UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Portable In-line Audio Equalizer (PIAE)

Team 8

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Motivation

- User preferences for audio
- Notch hearing loss
- Existing devices too large, too heavy, or not versatile

PIAE is the solution

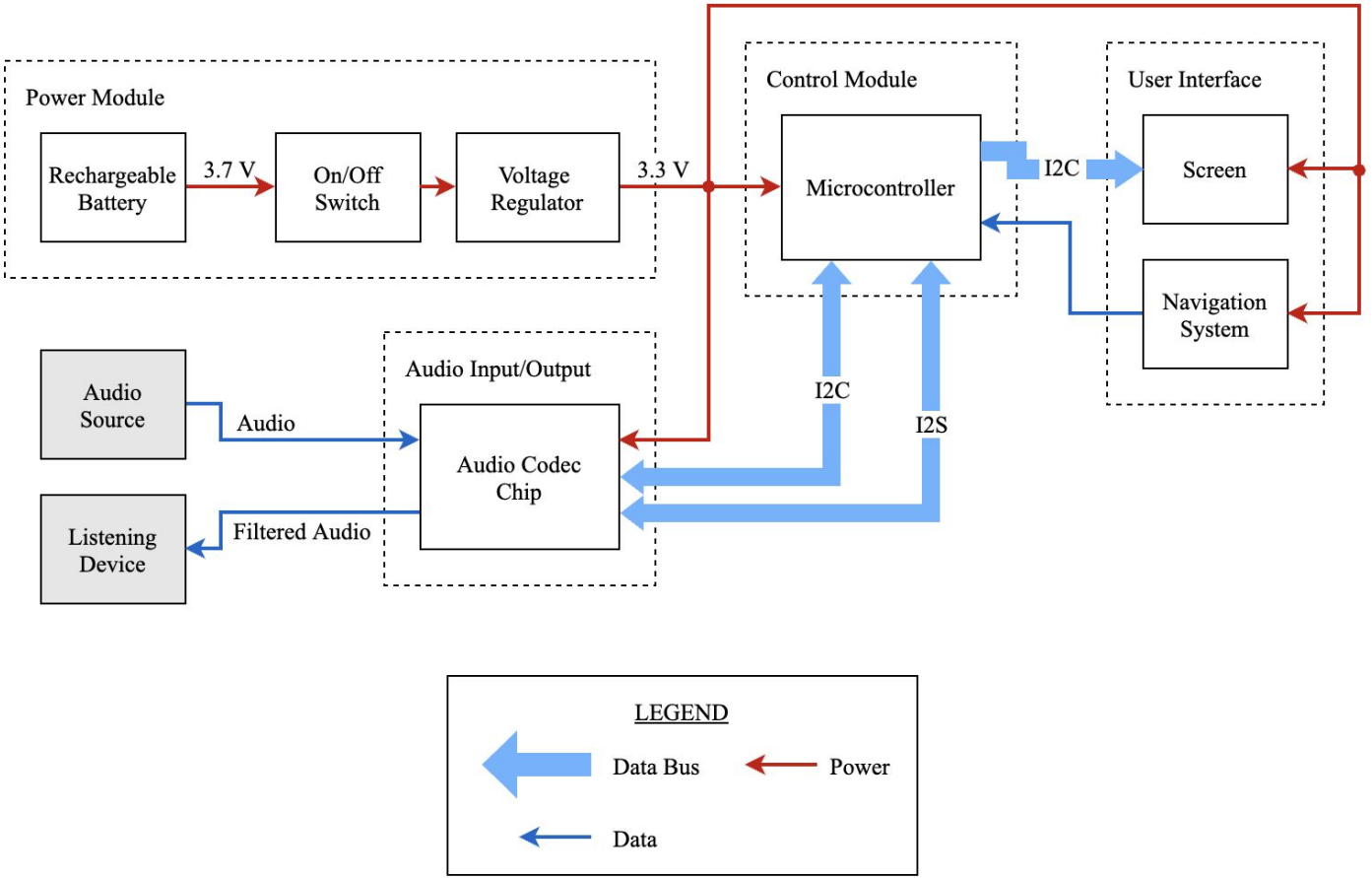
Objectives

- PIAE must have a latency of less than **100 milliseconds**

- PIAE should use **eight frequency bands**
  - [100, 250, 500, 1000, 2000, 4000, 8000, 16000] Hz

- PIAE must have a size of less than **16 x 12 x 6 cm** for the device to be sufficiently portable

