Sound Level Meter

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Abstract

1 Introduction

This report outlines the design and construction of a sound level meter. The device measures the sound level of the environment. This is the filtered through several filter stages and the sound level is displayed on an LED bar graph. The sound signal is filtered to select a band of frequencies and then low pass filtered to produce a DC voltage level proportional to the sound level.

1.1 Aims

- To understand the design of a common emitter amplifier for the first stage.
- To understand the design of an LC band pass filter.
- To understand the construction and operation of a signal rectifier.
- To understand the construction of a low pass filter.
- To understand how to program a PIC Micro controller.
- To understand the construction and testing of the circuit.

1.2 Objectives

- To determine the β of the transistor by experimentation
- To design a common emitter amplifier for the first stage of the circuit with appropriate gain
- To design an LC band pass filter and calculate the number of turns of wire to create the required inductance.
- To construct a rectifier to rectify the signal
- To construct a low pass filter to convert the signal to a dc voltage level.
- To create a program to change the number of LED's that are on depending on the sound level and program the Micro controller with the code.
- To test the completed stages and whole circuit to make sure it operates as intended.

2 Method

2.1 Design

2.1.1 Determining β

To determine β the circuit shown in figure 1. R_C was set to $3.9K\Omega$. R_B was then chosen to make $V_{CE} \approx 7.5V$. The base current was calculated by measuring the voltage across R_B and using Ohms law, the same was done for the collector current. To work out β the formula

$$\beta = \frac{I_C}{I_B}$$

was used. This gave a value of $\beta = 337$.

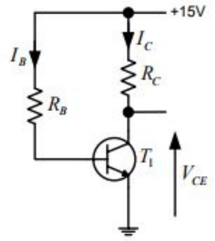

Figure 1: Circuit used to determine β

2.1.2 Common Emitter Amplifier

The first stage of the circuit is a common emitter amplifier to amplify the signal from the microphone to be processed by later stages. The transistor β was found to be $\beta = 337$. First the current I_C was calculated using the equation with $V_C = 7.5V$ and $R_3 = 3.9K\Omega$

$$I_C = \frac{15 - V_c}{R_3}$$

This equation gives an I_c value of $I_c = 1.92mA$. R_4 is then calculated with the equation

$$R_4 = \frac{1.5}{I_E}$$

with $I_e \approx I_c$ this makes $R_4 = 781\Omega$. To calculate the biasing resistors it is set that the current through the biasing resistors is $10 \times I_B$. The equation

$$R_2 = \frac{V_{BE} + V_E}{10 \times I_B}$$

This gives an $R_2 \approx 40K\Omega$ R_1 can then be calculated with the equation.

$$R_1 = \frac{V_{CC} - V_B}{10 \times I_B}$$

This gives $R_1 \approx 27K\Omega$

2.1.3 Bandpass Filter

The band pass filter uses a resonant LC circuit to set the filter characteristics. The resonant frequency of an LC circuit is given as

$$f = \frac{1}{2\pi\sqrt{LC}}$$

The capacitor that forms the resonant circuit is $C5 = 1\mu F$ to calculate the value for L the equation is rearranged to

$$L = \frac{1}{(2\pi f)^2 C}$$

This gives $L = 11.3mH$. To calculate the number of turns on the inductor the equation

