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Implementation of Audio Player Using ARM Cortex-M4

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Abstract: ARM is0one of the leading advanced digital technology in the industry. It enables the creation of new markets and transformation of the industries and society. At present processors are intelligent enough to deliver the applications in terms of enhanced capabilities with the advancement in embedded technology. Today, most of the electronic gadgets are equipped with audio hardware where the processing of audio signals is difficult in recording and storing. The present audio players have a drawback in the absence of the intelligent surface and incapability of replacing the storage devices. Consumers are searching for moderate interactive media gadgets with high performance and durability. The ARM Cortex-M4 meets the needs of smart embedded applications with integrated floating point unit that includes digital signal processing features. In this paper, ARM Cortex-M4 is used to play the wave format audio files from a USB flash drive and records the audio using MEMS microphone and PDM audio software decoding library.

Keywords: ARM Cortex-M4, MEMS, Pulse Density Modulation, Floating Point Unit, STM32F4.

I. INTRODUCTION

Portable audio players are becoming immensely popular in the recent years. The success of these audio players can be attributed to various factors ranging from the availability of massive amount of compressed music content, ease of use, memory storage, and declining cost. The expectation of next generation audio players is even more demanding with listeners wishing for longer audio playback time coupled with enriching listening experience. The silicon technology has improved over a past decade with the growing availability of the audio players.
Microcontrollers are available with highly powerful processors, acceleration engine, and specialized peripherals. But the design has become more complex with embedded applications. This paper discussed about the investigation of the MEMS microphone [1] of the digital MP45DT02.

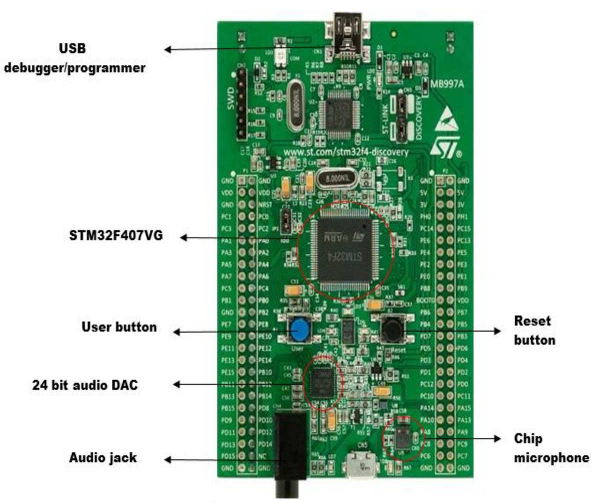

Fig.1. STM32F4 discovery board

The characteristics have been compared with the analog microphones where it does not include embedded systems in their real-time applications. The STM32F4 discovery board is a high-performance microcontroller. It operates at a frequency of 168MHz that executes 210 Dhrystone Million Instructions per Second (DMIPS) based on ARM Coretx-M4 core, it provides advanced floating point unit with the DSP capabilities.

The ARM Cortex-M4 microcontroller with the real time CMSIS-DSP library algorithms, but this CMSIS-DSP functions [2] discuss about the lab in a box kit for future developments with filters in routine. The real-time digital signal processing of the ARM cortex-M4 evaluation modules as teaching materials for the concepts that include various description on the board about various designers with slightly different change in library functions but they couldn't use any application on the EVMs available from the different manufacturer [3]. This board has been implemented with an audio player where the audio data (wave) will be stored in the USB flash drive. The audio data will be read using DMA peripheral through external USB drive of the STM32F407VG microcontroller and the data can also be recorded in the same format on the USB flash drive (wave). The output of such files with the high basic quality audio format is uncompressed files where the quality is nowhere to be conceded.

The paper discuss about the implementation of MEMS technology, which resonates the musical instruments with their audible frequency for certain range of mentioned frequency. But in the real-time applications, the tuning range has not been increased according to the particular

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high frequencies [4] This board has been implemented with an audio player where the audio data (wave) will be stored in the USB flash drive. The audio data will be read using DMA peripheral through external USB drive of the STM32F407VG microcontroller and the data can also be recorded in the same format on the USB flash drive (wave).