Block Diagram



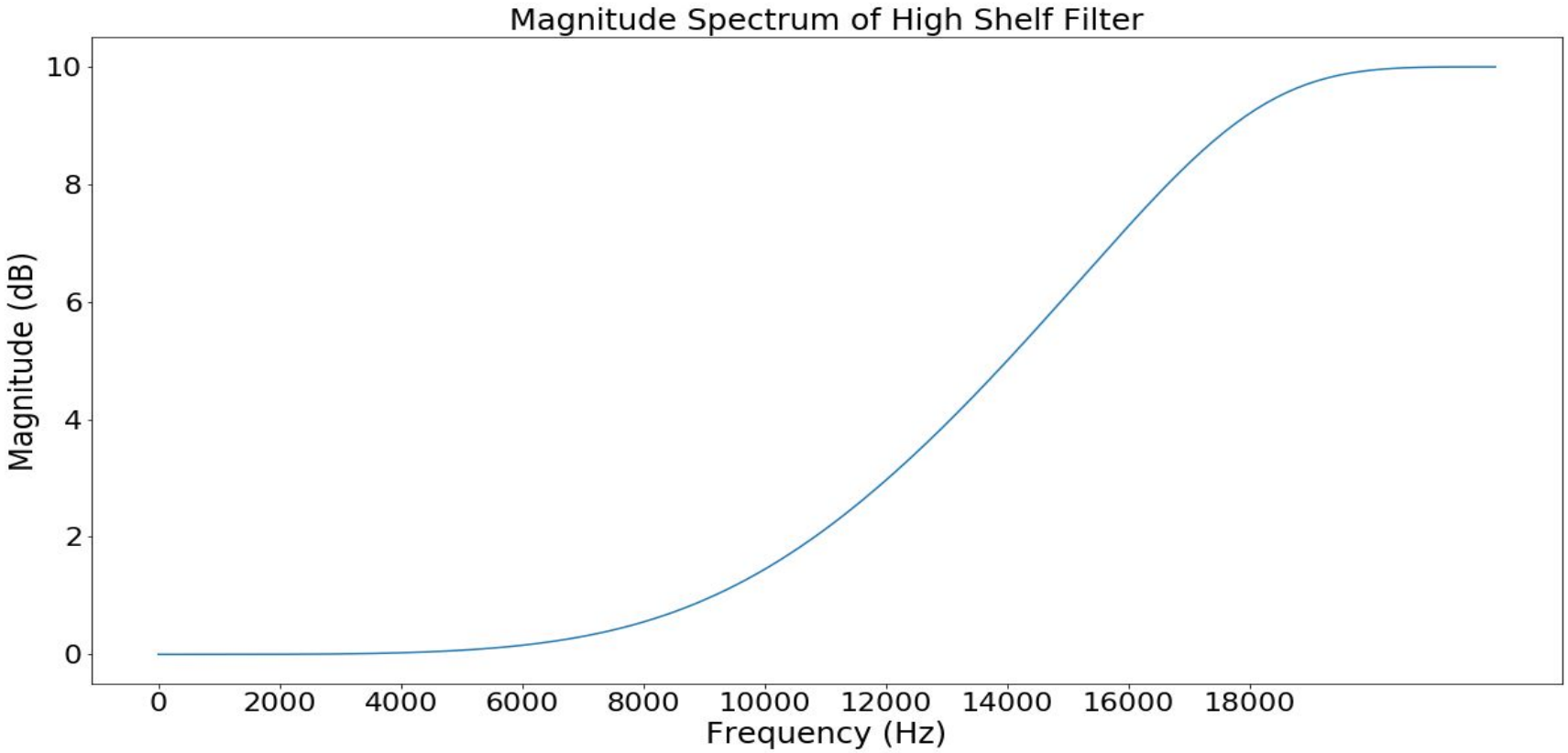
Control Subsystem

- Consists solely of microcontroller unit (MCU) and its filtering capabilities
- MCU used for demo: STM32H743ZI
- MCU intended for product: STM32H743VIT6

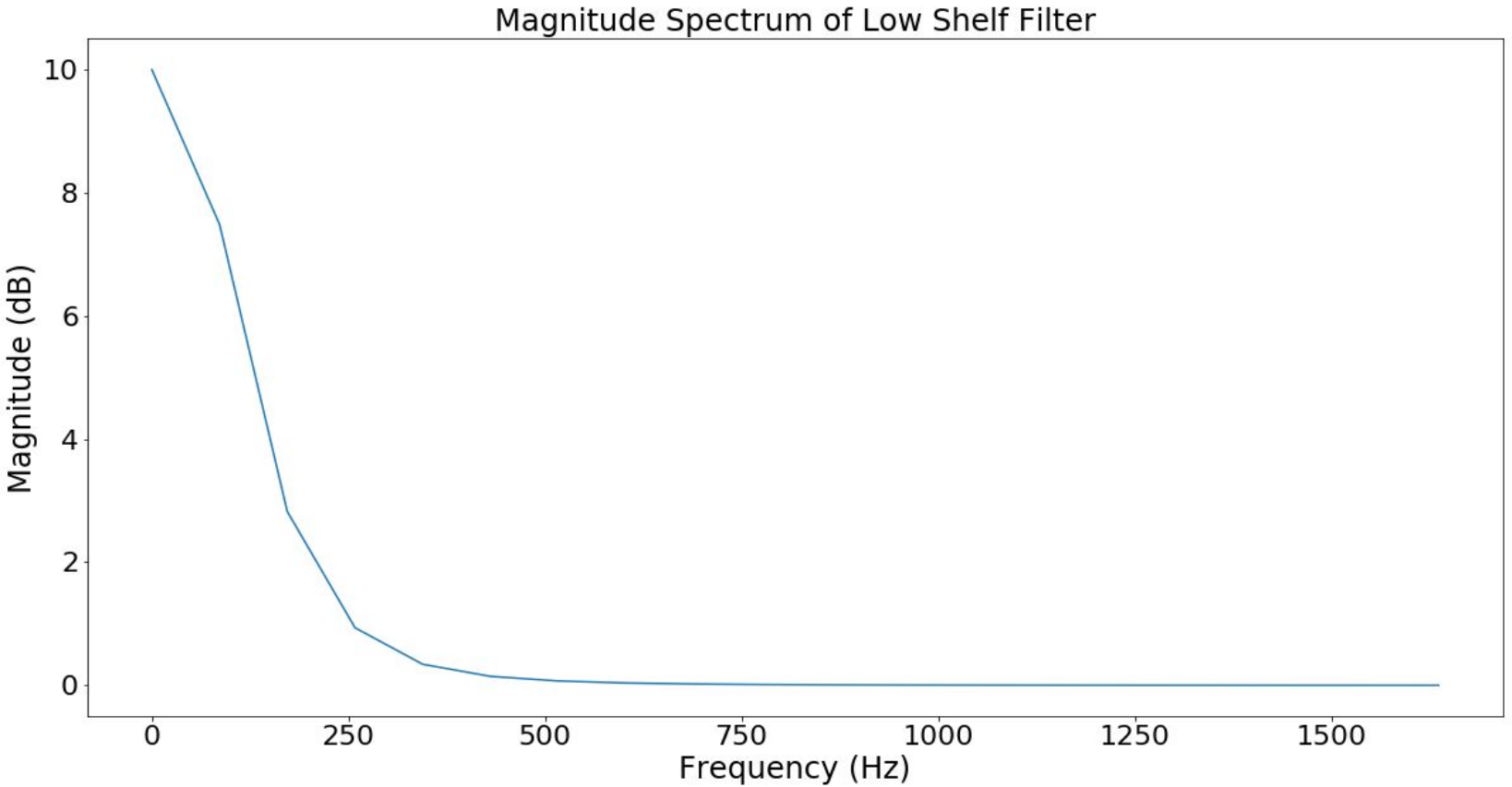
Filtering - Frequency Band Filters

- Six bell filters, one low shelf, one high shelf
- Center frequencies fixed, gains decided by user
- Frequency domain filters