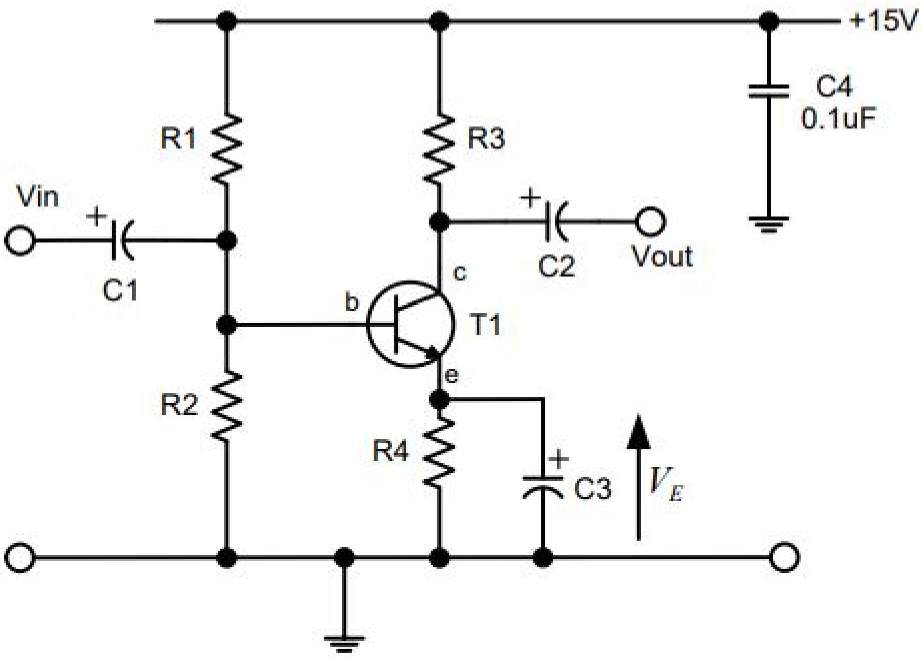

Figure 2: Common emitter amplifier circuit diagram

$$N = \sqrt{\frac{Ll}{\mu \times a}}$$

L = Inductance, l = length of magnetic circuit, μ = permeability and a = cross sectional area.

is used. This gives $N = 61$ Turns.

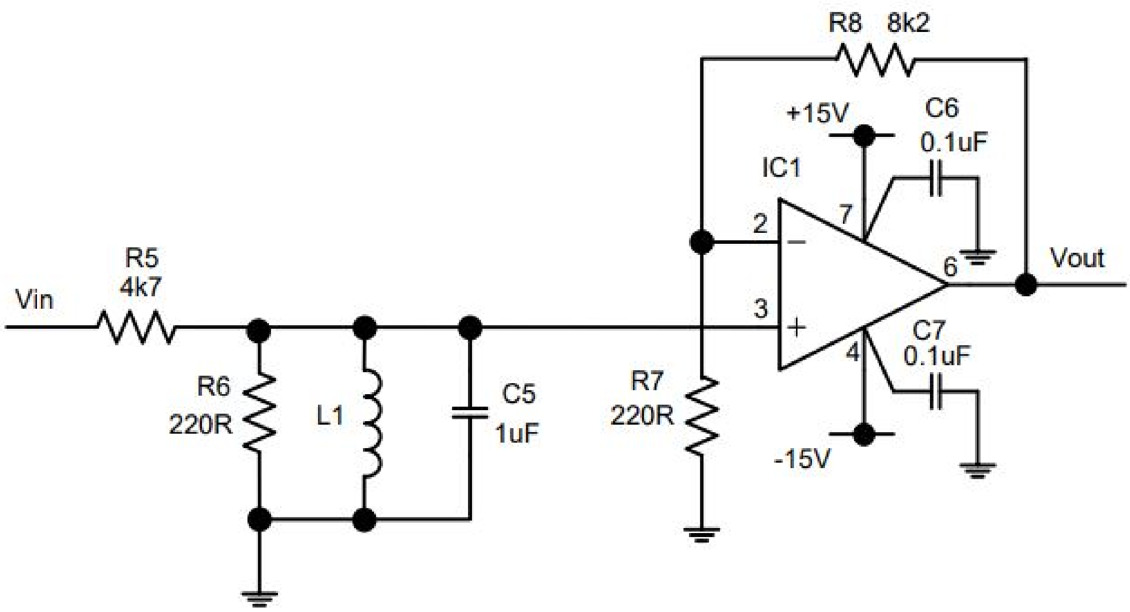

Figure 3: Band pass filter circuit diagram

2.1.4 Code

The code was made to light all the LED's when maximum sound level was achieved. This was done with a logarithmic scale to allow high sensitivity at low sound levels but allow a large range of sound levels to be measured without clipping at high end values.

Number of bars lit	Voltage level(mV)
0	0
1	1.8
2	3.28
3	5.94
4	10.76
5	19.49
6	35.3
7	63.95
8	115.8
9	209
10	380