The output of such files with the high basic quality audio format are uncompressed files where the quality is nowhere to be conceded. The ST MP45DT02 MEMS microphone is used to record audio on the discovery board, using a Pulse Density Modulation (PDM) decoding library software. The output analog data coming from MEMS microphone generates the PDM data which is then converted to PCM data and then saved in the USB flash drive. Such the developed device is user-friendly to record audio and play music which comes in handy.

II. BLOCK DIAGRAM

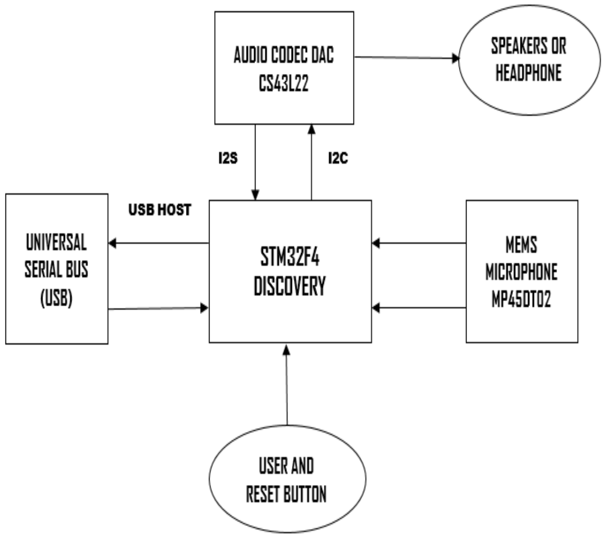

Fig. 2 .Block diagram

The USB peripheral configured in the host mode. Mass Storage Class (MSC) is implemented to transmit and receive the audio data through a USB key. The I2S (Inter-Integrated Sound) peripheral acts in Master Transmitter mode for transmitting the audio data to the external audio codec (DAC) which gives the analog output data through the DAC and it is also used as a receiver for the MEMS microphone (MP45DT02).

The I2C peripheral is used to control several external devices like the audio codec and to obtain data from this device. Whereas the audio DAC has one port for the digital audio signal which is interfaced with I2C and the control port was interfaced with I2S peripherals. User button and reset button are used to monitor the applications. And the MEMS microphone is in digital form when using PDM audio software decoding library or analog when using a low pass filter.

III. ARM (ADVANCE RISC MACHINES) CORTEX-M4

The Cortex-M4 is RISC (Reduced Instruction Set Computing) architecture with a 32-bit microcontroller accurately produced for an efficient signal processing applications. It has enhanced SMID (single instruction, multiple data) which highlights the extended Multiply-Accumulate (MAC) instructions with the Floating Point Unit (FPU). The Cortex M4 is nothing but M3 with special supports Digital Signal Processing (DSP) instructions. These Cortex-M processors which are expected to conclude the flexible solutions based on embedded applications, power optimization, engine control and modern robotics by blending the signal transformed through low power consumption with minimal expenses.

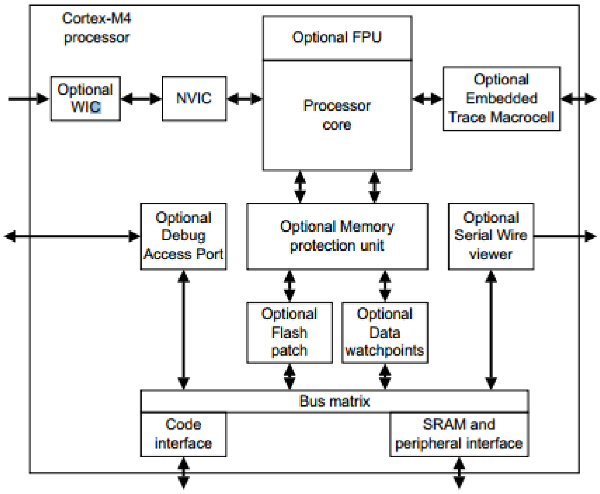

Fig.3. ARM Cortex-M4 Implementation

The Cortex-M4 features have been optimized as follows: ARM architecture V7, 3 steps pipelining and 16-bit Thumb instruction set with the compressed mode which supports the DSP instruction set.

