GCE ‘O’ Level Electronics

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Table of Contents

1 Project plan

The duration of the coursework spans over a period of 5 months. However, there will be some weeks that are taken up by school holidays, examination, and school events.

As part of the planning process, the following Gantt chart in Figure 1.1.2 and planned timeline for coursework in Fig 1.1.1 was drawn up.

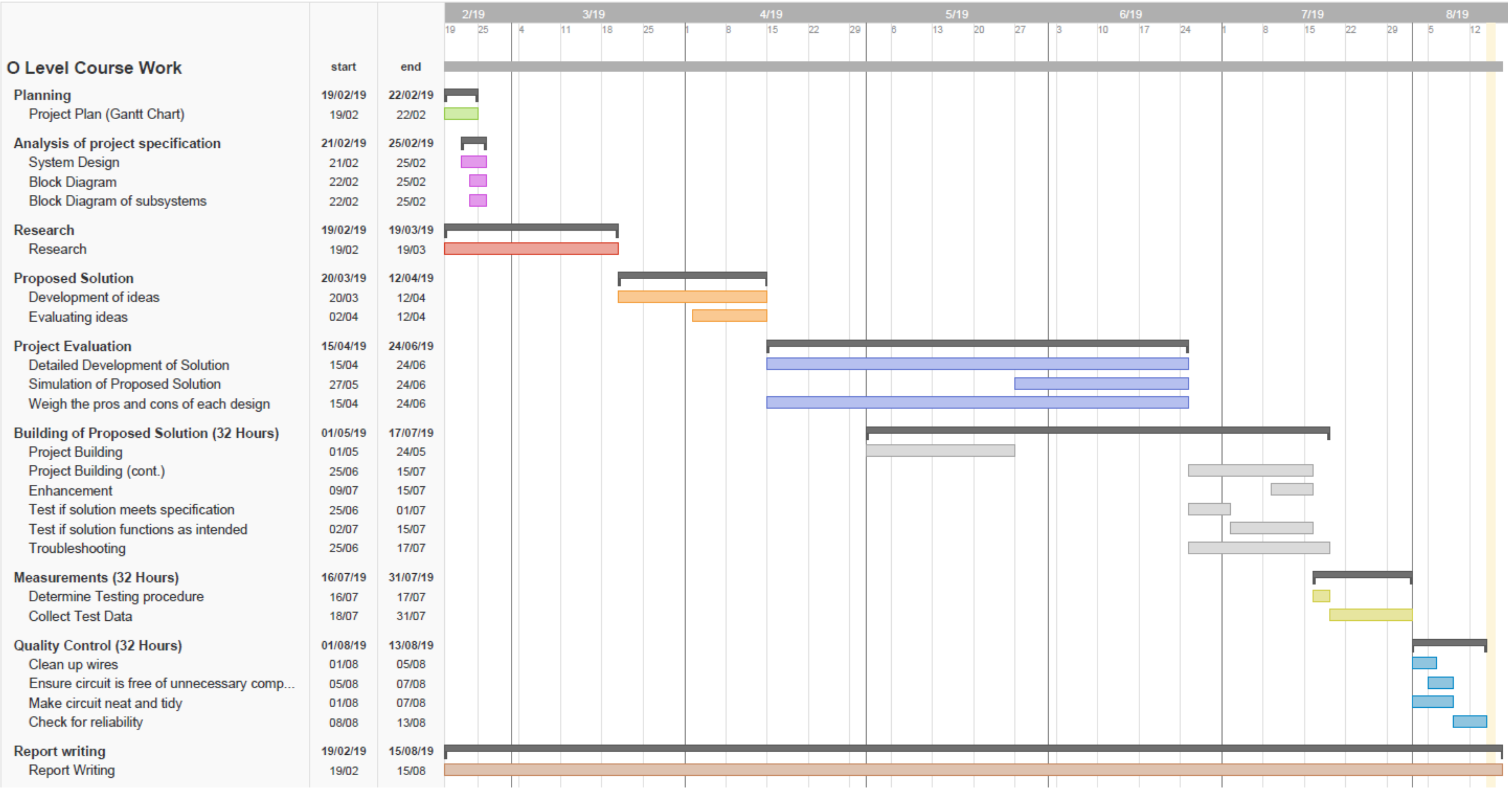
Figure 1.1.1 shows the details of the start date, end date and duration of the various activities. Different activities have a different colour.

1.1 Summary

Some of the key stages took a longer time to complete, which are the building and troubleshooting of the proposed solution. However, by working on some of the other activities concurrently such as doing research and generation of ideas together, the project was still completed before the submission deadline.

Section	Name / Title	Start Date	End Date
1	**Project Duration**	19/2/2019	15/8/2019
1.1	**Planning**	19/2/2019	22/2/2019
1.1.1	Project Plan (Gantt Chart)	19/2/2019	22/2/2019
1.2	**Analysis of project specification**	21/2/2019	25/2/2019
1.2.1	System Design	21/2/2019	25/2/2019
1.2.2	Block Diagram	22/2/2019	25/2/2019
1.2.3	Block Diagram of subsystems	22/2/2019	25/2/2019
1.3	**Research**	19/2/2019	19/3/2019
1.3.1	Research	19/2/2019	19/3/2019
1.4	**Proposed Solution**	20/3/2019	12/4/2019
1.4.1	Development of ideas	20/3/2019	12/4/2019
1.4.2	Evaluating ideas	2/4/2019	12/4/2019
1.5	**Project Evaluation**	15/4/2019	24/6/2019
1.5.1	Detailed Development of Solution	15/4/2019	24/6/2019
1.5.2	Simulation of Proposed Solution	27/5/2019	24/6/2019
1.5.3	Weigh the pros and cons of each design	15/4/2019	24/6/2019
1.6	**Building of Proposed Solution (32 Hours)**	1/5/2019	17/7/2019
1.6.1	Project Building	1/5/2019	24/5/2019
1.6.2	Project Building (cont.)	25/6/2019	15/7/2019
1.6.3	Enhancement	9/7/2019	15/7/2019
1.6.4	Test if solution meets specification	25/6/2019	1/7/2019
1.6.5	Test if solution functions as intended	2/7/2019	15/7/2019
1.6.6	Troubleshooting	25/6/2019	17/7/2019
1.7	**Measurements (32 Hours)**	16/7/2019	31/7/2019
1.7.1	Determine Testing procedure	16/7/2019	17/7/2019
1.7.2	Collect Test Data	18/7/2019	31/7/2019
1.8	**Quality Control (32 Hours)**	1/8/2019	13/8/2019
1.8.1	Clean up wires	1/8/2019	5/8/2019
1.8.2	Ensure circuit is free of unnecessary components	5/8/2019	7/8/2019
1.8.3	Make circuit neat and tidy	1/8/2019	7/8/2019
1.8.4	Check for reliability	8/8/2019	13/8/2019
1.9	**Report writing**	19/2/2019	15/8/2019
1.9.1	Report Writing	19/2/2019	15/8/2019

Figure 1.1.1


2/19
3/19
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6/19
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O Level Course Work
start
end
Planning 19/02/19 22/02/19
Project Plan (Gantt Chart) 19/02 22/02
Analysis of project specification 21/02/19 25/02/19
System Design 21/02 25/02
Block Diagram 22/02 25/02
Block Diagram of subsystems 22/02 25/02
Research 19/02/19 19/03/19
Research 19/02 19/03
Proposed Solution 20/03/19 12/04/19
Development of ideas 20/03 12/04
Evaluating ideas 02/04 12/04
Project Evaluation 15/04/19 24/06/19
Detailed Development of Solution 15/04 24/06
Simulation of Proposed Solution 27/05 24/06
Weigh the pros and cons of each design 15/04 24/06
Building of Proposed Solution (32 Hours) 01/05/19 17/07/19
Project Building 01/05 24/05
Project Building (cont.) 25/06 15/07
Enhancement 09/07 15/07
Test if solution meets specification 25/06 01/07
Test if solution functions as intended 02/07 15/07
Troubleshooting 25/06 17/07
Measurements (32 Hours) 16/07/19 31/07/19
Determine Testing procedure 16/07 17/07
Collect Test Data 18/07 31/07
Quality Control (32 Hours) 01/08/19 13/08/19
Clean up wires 01/08 05/08
Ensure circuit is free of unnecessary comp... 05/08 07/08
Make circuit neat and tidy 01/08 07/08
Check for reliability 08/08 13/08
Report writing 19/02/19 15/08/19
Report Writing 19/02 15/08

Figure 1.1.2

2 Analysis of project specification

A school library wishes to remind pupils that they should be quiet when working. The library has a sign which reads ‘Please Work Quietly’ and they require an LED on the sign to automatically illuminate when the sound level in the library rises above a set level.

In the library, students sometimes get too loud or noisy. This system would alert the students in the library if they become too noisy by turning on a LED mounted on a sign if a certain volume threshold is met.

The baseline design specification of the ‘Work quietly’ sign would include

- A LED which lights up when the noise level is above a pre-set threshold.
- The system would be powered by a PSU not exceeding 12V
- The system should function well and reliably
- The system should be able to measure and quantify the volume of its surroundings (Input)
- The system should turn a LED mounted on a sign on if the volume passes a set threshold (Output)

Based on these requirements, the overall system can be formed by three subsystems. They are:

1. The Input subsystem
2. The Comparing subsystem
3. The Output subsystem

2.1 Block Diagram

Figure 2.2.1 shows the overall block diagram:

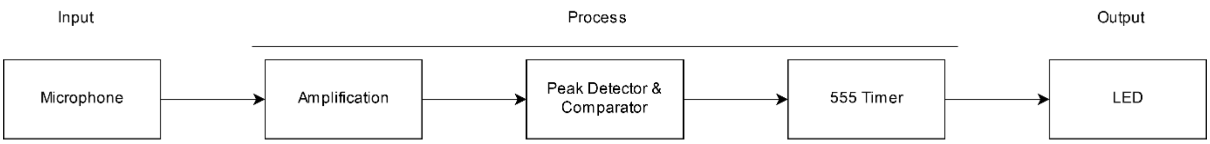


Figure 2.1.1

2.2 Input subsystem

Figure 2.3.1 shows the input subsystem which includes amplification

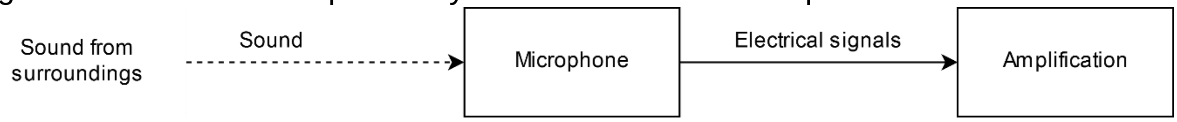


Figure 2.2.1

Some questions and possible areas of research:

- How to use a microphone?
- Is the electrical signal from the microphone large enough to drive the comparator?
- Does the signal need amplification?
- What kind of amplifier IC to use? What are their disadvantages and advantages?
- What is the appropriate gain needed?