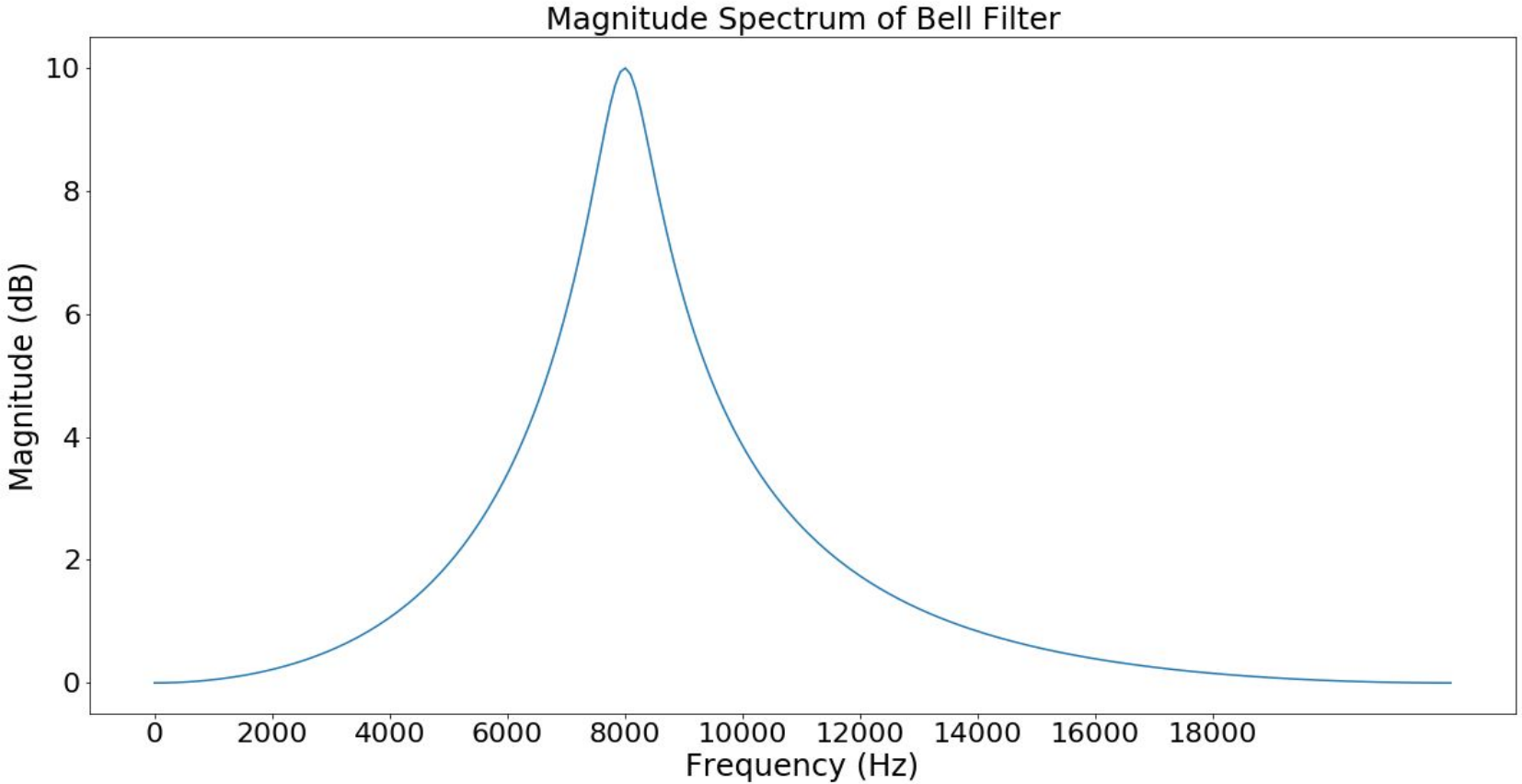
Filtering - Frequency Band Filters



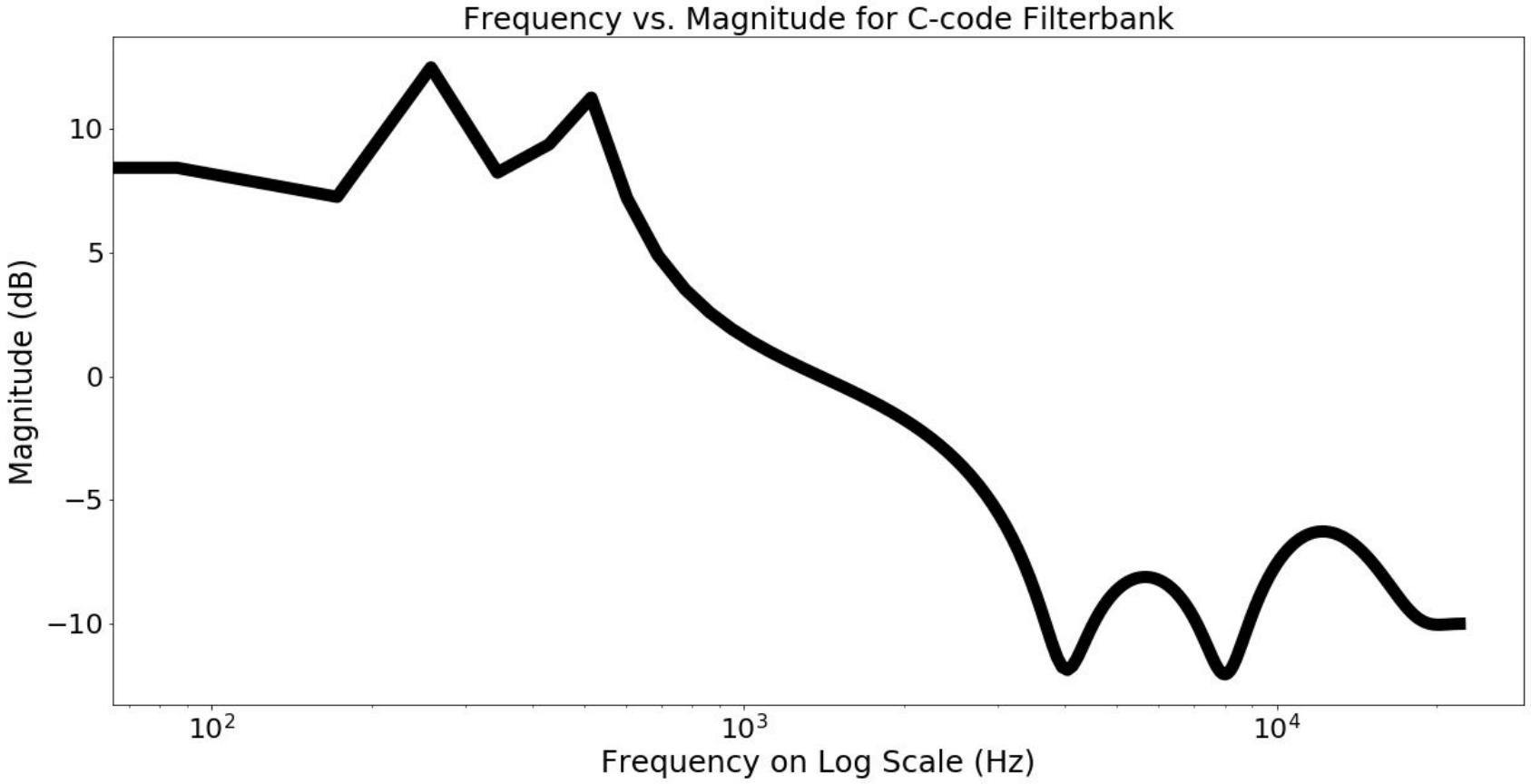
Filtering - Frequency Band Filters



Filtering - Frequency Band Filters

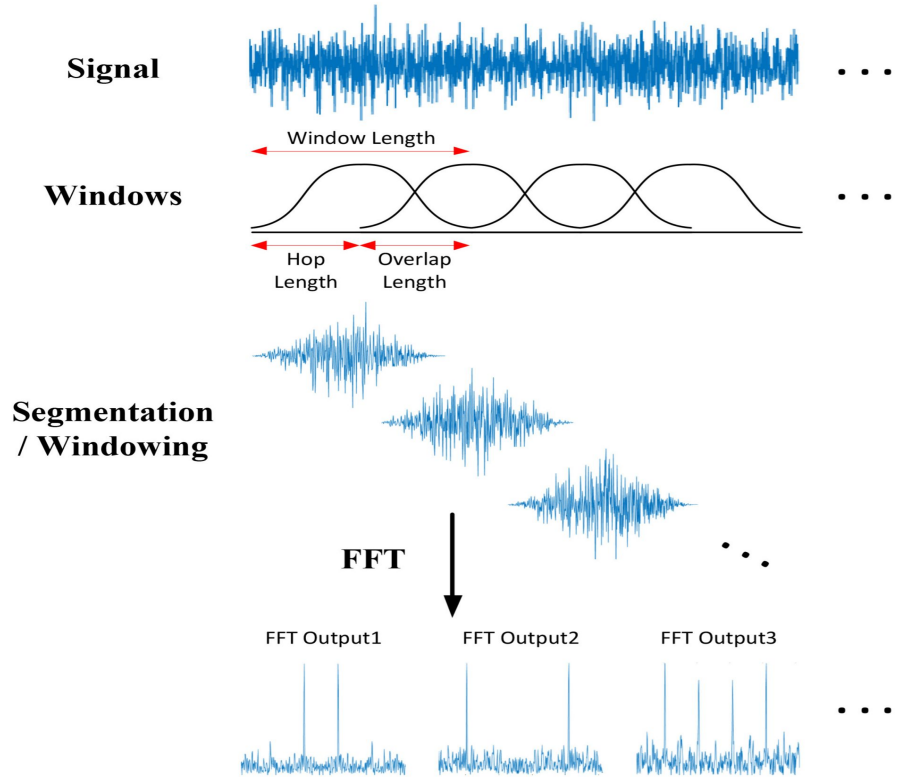


Filtering - Frequency Band Filters



Filtering - Transform and Multiplication

- First, short-time Fourier Transform
- Multiply each windowed segment by filter
- Transform back into time domain, send out on I2S



Control Unit - R&V

Requirements