These values were then used to create the code

Listing 1: PIC Code

```c
//Newcastle University - EEE - Stage 1 - Sound Level Meter
//16F819 PIC software to drive a 10-LED bargraph display from a dc level on ADC input 0 (AN0).
//Port A and B used to drive LEDs.
//Pin Configuration:
//Pin Configuration:
//1-RA2 (LED4) 18-NC
//2-RA3 (LED3) 17-AN0 (DC Sound Level input)
//3-NC 16-RA7 (LED1)
//4-MCLR 15-RA6 (LED2)
//5-VSS 14-VDD
//6-RB0 (LED10) 13-RB7 (PGD)
//7-RB1 (LED9) 12-RB6 (PGC)
//8-RB2 (LED8) 11-RB5 (LED5)
//9-RB3 (LED7) 10-RB4 (LED6)
#include <xc.h> //header file for device
#include <stdint.h> //header file for standard types e.g uint8_t
//fuse settings to configure device
//i.e. NOWDT - No Watchdog Timer, INTOSCIO - Internal clock used, pins available for I/O
#pragma config MCLRE = ON, CP = OFF, CPD = OFF, BOREN = OFF, WDTE = OFF
#pragma config PWRTE = OFF, FOSC = INTOSCIO, LVP = OFF, DEBUG = ON
void main()
{
 //*** INSERT ANY VARIABLE DECLARATIONS HERE ***
 //uint8_t = 8-bit unsigned number
 //unint16_t = 16-bit unsigned number
 uint16_t value;
 //*** The following code initializes the PIC ***
 OSCCONbits.IRCF = 0b111; //use internal 8MHz clock (FOSC=8MHz)
 TRISB = 0b00000000; //Port B all outputs
 TRISA = 0b00110011; //Port A B6/B7/B3/B2 outputs
 ADCON1bits.ADFM = 1; //A/D Result Format Right Justified
 ADCON1bits.ADCS2 = 1; //A/D clock Source divided by 2
 ADCON1bits.PCFG = 0b1110; //Enable AN0 input for sound level ADC
13
 ADCON0bits.ADCS = 0b01; //set ADC clock, should be between 1.6us and 6.4us (1/8MHz x 16 = 2us)
 ADCON0bits.CHS = 0b000; //select AN0 for input
 ADCON0bits.ADON = 1; //A/D Converter is operating
 do
 {
 //The code below will read the digital value from the 10-bit analogue to digital converter.
 //The range of the return value will be between 0 and 1023. Where 0V = 0 and 5V = 1023.
 //For example 2.5V on the ADC will return 511 to the variable value below.
 ADCON0bits.GO_nDONE = 1; //start A/D conversion
 while(ADCON0bits.GO_nDONE == 1); //wait for A/D conversion to complete
 value = ADRESH; //read MSB of ADC result
 value = value << 8; //shift left 8 bits
```

```
 value = value + ADRESL; //read LSB of ADC result. value now contains a 10-bit ADC number
 //*** INSERT YOUR PROGRAM CODE HERE TO ILLUMINATE THE LEDs***
 //The basic requirement of your code is:-
 //(i) To use the variable value to determine which LED bars should be switched on.
 //(ii) To write the appropriate code to the output pins RB0-RB5 and RA2,RA3,RA6,RA7.
 //The PIC PORTA and PORTB registers should be used to output a value to the Port pins
 //PORTA=0b00001111; will output a binary number to port A. Bits 7,6,5,4=0 and Bits 3,2,1,0=1.
 //Alternatively PORTA=15; for decimal equivalent.
 //The parameter may also be a variable instead of a constant e.g. PORTA=value;

if(value = 0){
PORTA=0b11111111
PORTB=0b11111111

}

if(value > 0 && value <= 1.8){
PORTA=0b01111111
PORTB=0b11111111

}

if(value > 1.8 && value <= 3.28){
PORTA=0b00111111
PORTB=0b11111111

}

if(value > 3.28 && value <= 5.94){
PORTA=0b00110111
PORTB=0b11111111

}

if(value > 5.94 && value <= 10.76){
PORTA=0b00110011
PORTB=0b11111111

}

if(value > 10.76 && value <= 19.49){
PORTA=0b00110011
PORTB=0b11011111

}

if(value > 19.49 && value <= 35.3){
PORTA=0b00110011
PORTB=0b11001111

}

if(value > 35.3 && value <= 63.95){
PORTA=0b00110011
PORTB=0b11000111

}

if(value > 63.95 && value <= 115.8){
PORTA=0b00110011
PORTB=0b11000011

}

if(value > 115.8 && value <= 209){
PORTA=0b00110011
PORTB=0b11000001

}

if(value > 115.8 && value <= 209){
```

```
PORTA=0b00110011
PORTB=0b11000001

}










 } while (1);
}
```

2.2 Construction

2.2.1 Common Emitter Amplifier

After the common emitter amplifier was constructed on bread board using the resistor values determined in the design stage. This was to determine that the amplifier had been designed correctly. To test the design the voltage between the transistor collector and ground was measured and was found to be $V_C = 7.62V$. This is within the allowable limit of $6V$ to $9V$. The circuit was then constructed on the circuit board and the collector voltage was once again measured and found to be the same as before. The decoupling capacitors were then added to the circuit board. To test the amplifier a $20mV Pk - Pk$ sine wave at $1kHz$ was applied to the input and the output measured on an oscilloscope. This is shown in figure 4. Using an input of $23mV$ and an output of $4.3V$ leads to a gain of $G = 215$.