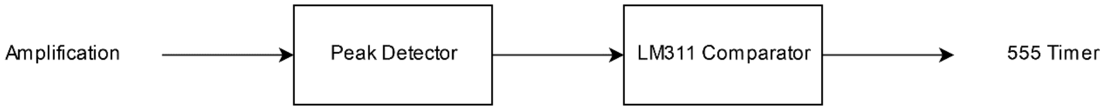


Figure 2.3.1

- Should the gain be adjustable?

2.3 Peak Detector and Comparing subsystem

Figure 2.3.1 shows the peak detector and comparing subsystem

Some questions and possible areas of research:

- What component do I use to build the LM311 comparator?
- Can the comparator be an operational amplifier?
- The output type of the LM311 comparator?
- How to implement a peak detector?
- Is a peak detector necessary?

2.4 555 Timer

Figure 2.5.1 shows the 555-timer subsystem

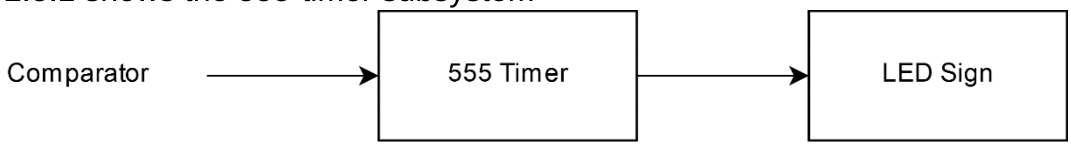


Figure 2.4.1

Some questions and possible areas of research:

- Should the 555 Timer use monostable or astable configuration?
- How do I calculate the required timing resistors and capacitors?

2.5 Voltage supply

An important consideration is that the whole circuit can be powered by a PSU that does not exceed 12V. If there is any component that needs voltages above 12V, then I would need to find a way to provide that voltage from the PSU. I have decided to use 12V for this project due to the issue of ‘clipping’ when using the LM386 on 5V.

3 Research

This section contains the findings from the research performed. The research was conducted based on the research questions described in the previous section.

3.1 Microphone Input and Amplification

3.1.1 Microphone

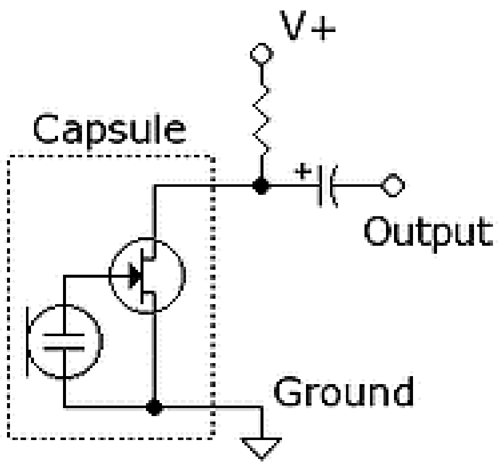


Figure 3.1.1 (Lopez, 2010)

Analysing the project specifications, I needed to make a device that can monitor the sound levels of its surroundings. I learnt from the textbook (page 194) that an input transducer can accomplish this job. The input transducer that I require is an electret microphone which turns sound into electrical signals. An electret microphone is a type of electrostatic capacitor-based microphone, which eliminates the need for a polarizing power supply by using a permanently charged material. I then researched the ways to build a circuit to attain an electrical signal from the microphone. The circuit to do that is as shown in Figure 3.1.1.

However, upon further research, I found out that the electrical signal taken directly from the microphone is very weak and cannot be used without amplification.

3.1.2 LM358

I did some research on the methods to amplify low amplitude signals and found that I need to use an Opamp (Operational Amplifier).

From *Electronic Tutorials*,

> *"An Operational Amplifier, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier"." (Electronics Tutorials, n.d.)*

Upon additional research, I found a common and cheap amplifier the LM358.

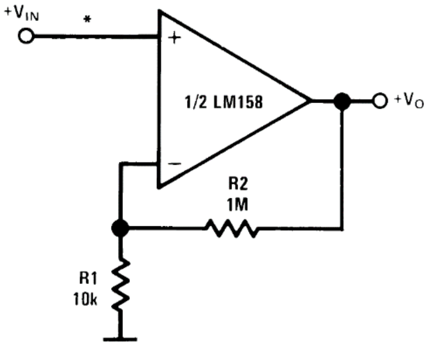


Figure 3.1.2 (Texas Instruments, 2000)

The following circuit (Figure 3.1.2) can be used for a simple non-inverting amplifier:

The following circuit (Figure 3.1.3) shows the inverting opamp configuration being used as a microphone amplifier:

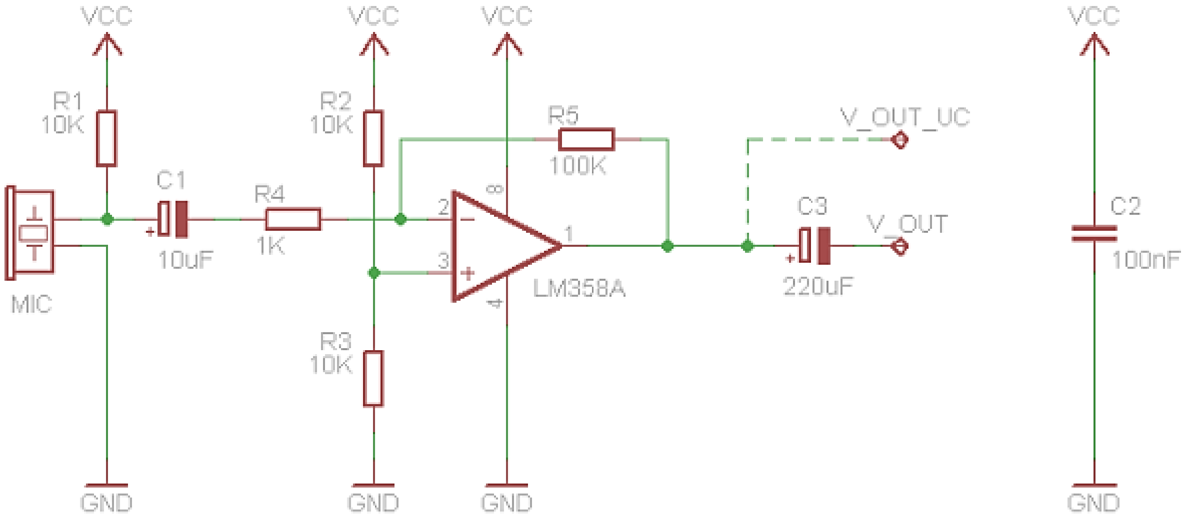


Figure 3.1.3 (Kovachev, 2012)

The gain of the above circuit is given by the following formula:

$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

Figure 3.1.5 (Electronics Tutorials, n.d.)

$$\text{Vout} = -\frac{\text{Rf}}{\text{Rin}} \times \text{Vin}$$

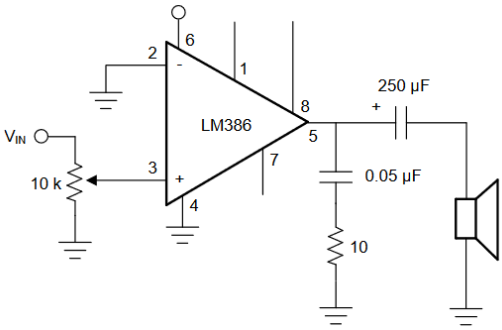
Figure 3.1.4 (Electronics Tutorials, n.d.)

3.1.3 LM386

While researching on the LM358, I came across the LM386 audio amplifier. The LM386 is an audio power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value from 20 to 200. The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The LM386 requires minimal external components. Figure 3.1.6 shows an example LM386 circuit.

9.2.1 LM386 with Gain = 20

Figure 10 shows the minimum part count application that can be implemented using LM386. Its gain is internally set to 20.



Copyright © 2017, Texas Instruments Incorporated

Figure 10. LM386 with Gain = 20

9.2.1.1 Design Requirements

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

Figure 3.1.6 (Texas Instruments, 2004)

3.1.4 Gain adjustment

According to the datasheet of the LM386:

> *"To make the LM386 a more versatile amplifier, two pins (1 and 8) are provided for gain control. With pins 1 and 8 open the 1.35-kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 1 to 8, bypassing the 1.35-kΩ resistor, the gain will go up to 200 (46 dB). If a resistor is placed in series with the capacitor, the gain can be set to any value from 20 to 200. Gain control can also be done by capacitive coupling a resistor (or FET) from pin 1 to ground. Additional external components can be placed in parallel with the internal feedback resistors to tailor the gain and frequency response for individual applications. For example, we can compensate poor*

speaker bass response by frequency shaping the feedback path. This is done with a series RC from pin 1 to 5 (paralleling the internal 15-kΩ resistor). For 6 dB effective bass boost: R ~= 15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 8 is open. If pins 1 and 8 are bypassed, then R as low as 2 kΩ can be used. This restriction is because the amplifier is only compensated for closed-loop gains greater than 9." (Texas Instruments, 2004)

This means that the gain to the amplifier can be adjusted the gain to the amplifier by putting a capacitor in series with a trim pot between pin 1 and 8.

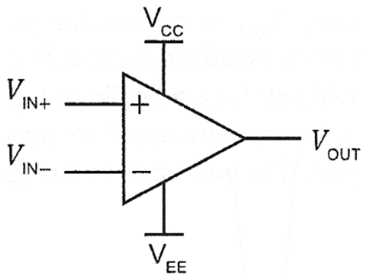


Figure 3.1.1 (Ministry of Education, 2017)

3.2 Comparator

From the Electronics textbook 335 to 344, I learnt that comparators can be used to compare two analogue signals. As shown in Figure 3.2.1, a voltage comparator has two analogue inputs, V_{IN-} and V_{IN+} and one digital output, V_{OUT}.

V_{IN+} is called the non-inverting input and is connected to the terminal labelled '+' while V_{IN-} is called the inverting input and is connected to the terminal labelled '-'.

The comparator has two voltage supply terminals. The upper terminal is connected to a positive supply voltage, V_{CC} The lower terminal is connected to a negative supply voltage, V_{EE} or 0 V (GND)

V_{OUT} is dependent on the two inputs:

If V_{IN+} is higher than V_{IN-}, V_{OUT} will be HIGH.
If V_{IN+} is lower than V_{IN-}, V_{OUT} will be LOW.