The microcontroller must be able to receive and store audio data of size **4000 bytes** incoming from the audio codec chip
The microcontroller must be able to **output modified audio data** through the audio codec

R&V Store and Receive

- Mixed Success - MCU able to store but not receive 4000 bytes
- FFT length is 512

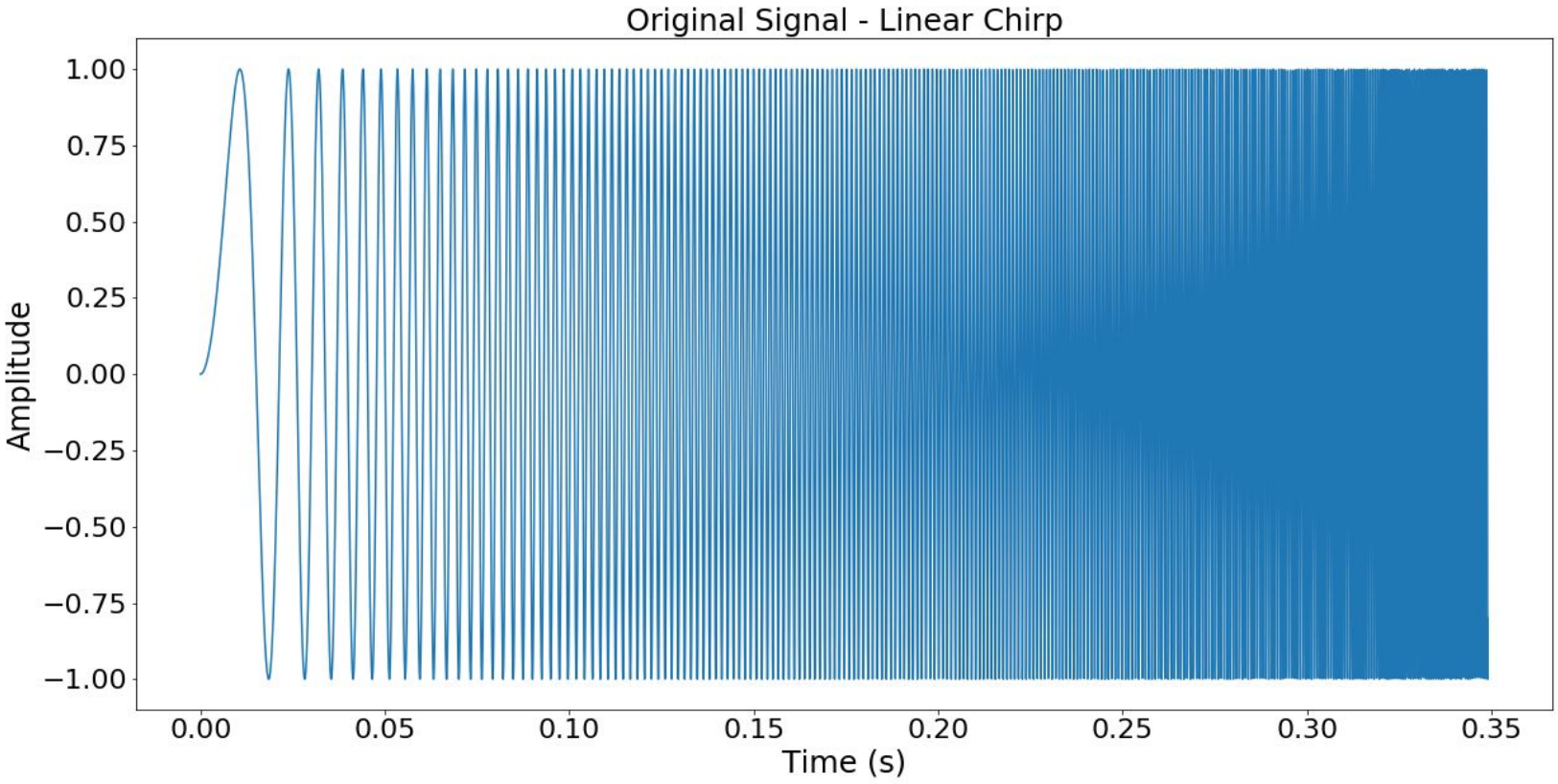
```
float freq_alter_right[audio_len];
float freq_alter_left[audio_len];


#define audio_len (2*fft_size)
```