The ARM processor which is formed by designing an instruction set of reduced utility of the sleep mode transition along the design specification of the board with the optional support of the memory protection unit. The data to be transferred using the bus matrix of the data that is being sent through the memory of the code interface and the SRAM peripheral interface changes the data from one bus to another with the each of the optional debug port of the device with NVIC instruction.

The STMicroelectronics has designed an STM32F4 Discovery board with a fast, advanced peripheral based Cortex M4. It has 32 bits of CPU along with the Floating Point Unit (FPU) and Adaptive Real-Time (ART) accelerator. The flash memory is based on 0-wait state execution with a frequency of 168 MHz for the memory protection unit with 210 Dhrystone Memory Instructions per Second (DMIPS) and it also has a memory of 1MB

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flash with 192+4 Kbytes of SRAM which incorporates the wide range of the increased peripherals with Input and outputs which are joined by the buses. This processor also allows the complex algorithm execution and efficient signal processing with a set of DSP instructions and speeds up the software using language tools. It is also used to manage the memory protection unit (MPU) by accessing the CPU to the memory by using one task at a time and corrupting accidently the organized resources with any of the active tasks with the specialized memory.

Inter-Integrated Sound peripheral is configured as transmitter mode, which is used to transfer the audio data through the external audio codec (DAC). The I2C peripheral is used for controlling several devices such as audio codec to obtain the data from the device and the user and reset button used to monitor the applications for playback and recording mode of operation.

IV. AUDIO PLAYBACK/RECORDER APPLICATION

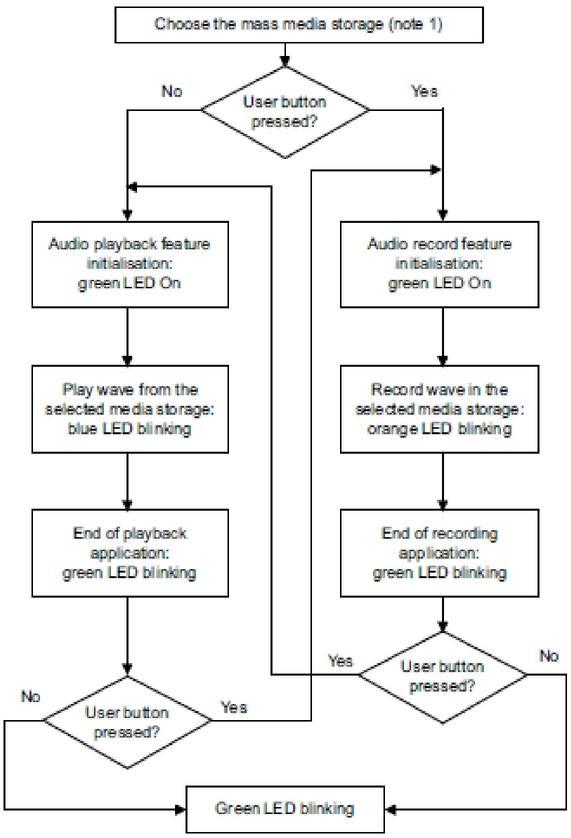

Fig.4. Audio playback and Recorder application flowchart

The time depends on the application when it is selected in the mass storage when the user button is pressed as yes, then the orange LED starts blinking as it is in the audio recording mode and it store the wave file in the USB drive. If the user button is not pressed it goes back to the playback mode automatically and the blue LED starts blinking.

V. AUDIO PLAYBACK APPLICATION

The USB key is said to be in wave format to configure the sample rate by using I2S peripheral. When the LED starts blinking it means the playback begins and the LED starts toggling as blue it mean the playback mode of the application. It is influenced by twice the buffering where the 1st buffer is used to retrieve the source of the data through the USB key which is stored as a wave format file by the use of the FATFs file system.