The voltage level of the HIGH output state is equal to V_{CC} Depending on the type of voltage comparator used, the LOW output state is equal to either V_{EE} or 0 V. Since we were only taught to how to use the LM311 using 0 V for V_{EE} the LOW output state will always be 0 V.

The pin diagram and pin definitions are shown in Figure 3.3.2 and Figure 3.2.3 below:

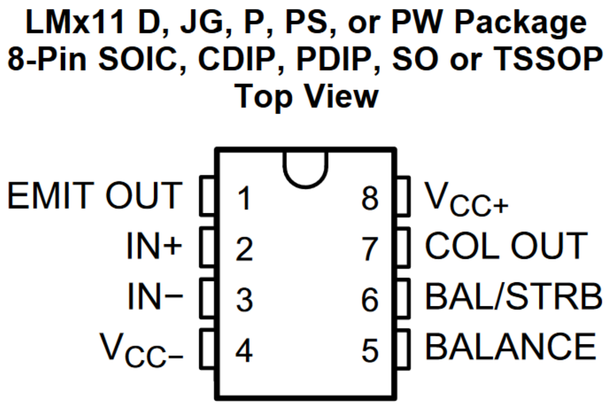


Figure 3.2.2 (Texas Instruments, 1973)

NAME	PIN				I/O (1)	DESCRIPTION
	LM211, LM311	LM311	LM111	LM111		
	SOIC, PDIP, TSSOP	SO	CDIP	LCCC		
IN+	2	2	2	5	I	Noninverting comparator
IN–	3	3	3	7	I	Inverting input comparator
BALANCE	5	5	5	12	I	Balance
BAL/STRB	6	6	6	15	I	Strobe
COL OUT	7	7	7	17	O	Output collector comparator
EMIT OUT	1	1	1	2	O	Output emitter comparator
V_{CC}–	4	4	4	10	—	Negative supply
V_{CC}+	8	8	8	20	—	Positive supply

Figure 3.2.3 (Texas Instruments, 1973)

The circuit on how to use an LM311 to perform voltage comparison is shown in Figure 3.2.4:

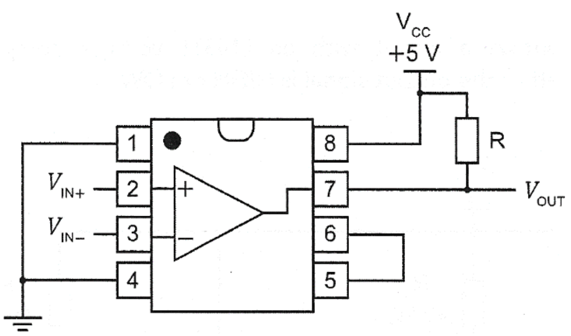


Figure 3.2.4 (Ministry of Education, 2017)

Since the LM311 has an open collector output, R will be needed to pull the voltage of pin 7 to V_{CC}. Without this pull-up resistor, the comparator will not be able to produce a HIGH output.

3.3 555 Timer

For the sign to be seen, I needed the output to stay HIGH for a few seconds. This can be achieved by using a 555-timer configured as a monostable multivibrator. From textbook pages 345 to 357, I learnt how to use the 555 timer as a monostable multivibrator.

Figure 3.3.1 and Figure 3.3.2 show the pin connection diagram and the pin functions, respectively.

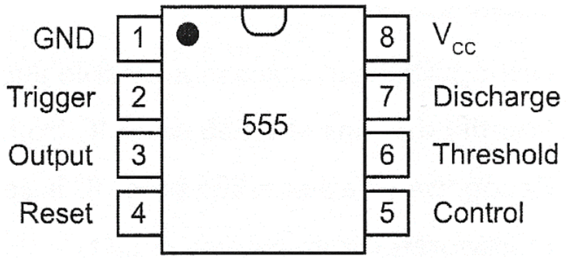


Figure 3.3.1 (Ministry of Education, 2017)

Pin	Name	Function
1	GND	Connects to 0 V (ground)
2	Trigger	Causes the output at pin 3 to go HIGH and starts the timing cycle when its voltage drops below $\frac{1}{3}V_{CC}$
3	Output	Produces a digital output: LOW (close to 0 V) or HIGH ($\approx V_{CC} - 1.5$ V)
4	Reset	Resets the timing interval when connected to the ground The timer will not start again until triggered by pin 2. When not in use, this pin is connected to V_{CC}.
5	Control	Controls the trigger and threshold level In most basic applications, this pin is not used and is connected to the ground through a 10 nF capacitor.
6	Threshold	Monitors the voltage across the external capacitor When the voltage at this pin reaches $\frac{2}{3}V_{CC}$, the timing cycle ends and the output on pin 3 goes LOW.
7	Discharge	Connects to the ground and discharges the external capacitor connected to it when the output is LOW and acts like an open circuit when the output is HIGH
8	V_{CC}	Connected to a positive voltage supply between 5 V and 15 V

Figure 3.3.2 (Ministry of Education, 2017)

The pulse width of the output is determined by this equation:

$$\tau = 1.1RC$$

Figure 3.3.3 shows the circuit of the 555-timer configured as a monostable multivibrator.

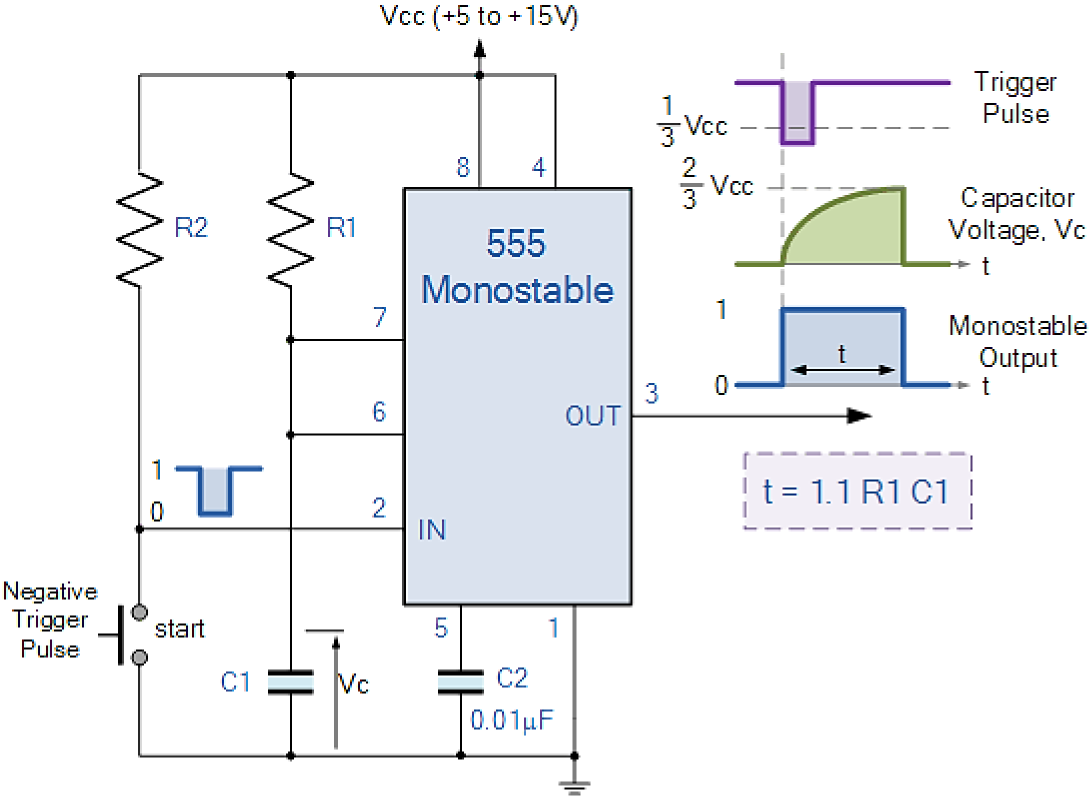


Figure 3.3.3 (Electronics Tutorials, n.d.)

3.4 BJT Output Driver

From page 221 to page 237 of the Electronics Textbook, I learnt how a BJT works and how to use a BJT as a switch to drive an LED.

Figure 3.4.1 shows how to use a BJT as a switch.

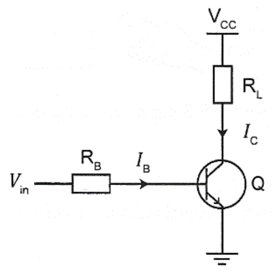


Figure 3.4.1 (Ministry of Education, 2017)

From the textbook page 235, the relevant equations to calculate R_b is as shown:

$$I_{C(sat)} = \frac{V_{cc} - V_{CE(sat)} - V_F}{R_L}$$

$$R_B = \frac{V_{in} - V_{BE}}{I_B}$$

3.5 SR Latch

From textbook pages 322 to 328, I learnt how to build an SR latch. In electronics, a latch is a type of digital circuit that can store a logic state (1 or 0), This makes it a single-bit memory system. The SR latch consists of two inputs (S and R) and two outputs (Q and $\bar{Q}$). We set the S-R latch when we want the output to become active (i.e. Q = 1). Conversely, we 'reset' the S.R latch when we want the output to become inactive (i.e. Q = 0). The output is always the inverse of $\bar{Q}$.

Figure 3.5.1 shows how to build an SR latch out of NOR Gates. Figure 3.5.2 shows the SR latch truth table.

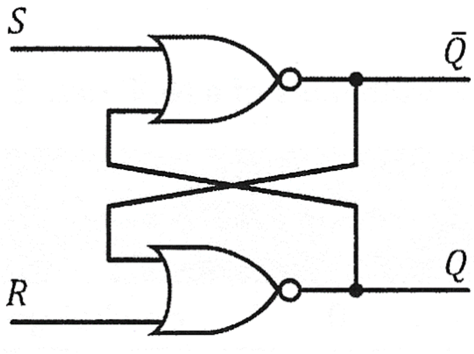


Figure 3.5.1 (Ministry of Education, 2017)

Inputs		Outputs		
S	R	Q	$\bar{Q}$	
0	0	no change		
0	1	0	1	← RESET state
1	0	1	0	← SET state
1	1	invalid		

Figure 3.5.2 (Ministry of Education, 2017)

3.6 Rectifier

In the Electronics textbook pages 167 to 169, we learnt about bridge rectifiers. The half-wave bridge rectifier works by letting current flow when it is forward biased and not letting it flow when reverse-biased. This converts an AC signal into a DC signal by removing the negative half of the AC signal.

Figure 3.6.1 shows a half-wave rectifier.