R&V - Output Modified Data

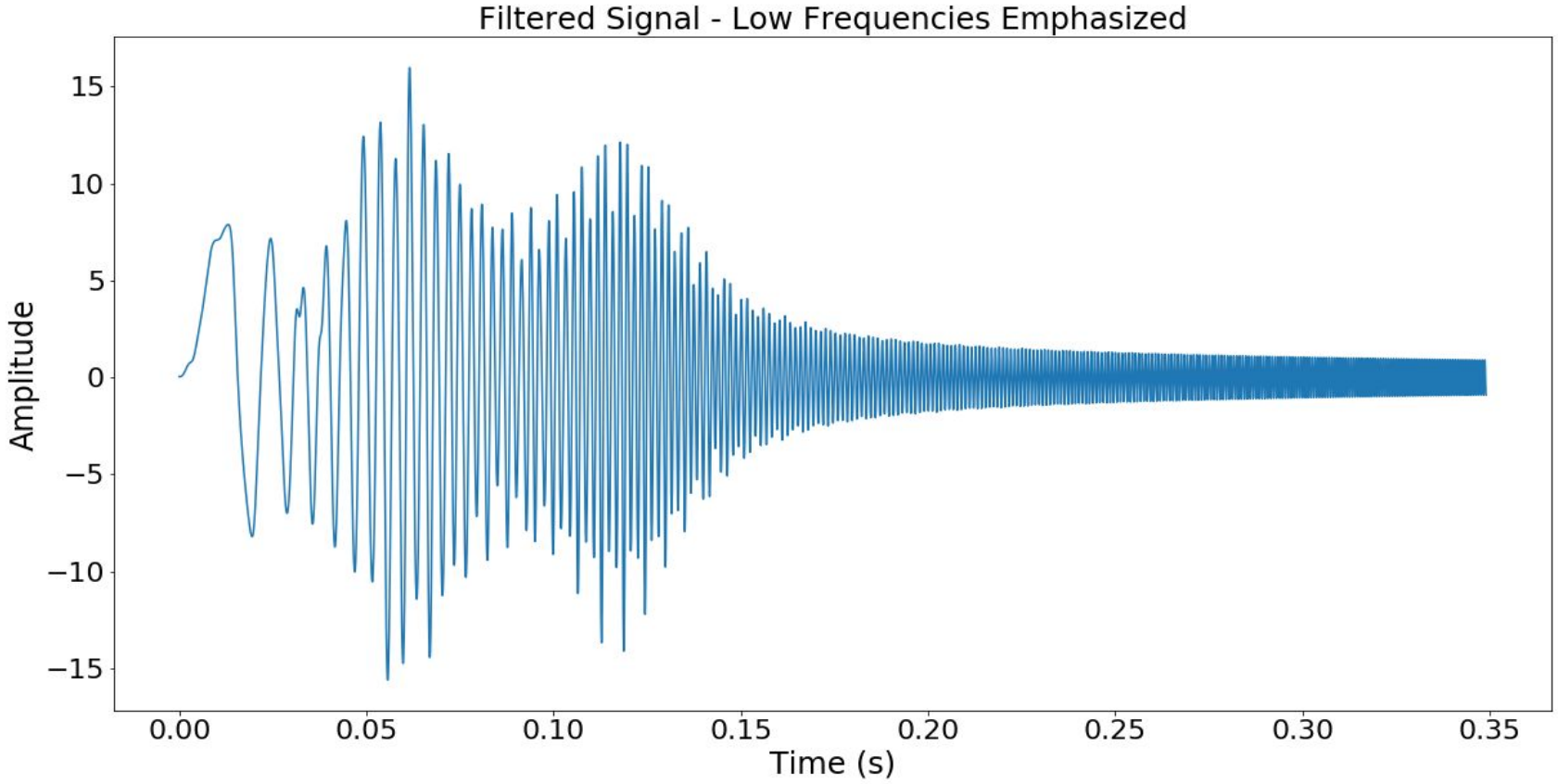
- Again, mixed success
- Device unable to send data to the audio codec chip
- Filtering takes 49 milliseconds with proper settings

$$\frac{1}{44100 \text{ samples/second}} \cdot 2560 \text{ samples} \cdot 1000 \text{ milliseconds/second} = 58 \text{ milliseconds}$$