Then the DMA transfers the external codec DAC contents by using I2S peripheral and the data is stored on the USB drive as the second buffer. Once the buffer fills completely, it changes from one buffer to another by storing the data bytes in the buffer at the end of this process. If the USB drive is removed from the STM32F4 controller then the blue LED stops toggling and red LED goes on as audio DAC goes off. If the USB is connected back it shows vice versa by running the application.

The audio format that can be specified with the PCM sampling pulse through which one byte of data is transferred as a single bit from the unique address. The transmission for changing 1 bit PDM data to 16-bit PCM data for the purpose of simple buffering of the data samples.

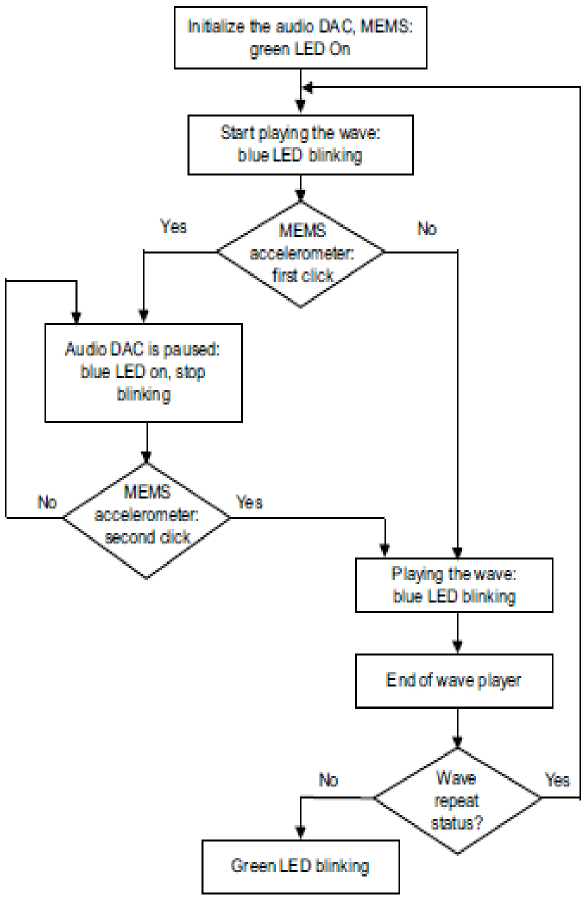

Fig.5. Audio playback application

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VI. AUDIO RECORDING APPLICATION

The I2S interface is configured in audio recording mode using I2S interface at 1024 KHz frequency as input clock pulses from the Micro Electro Mechanical Systems (MEMS). By initializing the microphone output data that is recorded as a buffer signal by filtering. The saved data is obtained as a PCM pulse signal at 16 KHz sampling rate and storing the output data from the microphone into the USB drive by using the PDM audio software decoding library.

