USB port of Nu-Link on NuMaker-PFM-M487 board.
2. Browse the sample code folder as described in the Directory Information section and double-click *PDM_Mic_on_SPI.uvproj* in *SampleCode\ExampleCode\M480_PDM_Mic_on_SPI\KEIL* directory.
3. In Keil uVision IDE
   - Click Build button to build the sample code;
   - Click Download button to download firmware to NuMaker-PFM-M487 board.
4. [Optional] If you want to see output message on console, run a terminal tool on PC, and open the COM port assigned for NuMaker-PFM-M487 board, where the baud rate is 115200.
5. Connect to USB 2.0 port on NuMaker-PFM-M487 board.
6. Press RESET button on NuMaker-PFM-M487 board to start firmware execution. The PC will have a USB audio device.
7. Run an audio tool on PC, e.g. Audacity, which is a freeware sound editor.
   - Specify the record device to USB Audio;
   - Click Record to start record;
   - Click Stop to stop record;
   - Click Play to play recorded sound.

6 Revision History

Date	Revision	Description
2021.12.30	1.00	1. Initially issued.

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