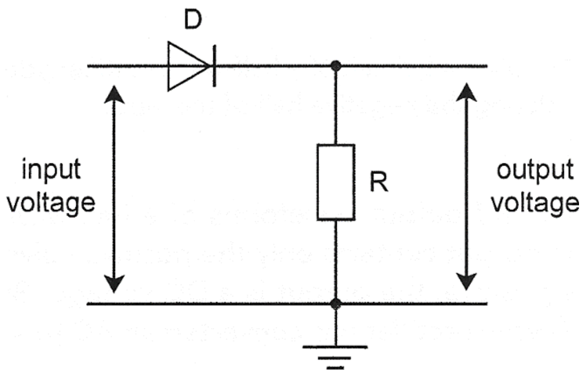


Figure 3.6.1 (Ministry of Education, 2017)

3.7 Peak Detector

3.7.1 Simple Diode

From Learning About Electronics, a peak detector circuit is a circuit that is able to measure the peak amplitude that occurs in a waveform. It is able to tell us what the highest value a waveform reaches. Figure 3.7.1 shows a simple diode peak detector circuit. It is similar to the half-wave rectifier with a filter capacitor on its output.

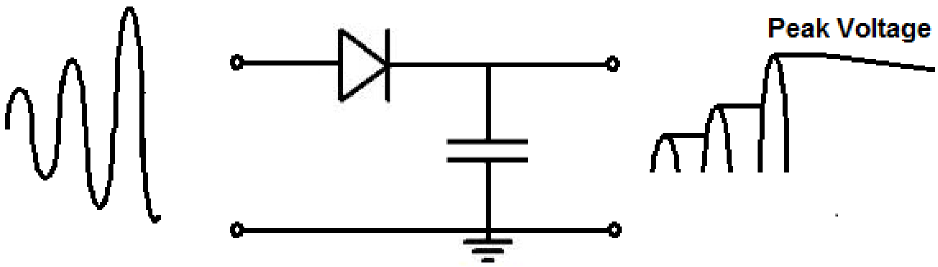


Figure 3.7.1 (Learning About Electronics, n.d.)

The diode conducts as described in the half-wave rectifier section, charging the capacitor to the waveform peak. When the input waveform falls below the DC “peak” stored on the capacitor, the diode is reverse biased, blocking current flow from the capacitor back to the source. Thus, the capacitor retains the peak value even as the waveform drops to zero. A resistor can be added in parallel with the capacitor to control how fast the peak detector resets.

One crucial point to note is that the capacitor should be sufficiently large as the larger the input voltage, the greater the capacitance needed.

3.7.2 Opamp based

Figure 3.7.2 shows an opamp-based peak detector. The circuit consists of two opamps configured as voltage followers (buffers) feeding into a simple diode peak detector.

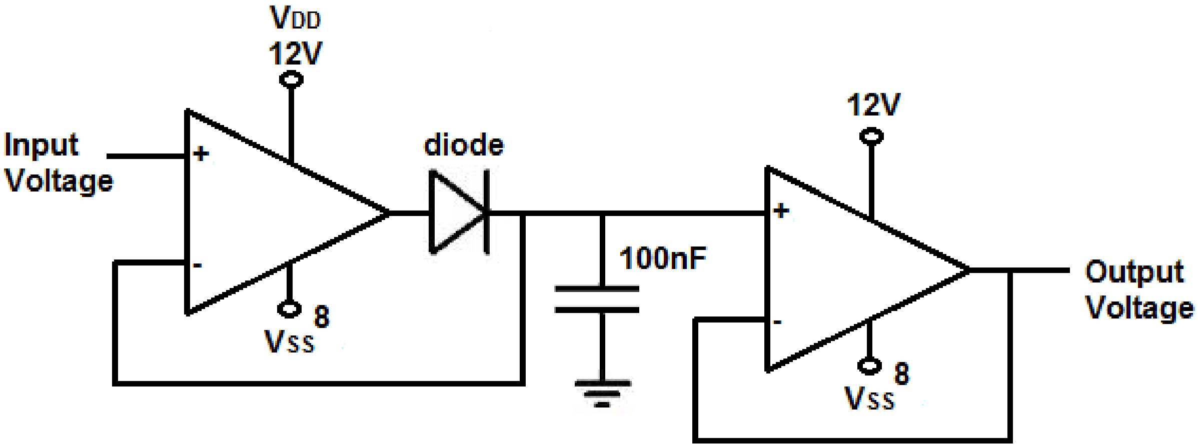


Figure 3.7.2 (Learning About Electronics, n.d.)

The website *Learning About Electronics* states the benefits of the opamp peak detector over a simple diode peak detector:

> *"So instead of using only simple components to build a peak detector circuit, we also add buffers to the circuit. The buffer is much more stable than a diode. A diode is a simple component that is not as precise. Understanding, the physics a diode is basically a PN junction semiconductor material and it is very sensitive to temperature variation. The reverse current is very sensitive to the junction temperature. If you're building this circuit at home, where you're at room temperature and you keep it there, you shouldn't encounter too any problems because of this. But if you're building a commercial-grade product, you wouldn't want to be use a diode for precision applications due to fluctuations the diode can cause. Instead an op amp provides much better stability with a diode rather than with just a diode alone." (Learning About Electronics, n.d.)*

This approach allows for precise peaks to be detected and stored as there is no voltage drop across the diode and the input impedance of the opamps are extremely high.

4 Investigation and generation of ideas

4.1 Peak Detector

4.1.1 Opamp based

Using the research that I did earlier, I simulated the following opamp based peak detector (Figure 4.1.1). Firstly, the input signal from the microphone (AC source) is fed into a half-bridge rectifier. The always positive signal is then fed into the circuit described in my research. The smoothed signal is the output from the 2nd opamp.

One of the limitations that I found for this design is the need for a negative supply rail. (i.e. -12V)

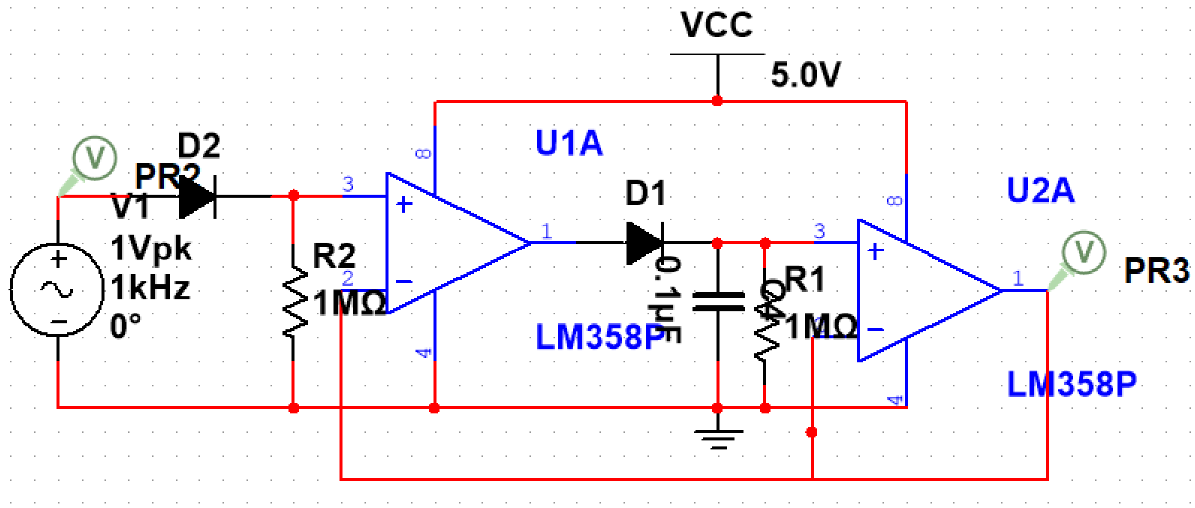


Figure 4.1.1

In Figure 4.1.2, the input is represented as blue and the smoothed output as green.

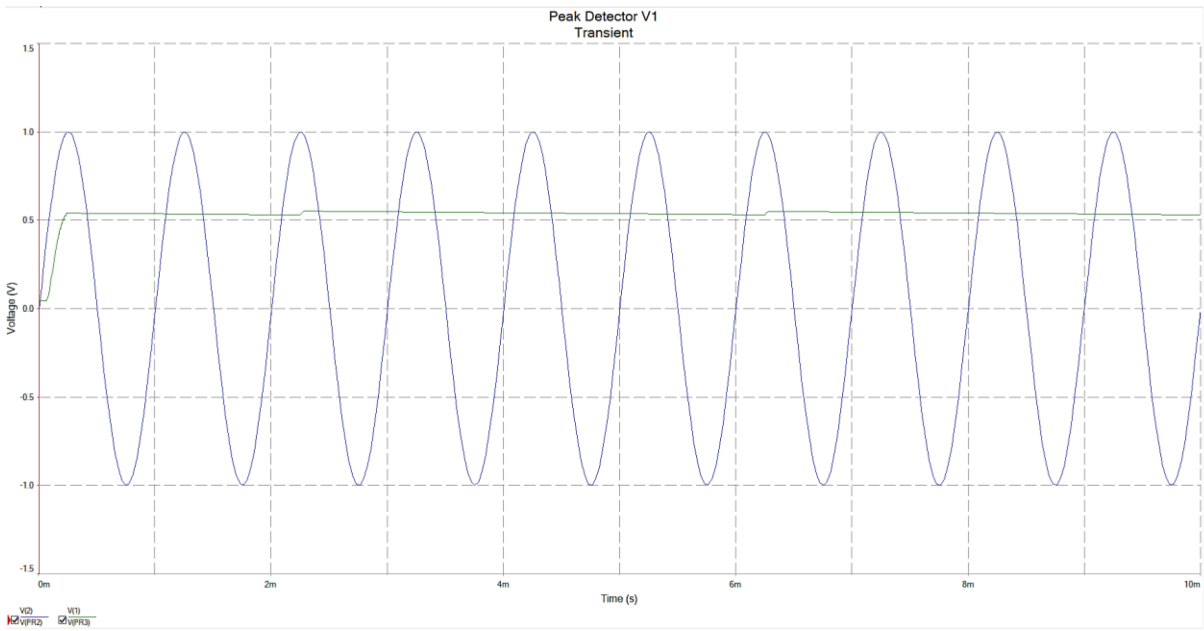


Figure 4.1.2

4.1.2 Simple diode

Using the research that I did earlier, I simulated the following diode peak detector. This circuit consists of a half-bridge rectifier and a capacitor, letting current pass through when the AC signal is in the positive phase. The circuit worked as expected as managed to smooth the AC signal.

This circuit is shown in Figure 4.1.3 and the output graph in Figure 4.1.4. The input is represented as blue and the smoothed output as yellow.