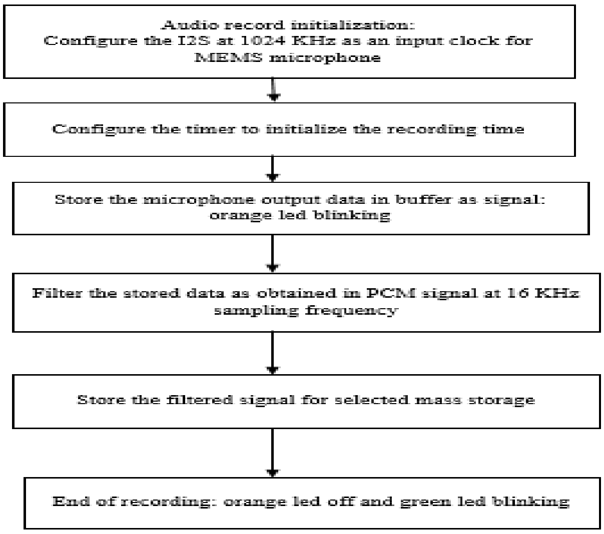

Fig.6. Audio Recording application flowchart

The design of the I2S protocol generates data which is coming from the MEMS microphone is sent to the decimation process. Which converts the data into two parts using two decimation IIR filters, where the data can be changed from 1-bit PDM to PCM? Then the reconfigured audio is said to be in a 16-bit Pulse Code Modulation format. Once the data is converted it produces the analog output which is depending on the application implementation. And it stores as a wave file in the compressed form. Then the USB is transferred to the external audio codec DAC by using I2S peripheral.

The PDM audio software decoding library is used for filtering process where it implements several filters with a signal output data that is analog output coming from the decimation filter. Which will change the analog data to digital data by IIR filter. The process in the filtration changes the analog data to digital using wrapping method by 128 samples per second and again changes the data from the second decimation process at 1024 samples per second using pre wrapping method. The writing through the USB key and the filtering process are both managed by double buffering. When the PDM Library is filtering microphone data, the filtered data is stored on the USB key. Hence the PDM signal from the microphone is filtered and decimated in order to obtain a sound signal at the required frequency and resolution.

VII. RESULTS

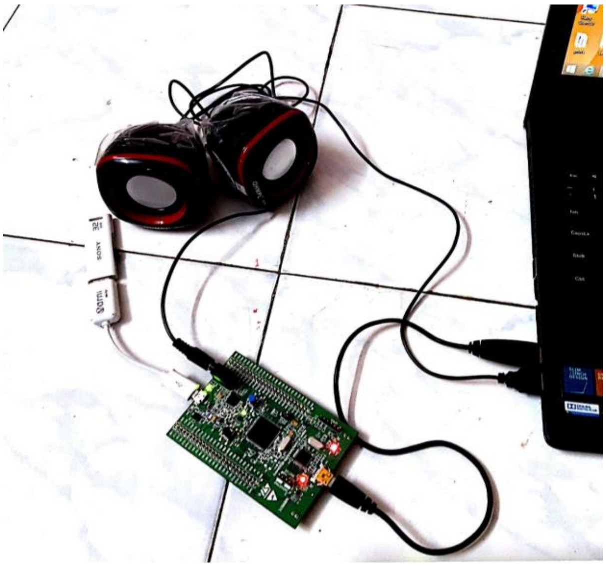
Fig.7. Initial state (Green led blinking)

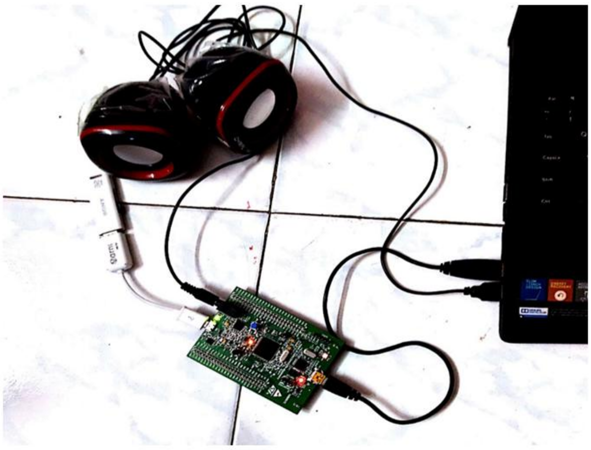
Fig .8. Recording mode (Orange led blinking)


Fig. 9. Playback mode (Blue led blinking)

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VIII. CONCLUSION

An audio player and recorder are implemented on ARM Cortex-M4 for playing the wave audio file stored in a USB Flash Drive and recording audio in the same format on USB flash drive. For playing the audio file from USB drive, data is transferred from the USB drive to the internal SRAM of the microcontroller in the first DMA buffer. Once this buffer is filled, then the DMA sends the data to I2S peripheral which transfers this to external audio codec DAC. The audio data is decoded from the USB and stored in the second buffer.

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