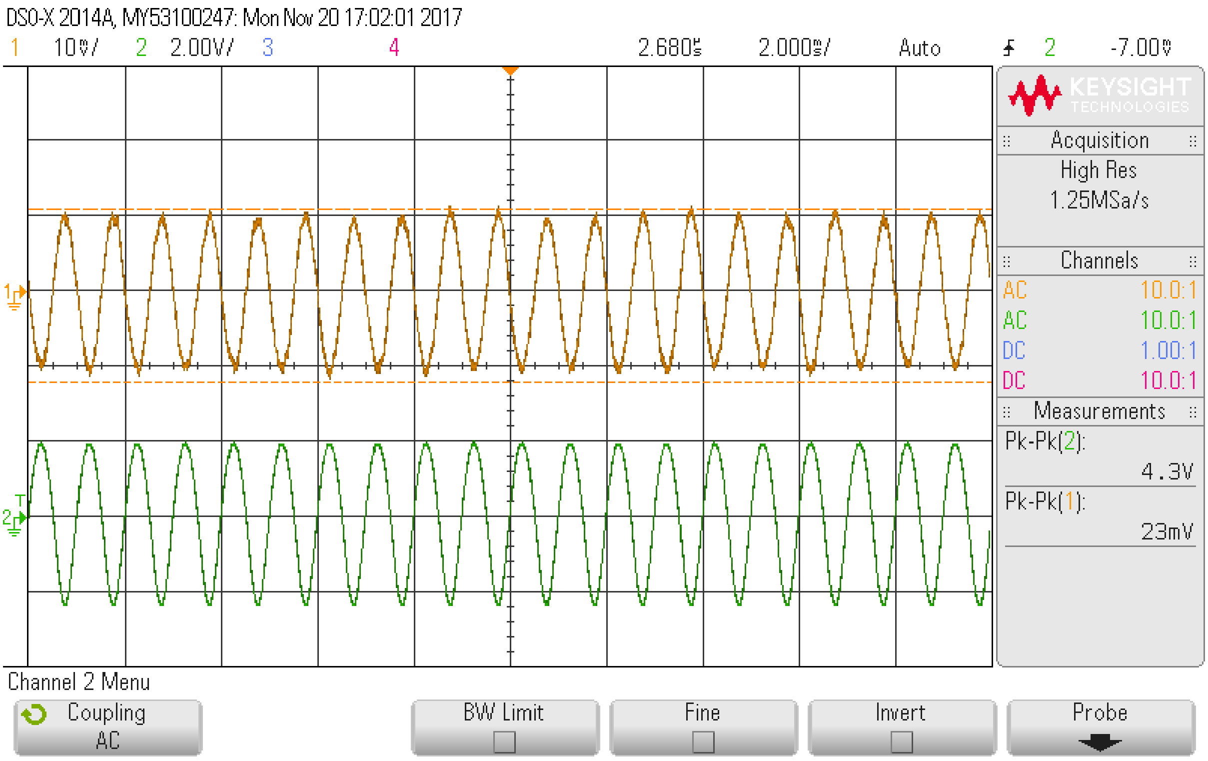

Figure 4: Testing of the Common Emitter Amplifier

2.2.2 Band Pass Filter

To construct the band pass filter the Inductor must first be made. It was calculated that the required inductor would be made of 61 turns. This Inductor was created and its inductance was measured using an LCR meter. The desired inductance is $11.3mH$ however the inductance was measured as $11.9mH$, to reduce this turns were removed and the Inductor re measured until its inductance was equal to $11.3mH$. This was achieved with 56 turns. The circuit was then constructed on the circuit board according to the circuit diagram shown in Figure 2.1.3. Once completed the filter was characterised between $1Hz$ and $5kHz$ with a $2VPk - Pk$ sine wave input shown in figure 5.