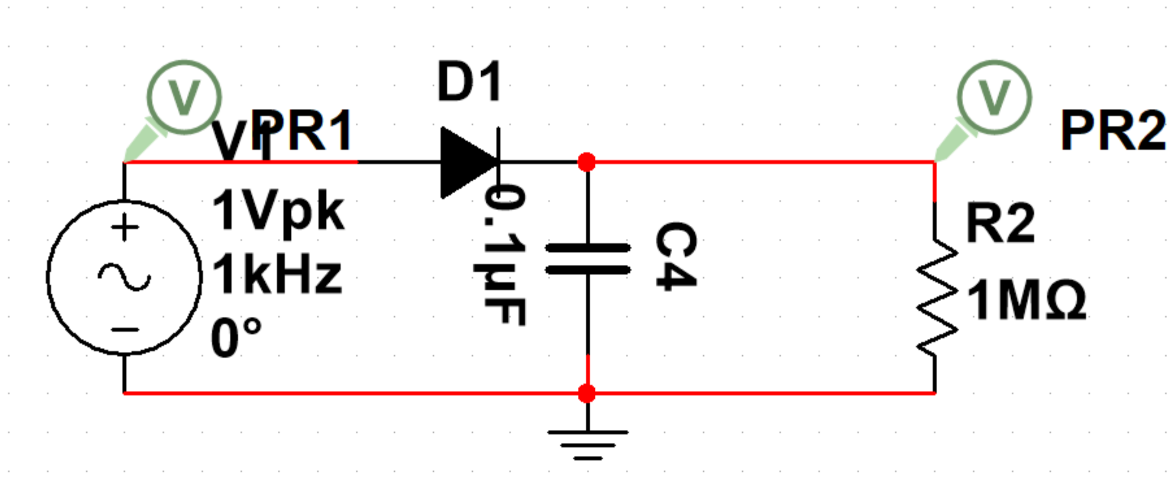


Figure 4.1.3

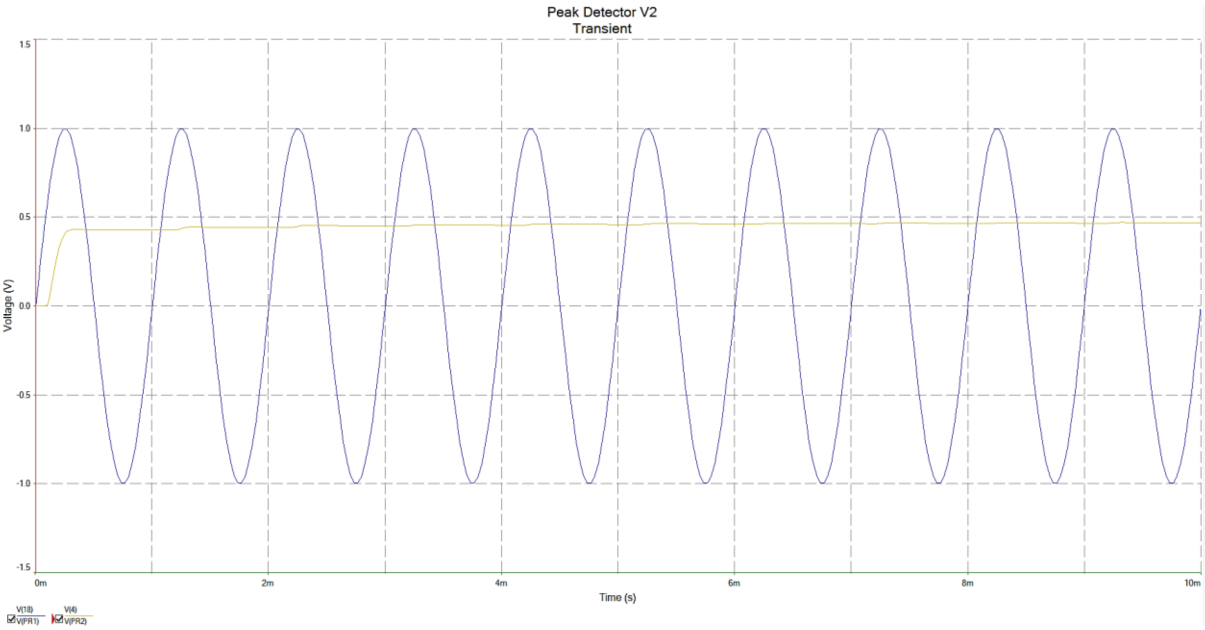


Figure 4.1.4

4.2 555 Timer

I did a detailed investigation of the 555 Timer using Multisim. I simulated the following circuit of a 555 configured in a monostable configuration with an SR latch reset pin connect to its output and the SR latch reset pin connected to the input button with a NOT gate attaching it to the trigger pin of the 555 Timer. The circuit is shown in Figure 4.2.1.

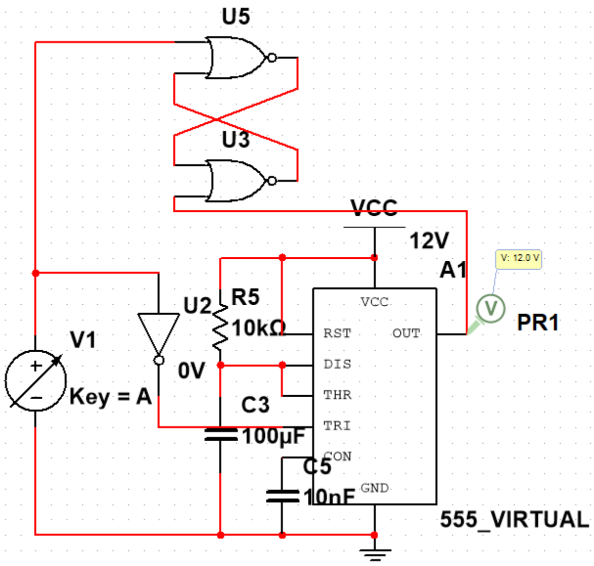


Figure 4.2.1

However, after simulating the circuit, I discovered that I could simplify the circuit into a standard monostable circuit. The circuit is shown in Figure 4.2.2.

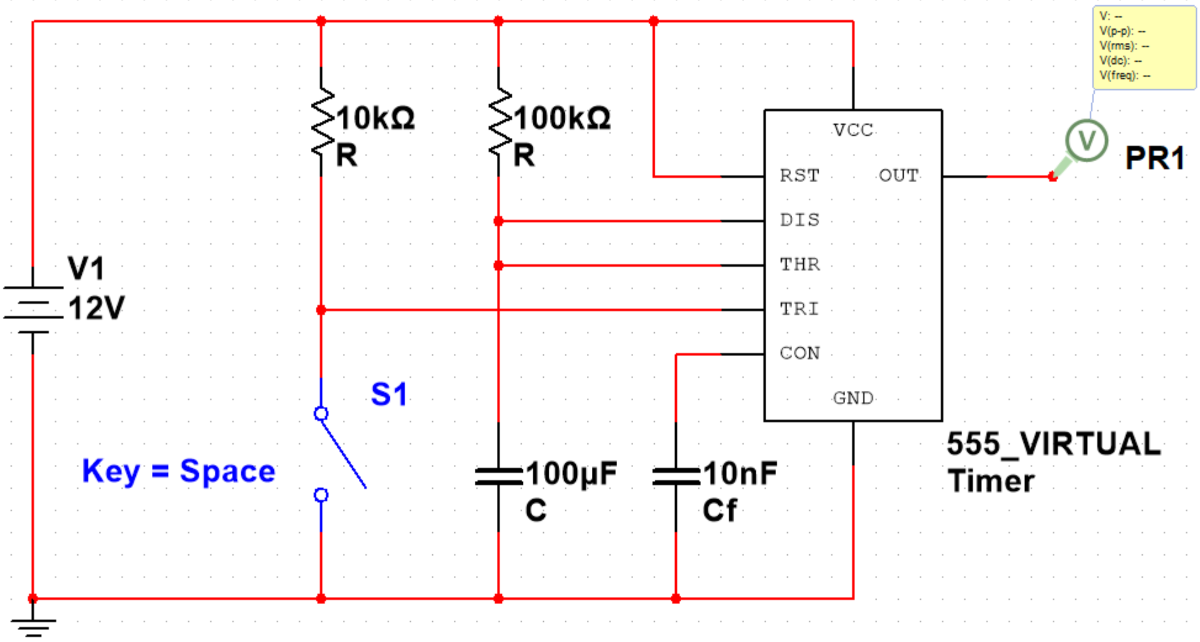
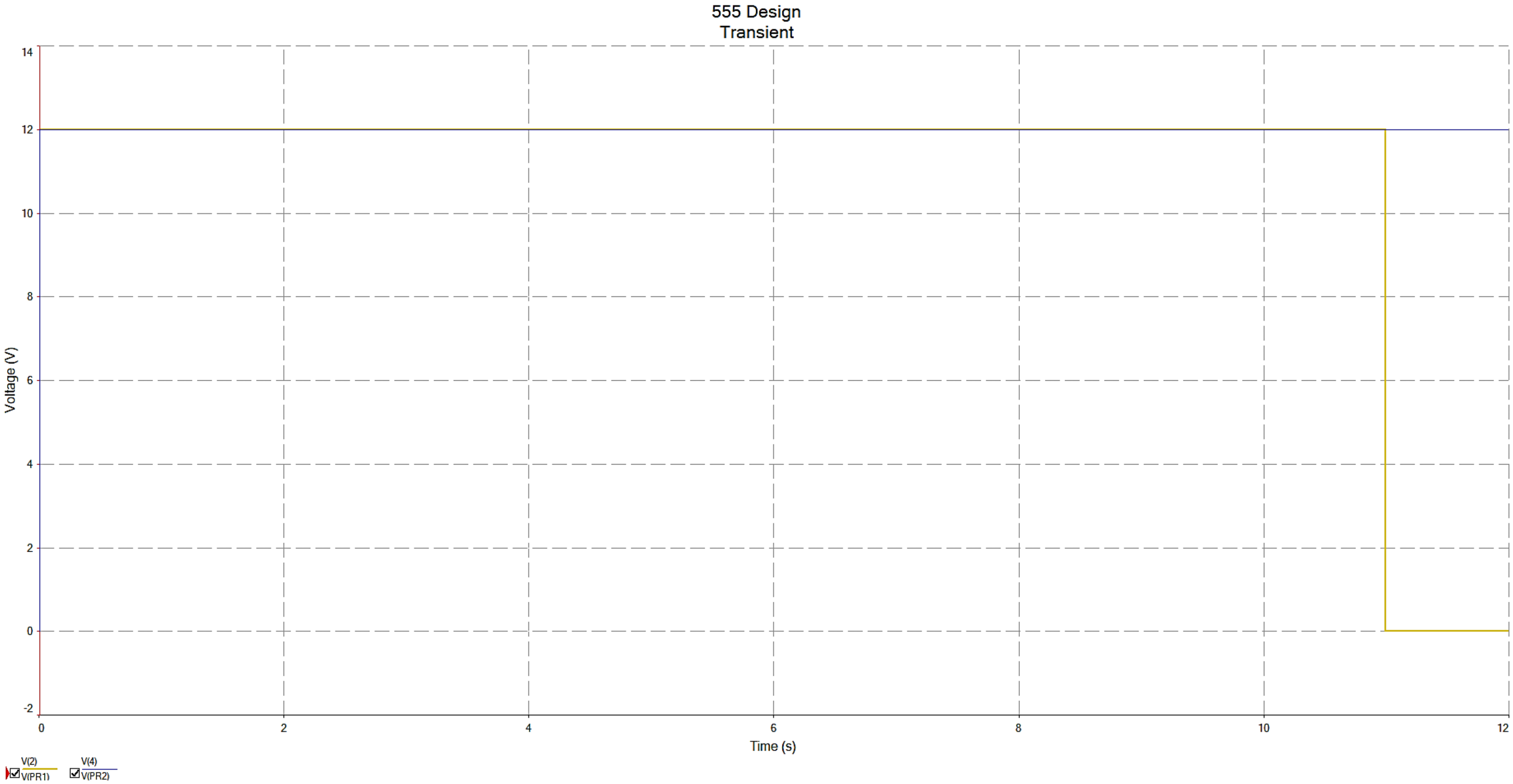


Figure 4.2.2

I simulated the circuit again and it gave a nice rectangular output pulse with a period of about 11s. The output of the simulation is shown in Figure 4.2.3 with the output represent as yellow and the input as blue.