R&V - Output Modified Data



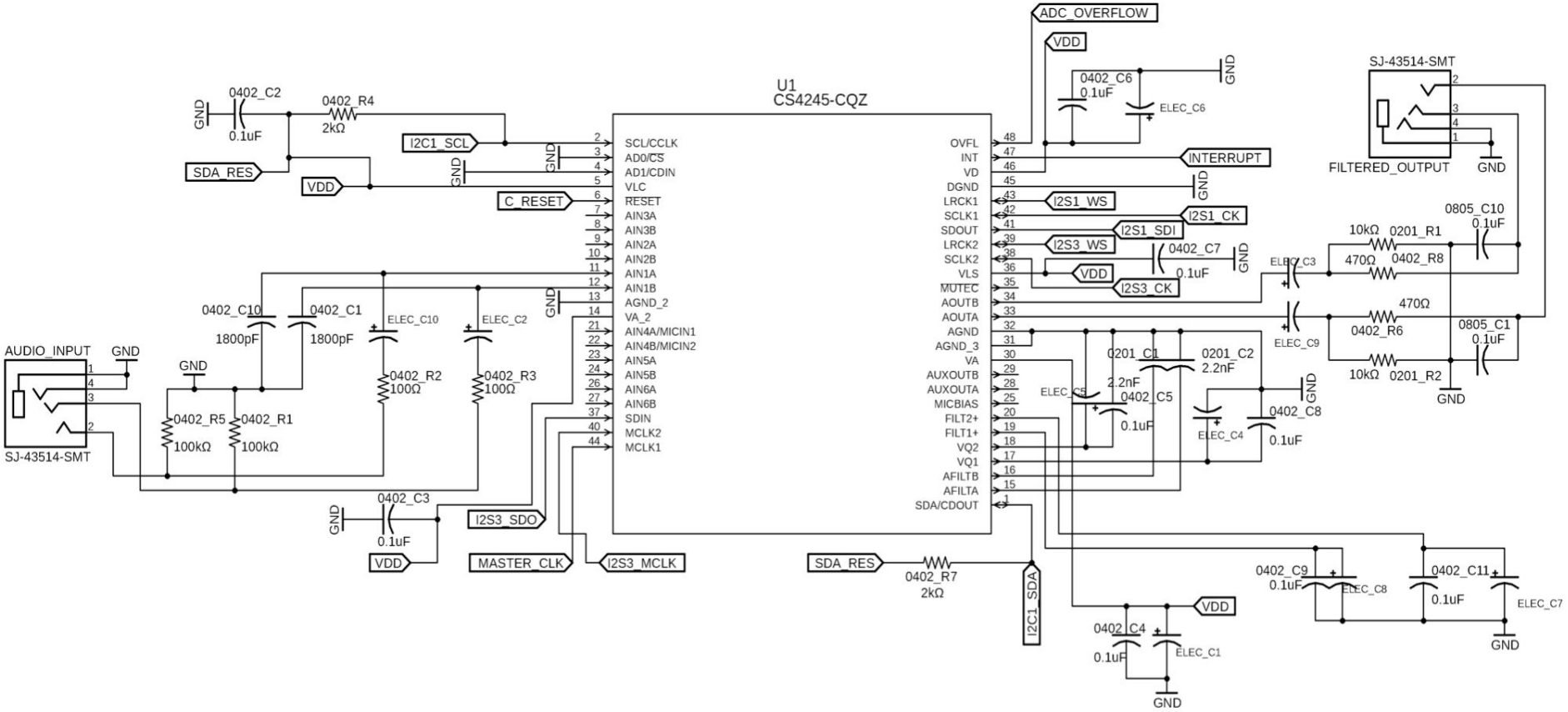
R&V - Output Modified Data



Audio Input/Output Subsystem

- Centerpiece is audio codec chip
- Interfaces with 3.5 mm connector ports and MCU
- Unable to get it to work

Audio Input/Output Subsystem

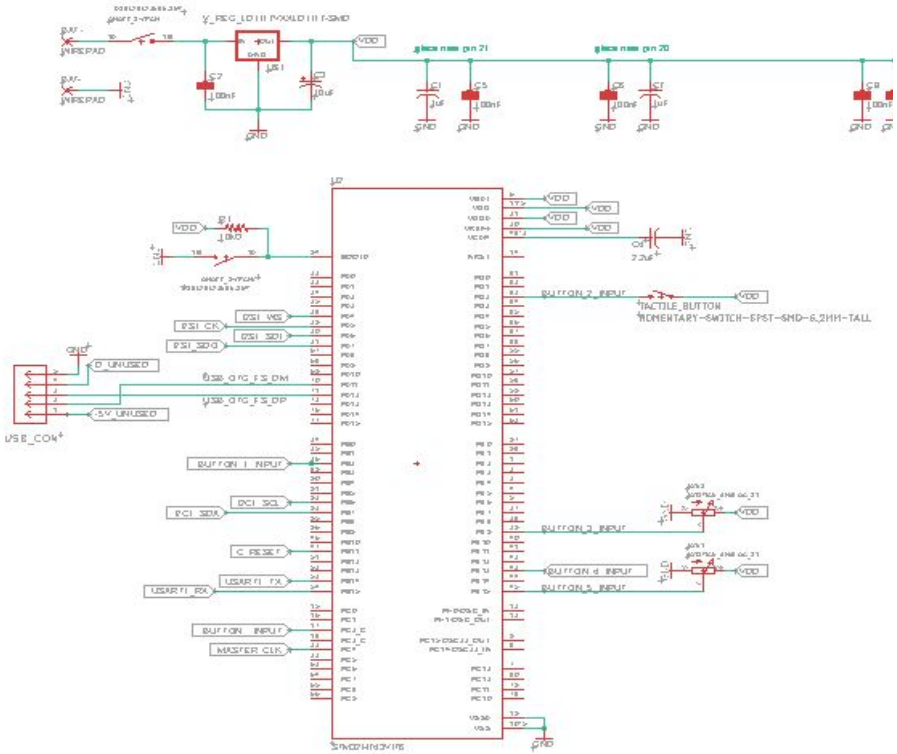


Audio Input/Output - R&V

Requirements
The audio codec must have a total system latency of less than **10 ms**
The audio codec must be able to sample the audio data at a rate of at least **40,000 Hz**

Control Module and User Interface

- Microcontroller schematic
- I2C and I2S for communications
- Power Module Drives with 3.3V and 800 mA
- Programmable via USB and bootloading enabled on Microcontroller
- Switches for user input

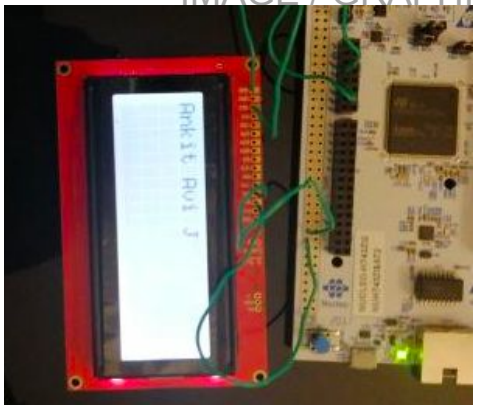


Microcontroller LCD Communication

- I2C Initialization in accordance with datasheet. Set bits for read/write
- To write to the screen, copy a string buffer to the address specified and send a signal to LCD for it to read and write to the characters to display
- Memory fence exists in Microcontroller, max buffer size of 32 bytes of data.