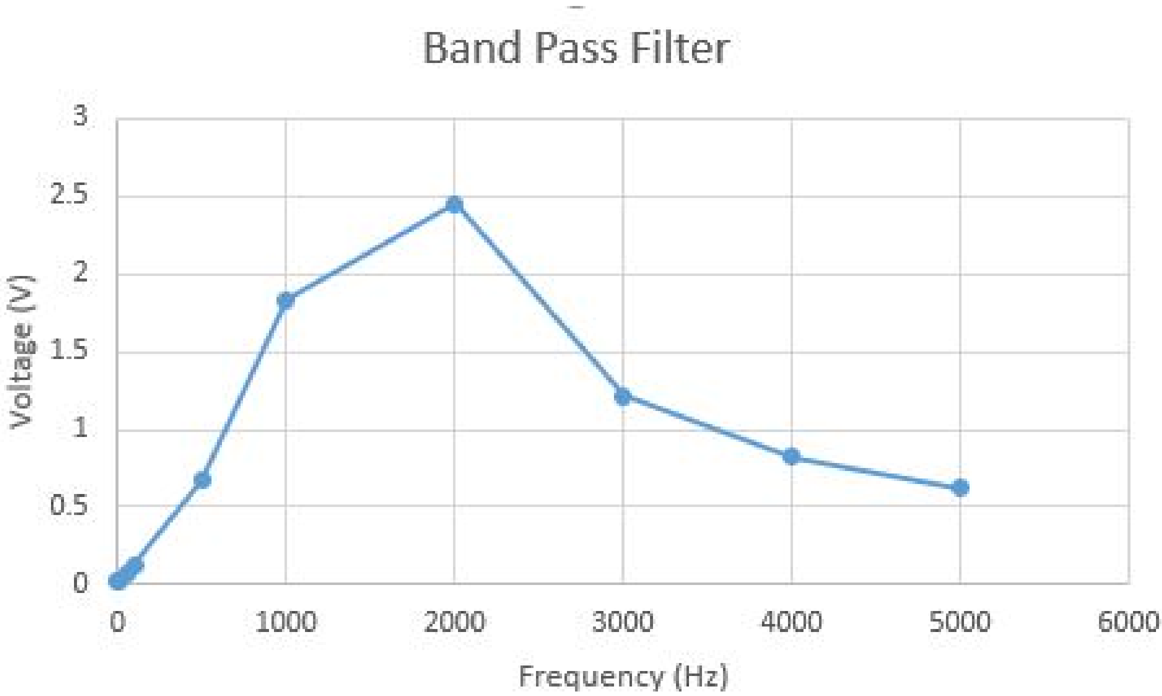

Figure 5: Characterisation of Band Pass Filter

2.2.3 Signal Rectifier

The circuit shown in figure 6 was constructed on the circuit board and was then tested as shown in figure 7 with a $1.5kHz$ $5V$ sine wave.

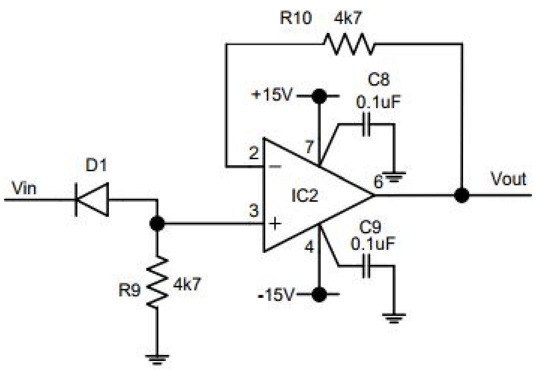

Figure 6: Rectifier Circuit Diagram

2.2.4 Low Pass Filter

The Low Pass Filter was constructed on the circuit board according to the circuit diagram shown in figure 8. After the circuit was constructed it was tested by inputting a $1VPk - Pk$ sine wave as shown in figure 9. The filter was then characterised between $1Hz$ and $1kHz$ with a $1VPk - Pk$ input sine wave shown in figure 10.