555 Design
Transient
14
12
10
8
6
4
2
0
-2
Voltage (V)
0
2
4
6
8
10
12
Time (s)
V(2)
V(PR1)
V(4)
V(PR2)

Figure 4.2.3

4.3 Comparator

I did a detailed investigation of the LM311 comparator using Multisim. I simulated the following circuit (Figure 4.3.1 and Figure 4.3.2) found in my research to understand how it worked:

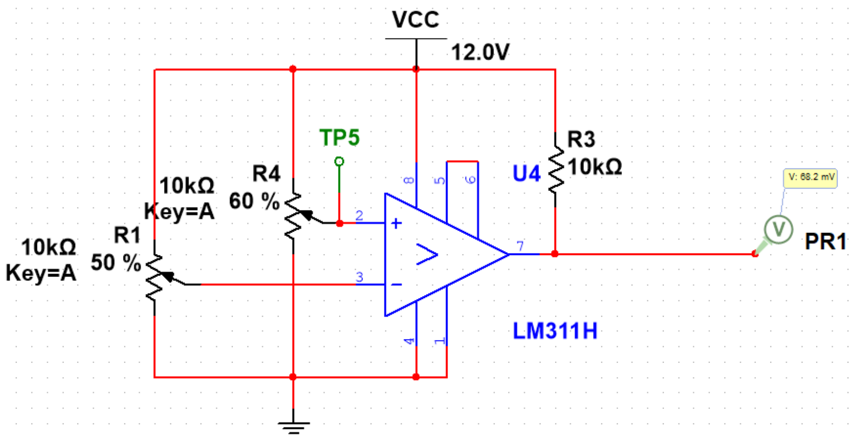


Figure 4.3.1

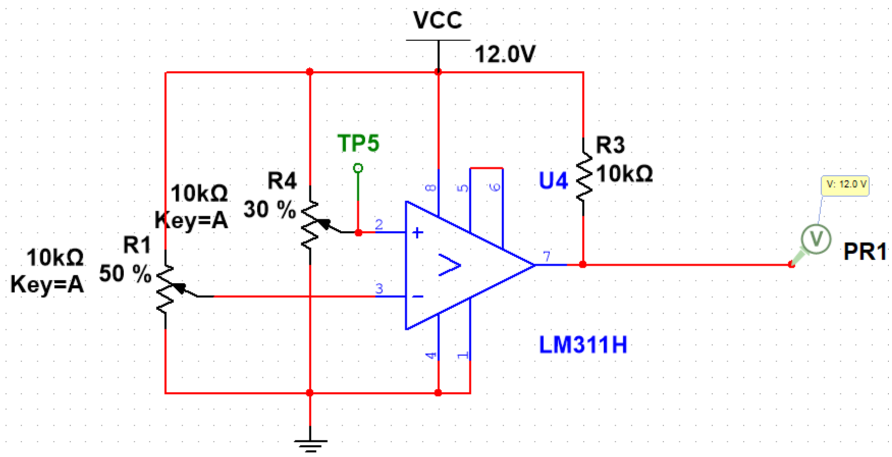


Figure 4.3.2

Figure 4.3.1 shows the output of the comparator when the “+” input is greater than the “-” input.

Figure 4.3.2 shows the output of the comparator when the “+” input is less than the “-” input.

4.4 LM386

4.4.1 Version 1

I did a detailed investigation of the LM386 integrated audio amplifier using Multisim. As the symbol and component were unavailable for the LM386, I had to create my own custom component using the Component Wizard[1] and entered the SPICE model of the LM386[2]. I simulated the following circuit (Figure 4.4.1) found in my research under the section of LM386 to understand how to use it. An AC source is used in this circuit to simulate a microphone. The AC signal is fed into the + input of the LM386. The LM386 is configured for a gain of 20. The output is then filtered through a coupling capacitor to block any DC but allow AC signals to pass through.

The output waveform is shown in Figure 4.4.2 with blue representing the output and yellow representing the input.

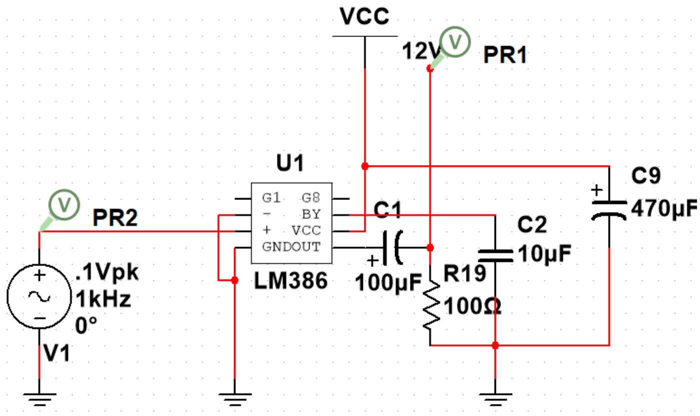


Figure 4.4.1

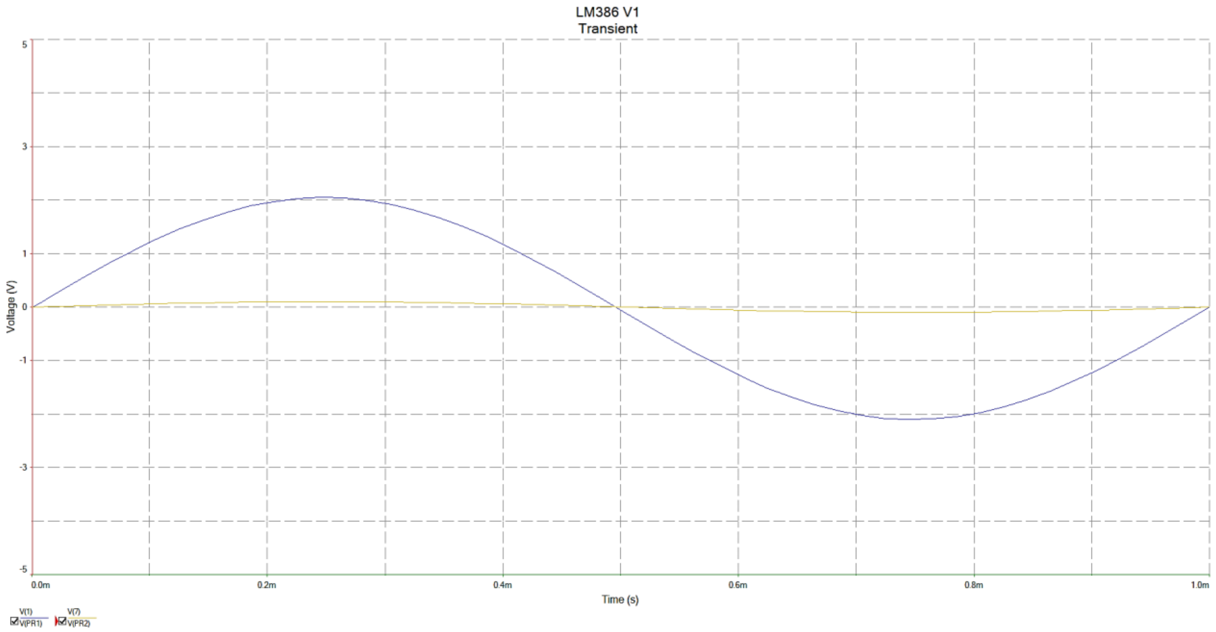


Figure 4.4.2

[1] http://ecee.colorado.edu/~mathys/ecen1400/Software/CreateLM386.html
[2] https://raw.githubusercontent.com/knightshrub/Spice-models/master/sub/LM386.sub

4.4.2 Version 2

Knowing that the basic circuit in version 1 worked, I improved upon it by implementing adjustable gain using a capacitor and a variable resistor in series (Figure 4.4.3).

The output waveform is shown in Figure 4.4.4 with blue representing the output and yellow representing the input. The waveform's amplitude is double that of the previous version.