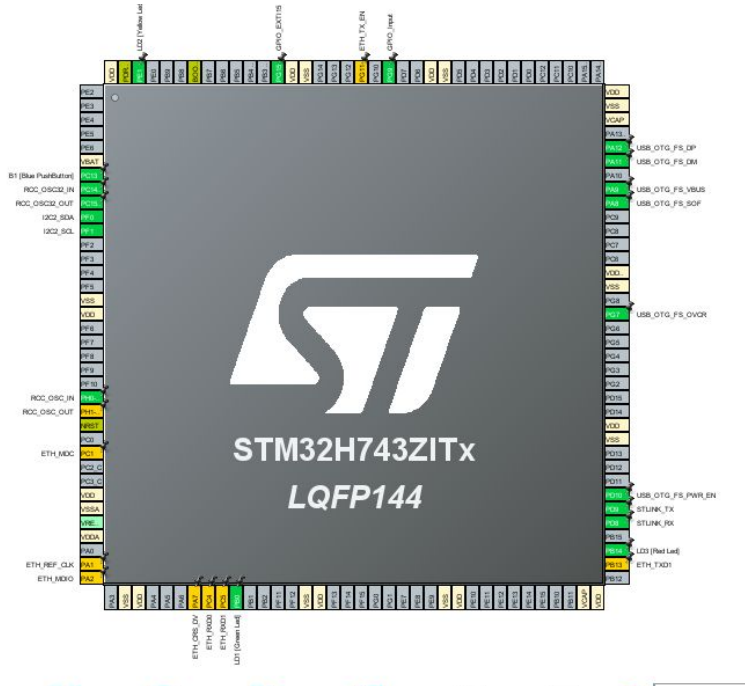
```
*/
uint8_t displayInit(I2C_HandleTypeDef *hi2c)
{
    uint8_t retval = LCD_OK;

    _i2cHandler = hi2c;          // pointer for i2c handler is stored in library

    // create i2c data stream
    uint8_t TransmitData[6] = {SPECIAL_COMMAND,                    // special command character
                               [redacted] | _displayControl,       // display command
                               SPECIAL_COMMAND,                    // command character
                               LCD_ENTRYMODESET | _displayMode,    // entry mode command
                               SETTING_COMMAND,                    // Put LCD into setting mode
                               CLEAR_COMMAND                       // clear display
                               };

    // transmission of data stream
    if(HAL_I2C_Master_Transmit(_i2cHandler, DISPLAY_ADDRESS1<<1, TransmitData, sizeof(TransmitData), 100) != HAL_OK)
        retval = LCD_ERROR;

    HAL_Delay(50);

    return retval;
}
```

IMAGE / GRAPHIC



Pin Planner and External Interrupts

- Send Interrupts based on high voltages in hardware and read them in software
- Solution : Interrupt handler + global flags
- Specify pin that current will be sent to as an external interrupt handler
- Program interrupt handler to indicate which pin (button) has sent



Interrupt Handlers and Global Flags

- Enter infinite loop, look for interrupt flag
- External interrupt for options cycles between frequency/db values
- When selection interrupt exit loop
- Make decisions based on value selected by user
- Ideally, we send the user selection options and run our DSP algorithms

```
667 }
668
669 /* USER CODE BEGIN 4 */
670     void HAL_GPIO_EXTI_Callback( uint16_t GPIO_PIN ) {
671         if(GPIO_PIN == GPIO_PIN_15) {
672             user_inputput1_flag = 1;
673             return;
674         } else {
675             __NOP();
676         }
677     }
678 /* USER CODE END 4 */
```

```
while (1) {
    if(HAL_GPIO_ReadPin(GPIOC, GPIO_PIN_13) == 1){
        if(check == 0) {
            displayWriteString("dB Setting :        ");
            check = 1;
        }
    }else{
          HAL_GPIO_WritePin(GPIOD, GPIO_PIN_13, GPIO_PIN_RESET);
          check = 0;
    }
    if(user_input1_flag == 1 ){
        displayClear();
        break;
    }
}
```

User Interface Demo

Power Module: Voltage Regulator

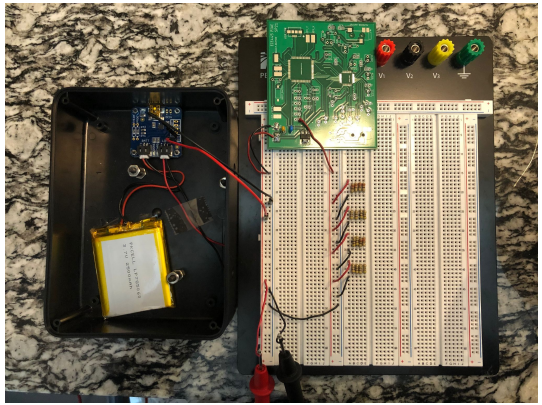
- Must supply **3.3 V** +/- 5%

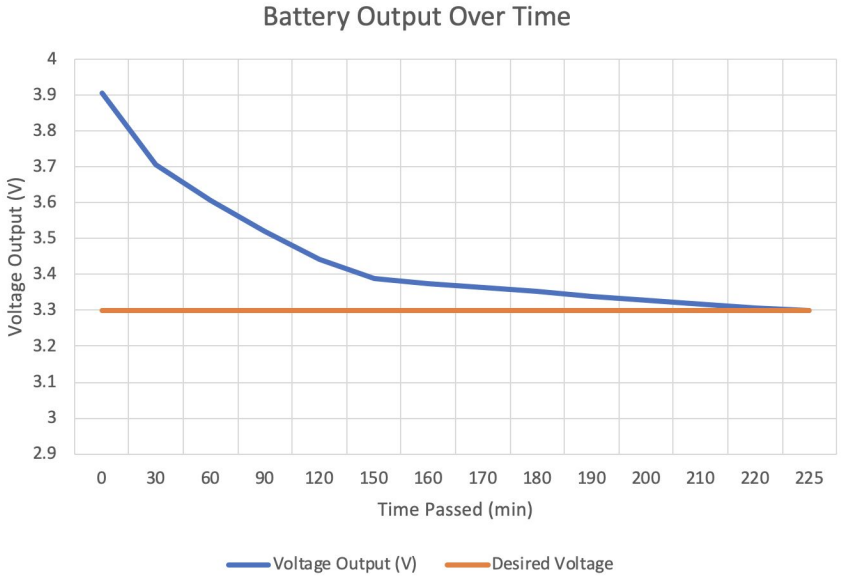
Voltage Regulator Input	Voltage Regulator Output
5.0 V	3.29 V
4.0 V	3.22 V
3.3 V	3.18 V