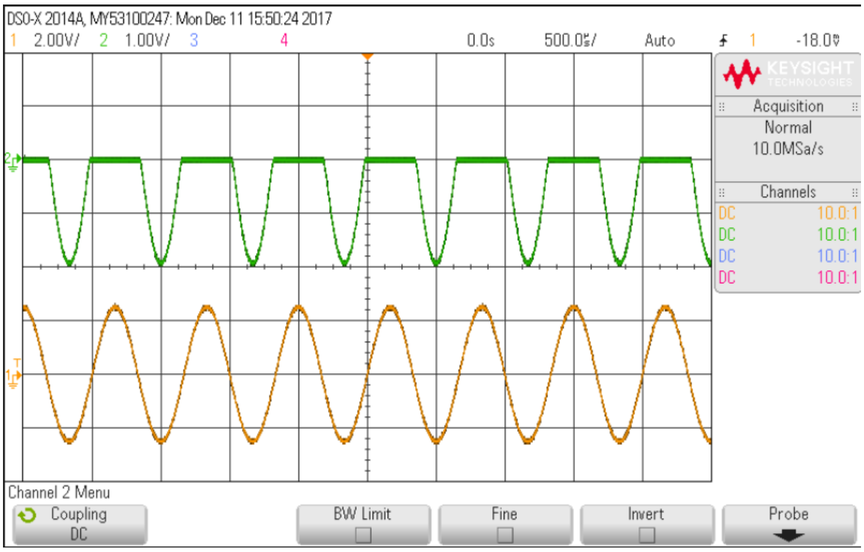

Figure 7: Rectifier analysis

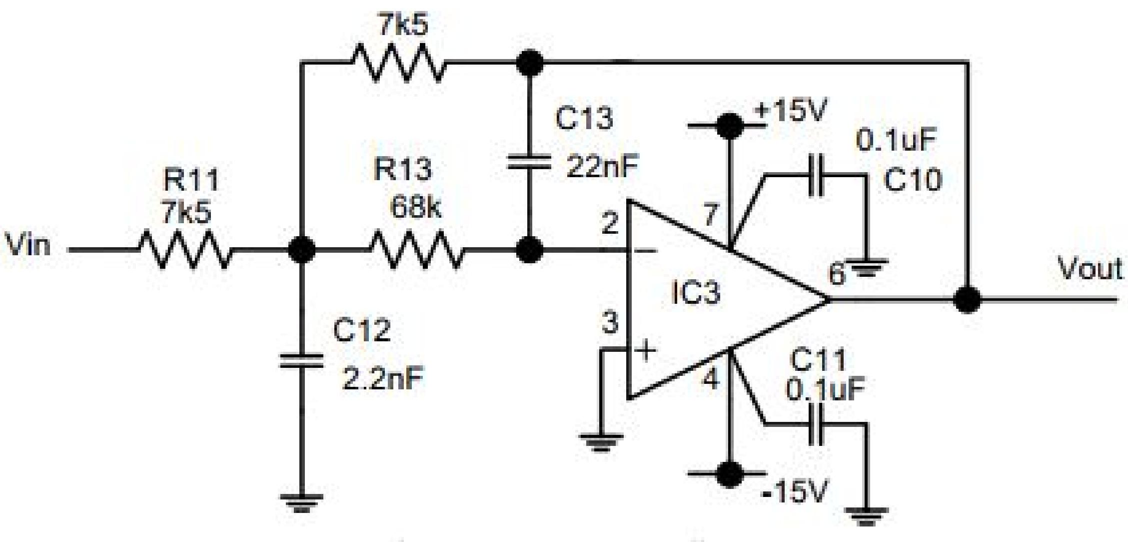

Figure 8: Low Pass Filter Circuit Diagram

2.2.5 PIC Microcontroller

The Microcontroller circuit was constructed according to the circuit diagram shown in figure 11. The PIC was then programmed with the code shown in the design phase shown in figure **??**.

2.2.6 Final Test

Once all parts of the circuit were connected together the meter was tested by playing a $1.5kHz$ tone through a speaker from a signal generator near the meter and observing the LED's.

3 Analysis

3.1 Common Emitter Amplifier

The Common Emitter Amplifier is used to amplify the low level signals coming from the microphone. This amplifier is used due to multiple attributes of the amplifier, namely, high input impedance, class A operation to prevent distortion and high single stage gain.