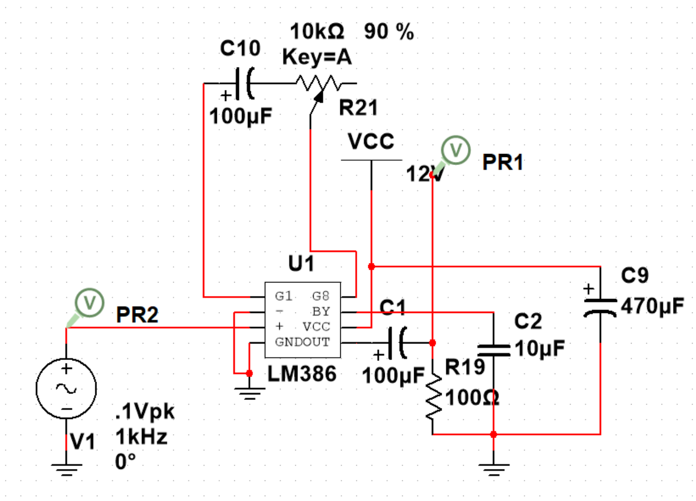


Figure 4.4.3

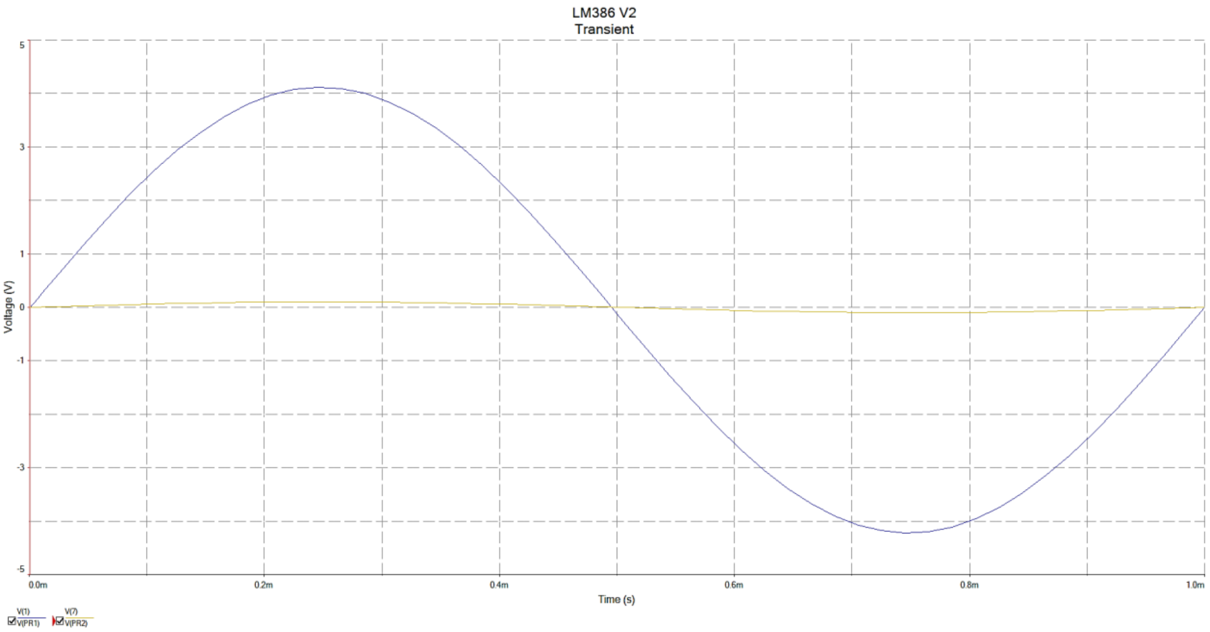


Figure 4.4.4

4.5 LM358

I did a detailed investigation of the LM358 opamp using Multisim. I simulated the following circuit (Figure 4.5.1) found in my research under the section of LM358 to understand how it to use it. An AC source is used in this circuit to simulate a microphone. The AC signal is then fed into an inverting amplifier configured for a gain of 10. The output is then filtered through a coupling capacitor to block any DC but allow AC signals to pass through.

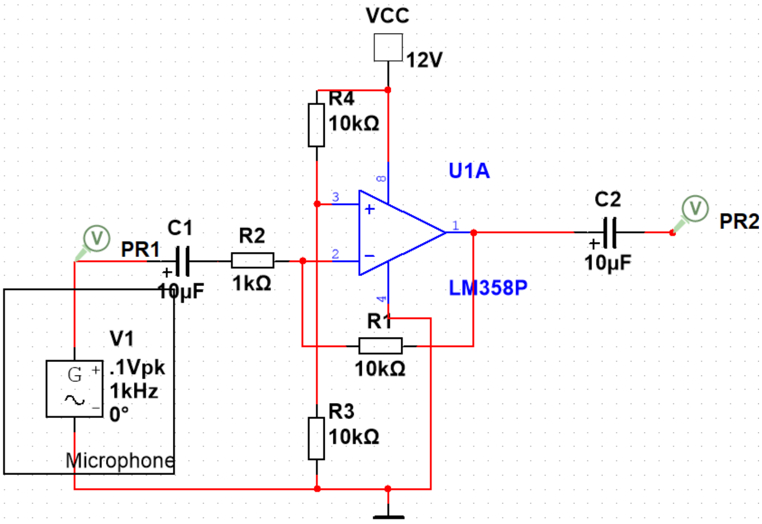


Figure 4.5.1

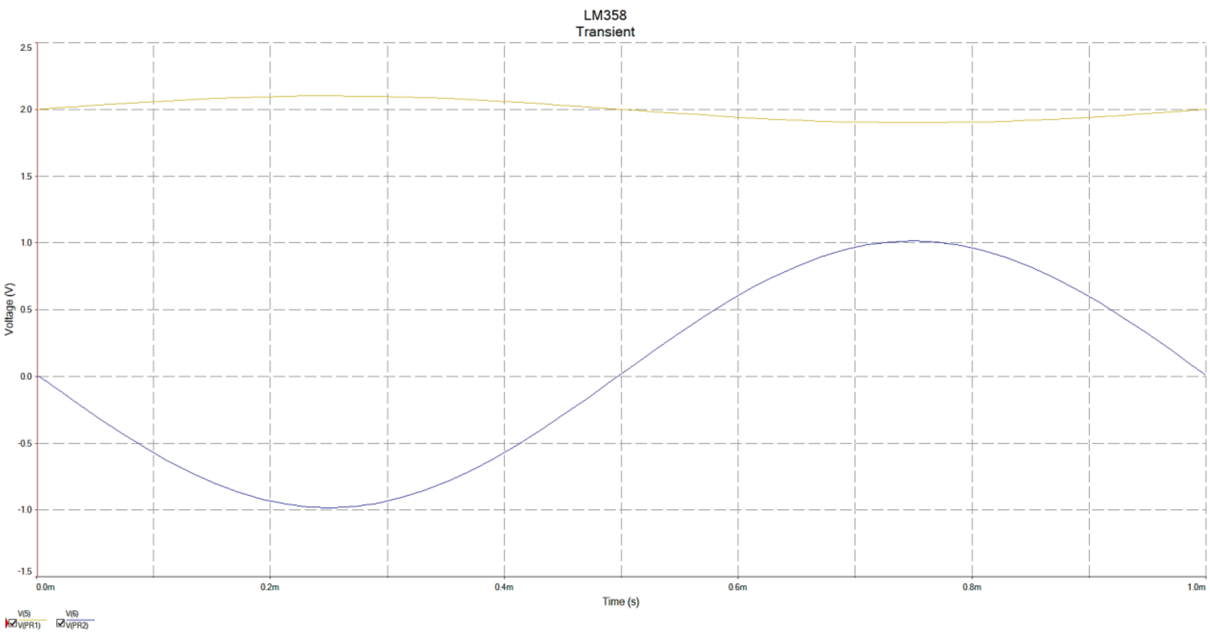


Figure 4.5.2

4.6 Enhancements

These are the following enhancements that would make the prototype perform significantly better than the baseline specification and improves the user experience.

1. The LED sign should remain on for a specific time
2. An audio bar graph can be implemented and can be used to calibrate the noise threshold

For point 1, the baseline specification only specifies that the LED should light up if the volume of the surroundings exceeds a predetermined threshold. However, the noise level usually exceeds the threshold only for a few seconds and thus the LED would only light up for a few seconds and then turn off. This defeats the purpose of the sign to alert students if their noise level is too high. Therefore, I propose that an enhancement to the baseline specification would be to let the LED light up for about 12 seconds. This gives allows students to see that they are too noisy and lower their volume.

For point 2, there is difficulty in calibrating the threshold for when the device triggers. This is because the ‘loudness’ of the surroundings is hard to quantify. Therefore, I propose that an audio bar graph to be implemented to facilitate calibration of the device. The audio bar graph would use the same signal as the comparator and display the volume in a visual form. Thus, it allows precise calibration of the device as how loud the surrounding is can be seen from the number of LEDs lighted up.

5 Test results

Testing setup and parameters:

- Function Generator is used in place of the microphone.
- Frequency of Function generator: 1kHz
- 40dB attenuation set
- Function Generator V_{pk-pk}: 50mV
- No offset

5.1 Expected Voltage Values

Test Point	Description	Values (V)	Remarks
TP5	Threshold voltage for comparator	3.75	
TP7	Offset voltage for bar graph	3.385	
TP9	Output of 555 Timer	10.66	21mV when off
TP10	Reference voltage for bar graph	2.923	
TP11	Reference voltage for bar graph	2.349	
TP12	Reference voltage for bar graph	1.765	
TP13	Reference voltage for bar graph	1.181	
TP14	Reference voltage for bar graph	0.602	

5.2 Testing procedures

Description and objective of the test	Test conditions and procedures	Observation and measurements
1. To test if the system fulfils the baseline specification	a. Conduct the test in a quiet environment b. Conduct the test in a noisy environment	a. The Yellow LED should not light up b. The Yellow LED should light up for around 12 seconds
2. To test if the gain adjustment trim pot allows the gain to be adjusted	a. Connect an oscilloscope to TP1 and TP3 b. Connect a function generator to TP1 c. Adjust the gain by adjusting the trim pot	a. The amplitude of the signal at TP3 should vary according to how much the trim pot is turned
3. To determine the noise threshold	a. Conduct the test in a quiet environment b. Connect a multimeter to TP8 c. Adjust the comparator trim pot so that the voltage at TP8 remains at 5V d. Verify the adjustment by conducting the test in a noisy environment e. The voltage at TP8 should be 0V	a. The Yellow LED should remain off in a quiet environment b. The Yellow Led should remain on in a noisy environment
4. To set the offset of the bar graph	a. Conduct the test in a quiet environment b. Adjust the trim pot of the bar graph subsystem so that the first green LED just turns from on to off c. Verify that the bar graph works by blowing into the microphone	a. When the microphone is blown, the bar graph should light up all the way into the red zone

5.3 Field Test

5.3.1 Function Generator assisted testing

All test conducted under this section has the following parameters unless stated otherwise:

- Function Generator is used in place of the microphone with it being connected to TP1
- Function Generator $V_{pk\text{-}pk}$: 50mV
- 40dB attenuation set
- No offset

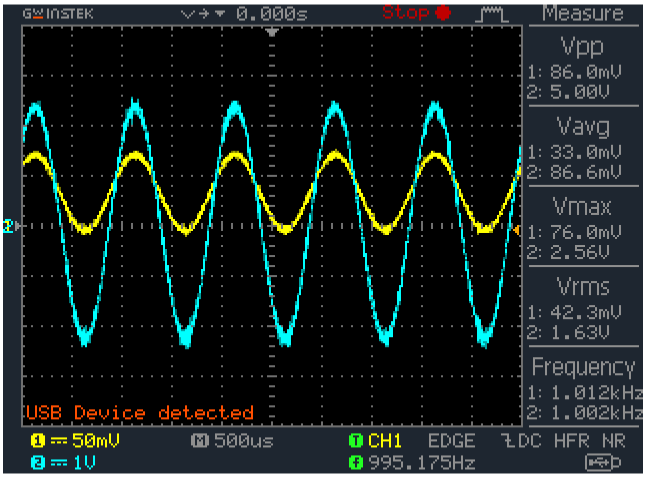


Figure 5.3.1 (500µs/div)

TP1 – TP3

TP1 – Yellow – 50mV/div

TP3 – Blue – 1V/div

This test shows that the amplifier amplifies the signal

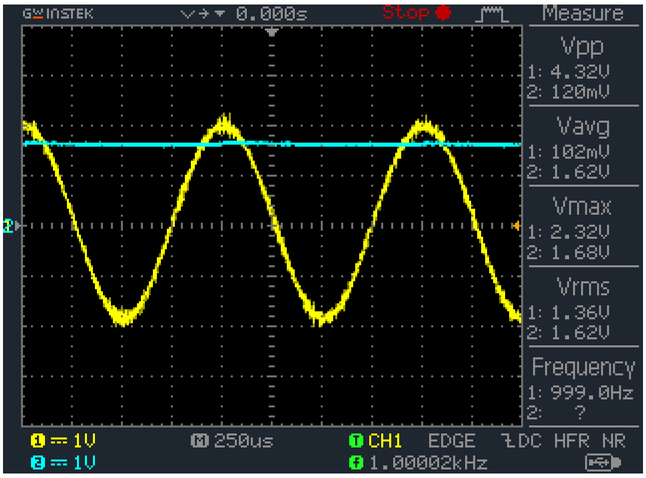


Figure 5.3.2 (250µs/div)

<u>TP3 – TP4</u>

TP3 – Yellow – 1V/div

TP4 – Blue – 1V/div

This test shows the smoothing effect of the peak detector.