Power Module: Battery

- Battery lifetime of at least **3 hours**

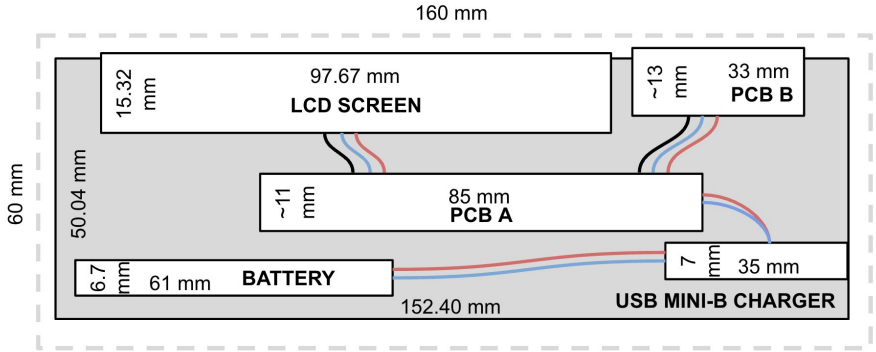
Battery Life = Battery Capacity / Load Current
≈ 2500 mAh / 791.1 mA
≈ 3 h





Portability

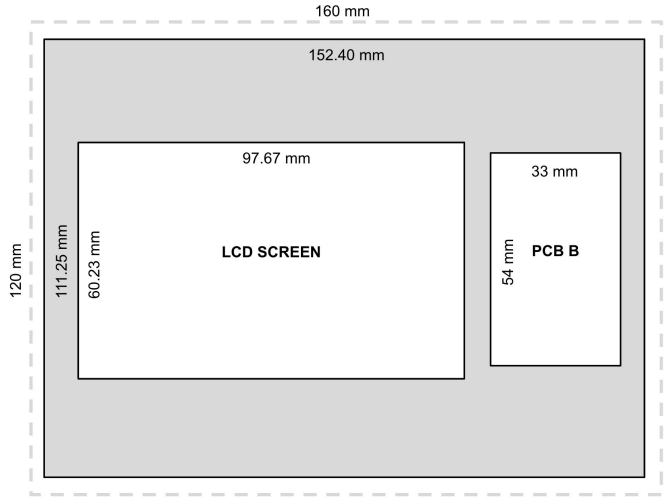
- Dimensions less than **16 x 12 x 6 cm**



Long Side View Inside Box

Portability (cont.)

- Dimensions less than **16 x 12 x 6 cm**

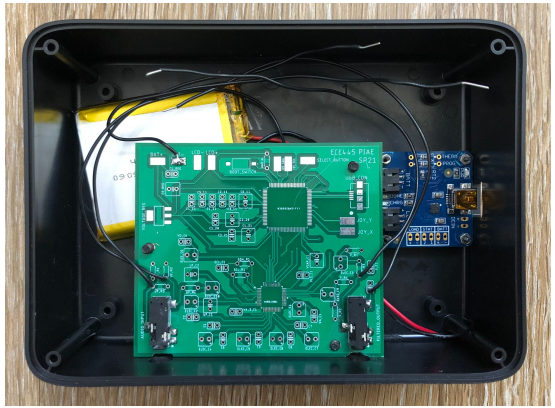


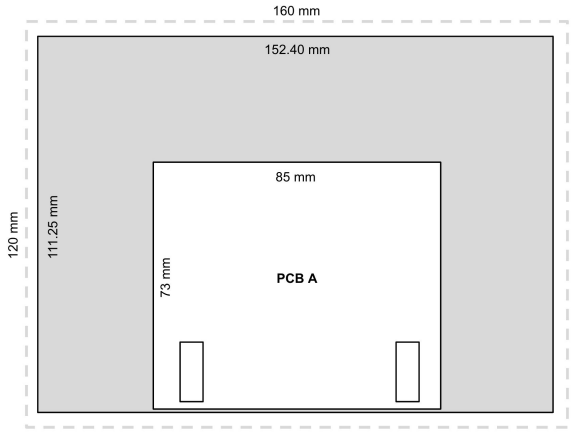
Top Layer Inside Box

Portability (cont.)

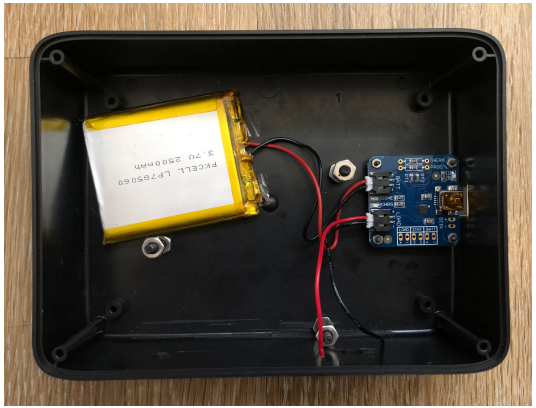
- Dimensions less than **16 x 12 x 6 cm**

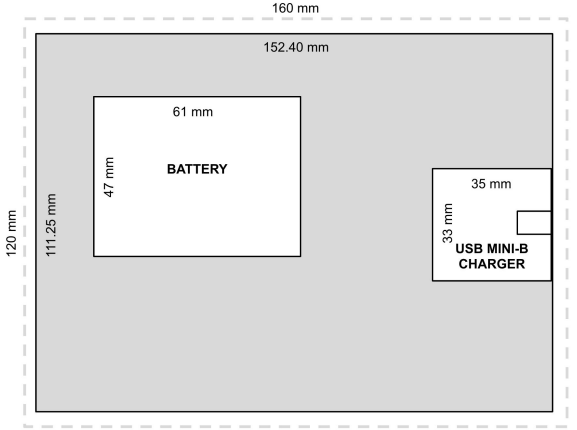
Middle Layer →





Bottom Layer →





Future Work

- Resolve audio codec chip
- Improve latency
- Better portability

Thank You

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