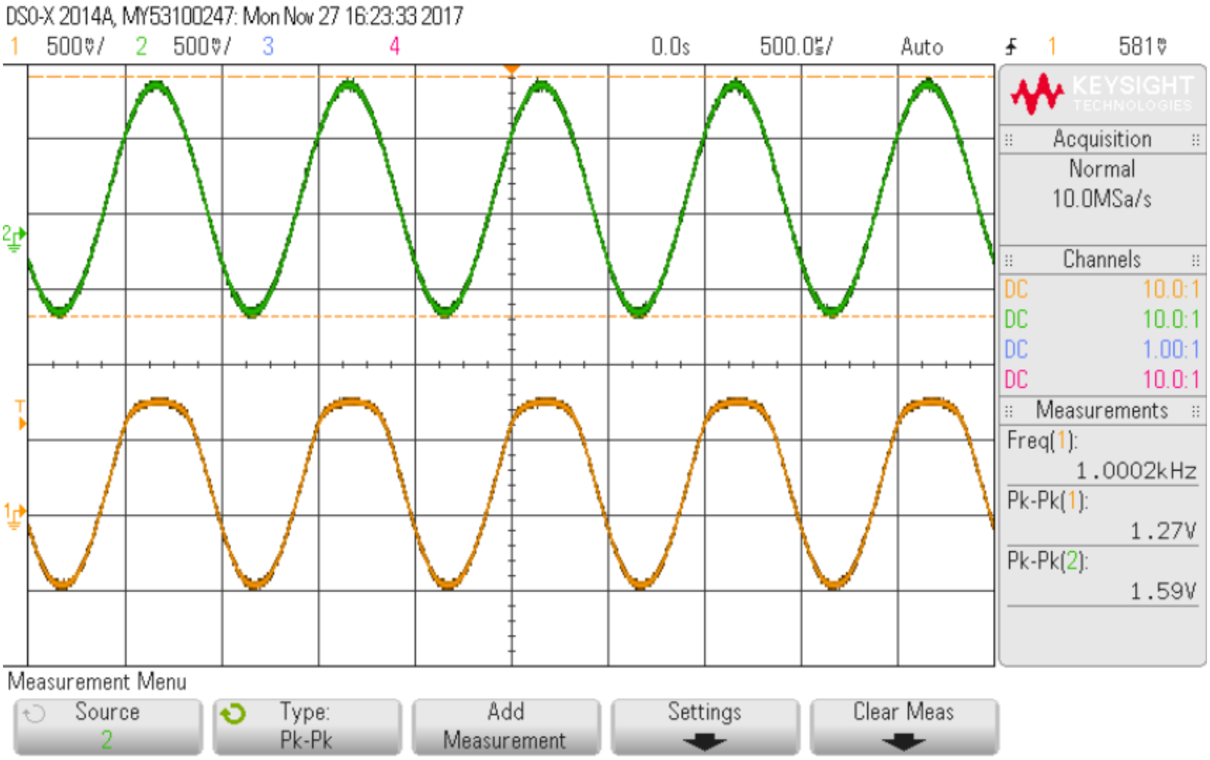

Figure 9: Low Pass Filter input & output

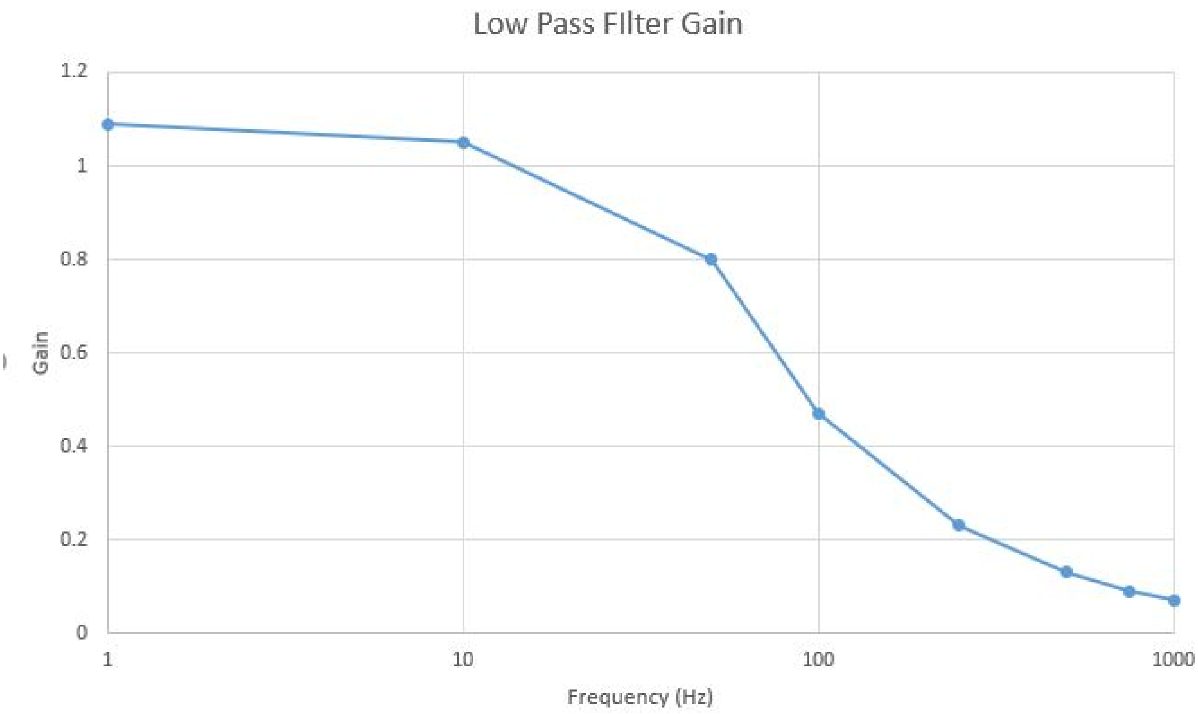

Figure 10: Low Pass Filter Characterisation

3.1.1 Input Impedance

The high input impedance is needed as the microphone is a high impedance device and to allow maximum power transfer between the microphone and the amplifier $Z_{mic} \approx Z_{amp}$. If this were not the case the already small signal from the microphone would be reduced even more due to internal losses in the

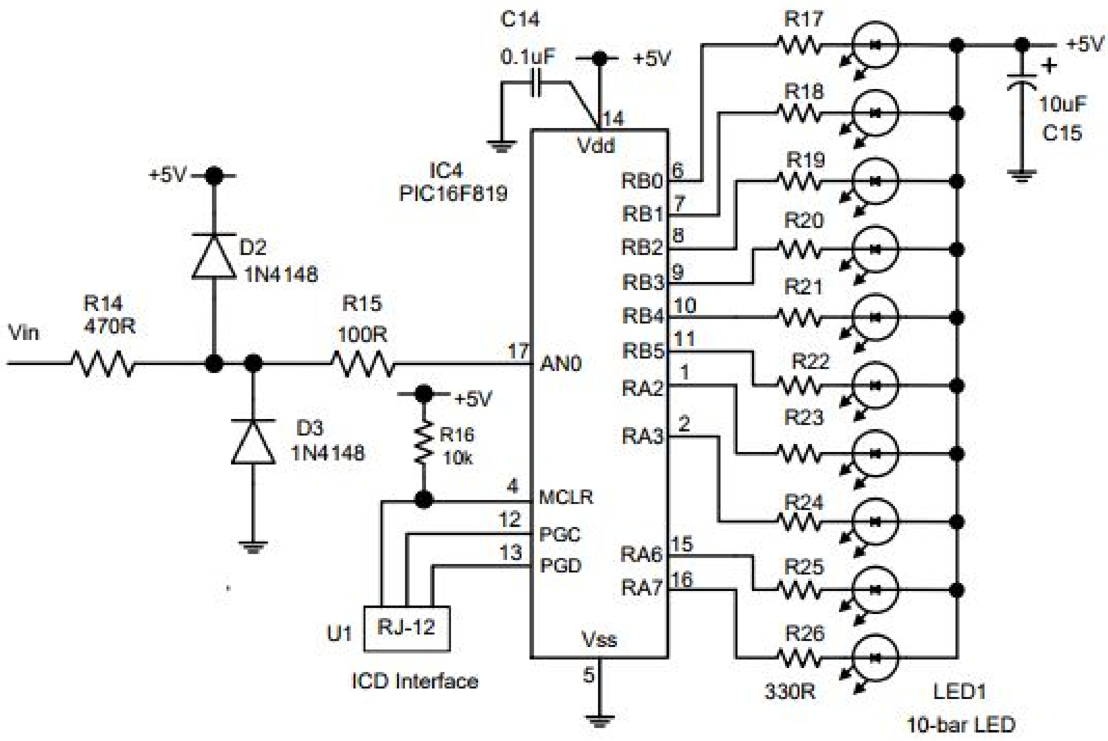

Figure 11: PIC Microcontroller circuit diagram

internal series impedance of the microphone. The input impedance of the amplifier can be calculated by looking at what impedance the input sees looking in to the input, this is ,$R1$,$R2$ and the impedance lookin in to the base all in paralell [1]. $R1 = 270k\Omega$,$R2 = 40k\Omega$ and the impedance looking in to the base is $h_{fe} \times R_E$ as h_{fe} is equal to β [1] $265k\Omega = 787(R_4)\Omega \times 337(\beta)$. this works out to be

$$Z_{in} = (\frac{1}{270\times10^3}+\frac{1}{40\times10^3}+\frac{1}{265\times10^3})^{-1} \approx 31k\Omega$$

The input capacitor $C_1 = 10\mu F$ is in series with the input impedance of $31k\Omega$, the capacitor also forms a high pass filter with the input impedance

$$F_c = \frac{1}{2\pi RC} = 0.5Hz$$

[1] As the $3dB$ cut-off point is $0.5Hz$ almost all signal energy will be well above this point so the attenuation of this high pass filter can be ignored as it is negligible at frequencies of interest.

3.1.2 Output Impedance

The output impedance of the amplifier is calculated as the collector resistor in parallel with the resistance looking in to the collector. The resistance of the collector resistor is know as $3.9k\Omega$ and the resistance looking in to the collector is te resistance of the transistor and the emitter resistor in series. As the transistor can be modelled as a current source there is a current source in series with R_E. A current source has impedance $\approx \infty$. The output impedance is therefore the $3.9k\Omega$ resistor in parallel with a near infinite resistance so $Z_{out} \approx 3.9K\Omega$. This output impedance is low enough to allow good signal transfer to the next stage as the input impedance to the next stage is at lowest $4.7k\Omega$ which is higher than the output impedance.

4 Conclusion

References

[1] Paul Horowitz. *The art of electronics*. eng. 2nd ed.. Cambridge [England] ; New York: Cambridge University Press, 1989. ISBN: 0521370957.