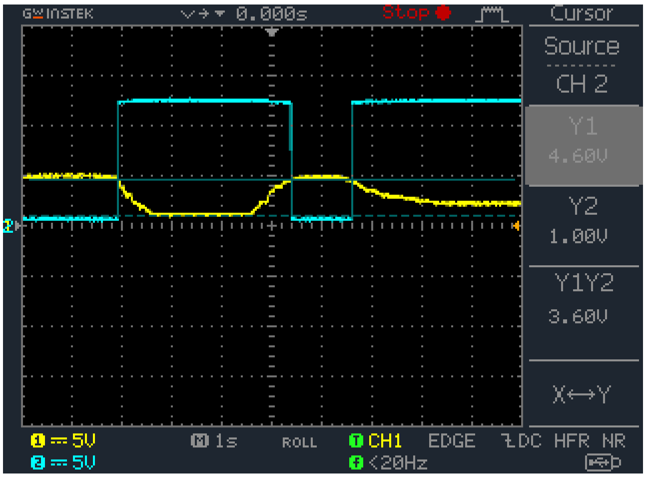


Figure 5.3.3 (1s/div)

<u>TP4 – TP8</u>

TP4 – Yellow – 5V/div

TP8 – Blue – 5V/div

The amplitude of the function generator (V_{pp}) was adjusted to simulate noise level changes.

This test is to show the effects of various levels of noise on the output of the comparator

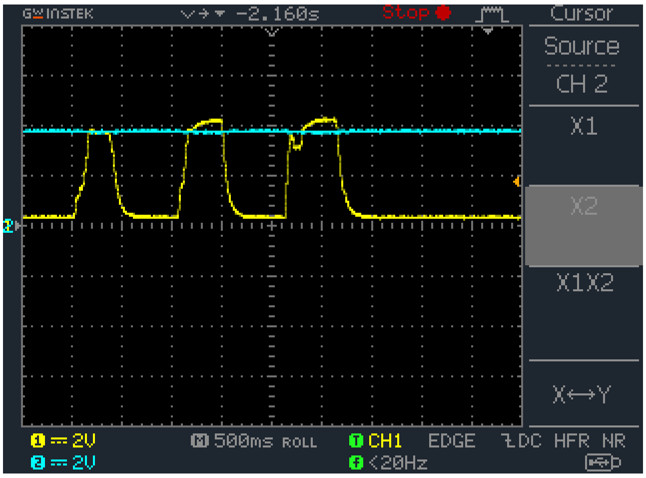


Figure 5.3.4 (500ms/div)

TP4 – TP5

TP4 – Yellow – 5V/div

TP5 – Blue – 5V/div

The amplitude of the function generator (V_{pp}) was adjusted to simulate noise level changes.

This test is to show the effects of various levels of noise vs the reference threshold voltage

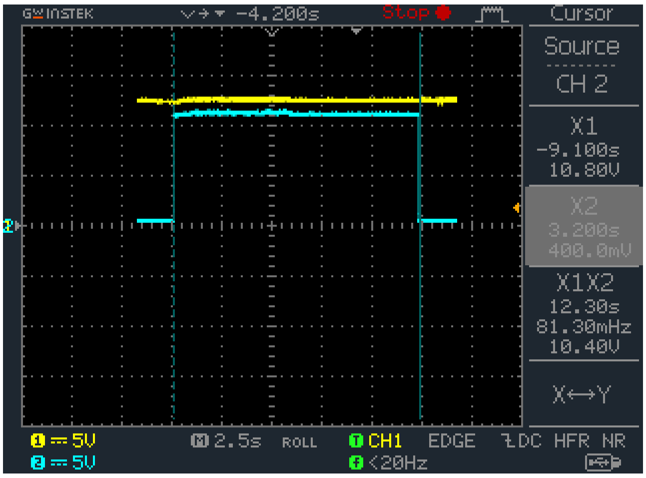


Figure 5.3.5 (2.5s/div)

TP8 – TP9

TP8 – Yellow – 5V/div

TP9 – Blue – 5V/div

This test is to show how long the LED remains on for. It remains on for 12.30s

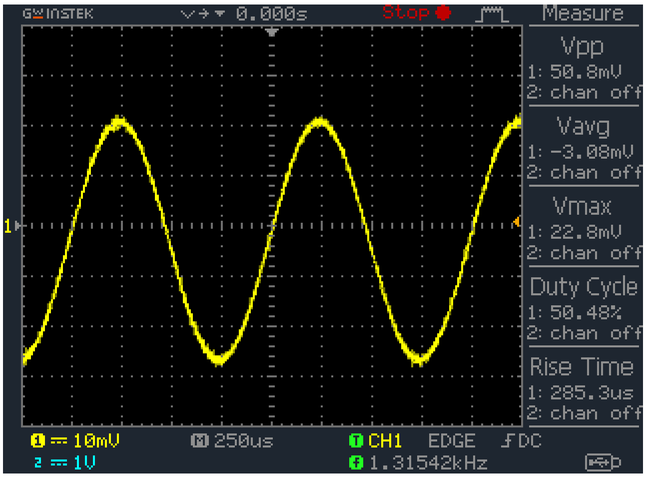


Figure 5.3.6 (250µs/div)

TP1

TP1 – Yellow – 10mV/div

This shows the input signal used for the tests above. (50mV V_{pk-pk})

5.3.2 Microphone test

All test conducted under this section uses a microphone and a person speaking into the microphone

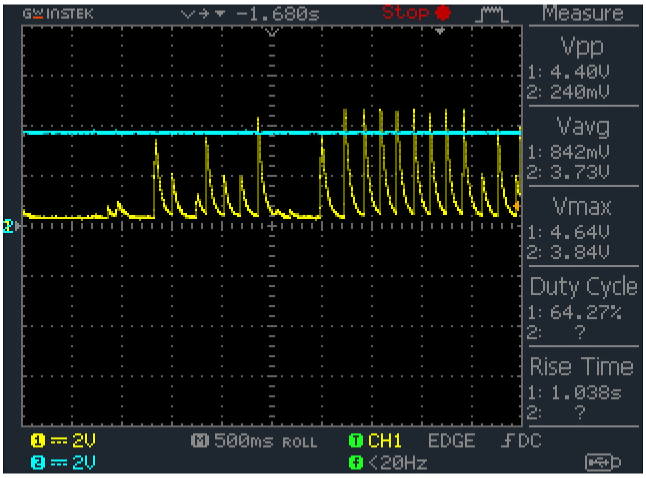


Figure 5.3.7 (500ms/div)

<u>TP4 – TP5</u>

TP4 – Yellow – 2V/div

TP5 – Blue – 2V/div

This test was conducted by saying ‘hello’ in various loudness.

This test is to show the effects of various levels of noise vs the reference threshold voltage

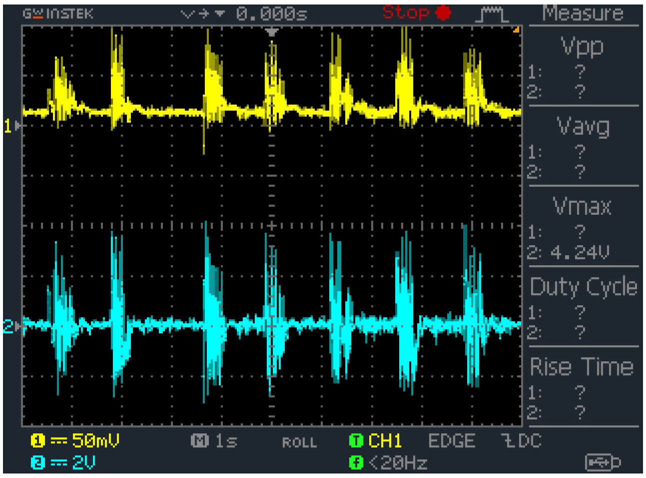


Figure 5.3.8 (1s/div)

<u>TP1 – TP3</u>

TP1 – Blue – 50mV/div

TP3 – Yellow – 2V/div

This test was conducted by saying ‘hello’ in various loudness.

This test shows that the amplifier amplifies the signal.

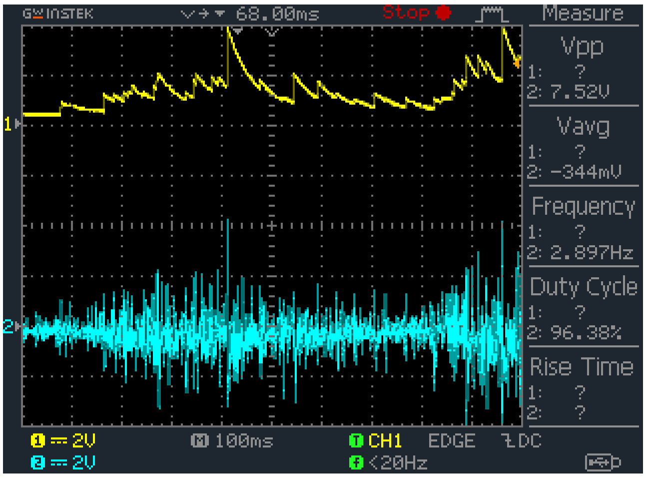


Figure 5.3.9 (100ms/div)

<u>TP1 – TP4</u>

TP1 – Blue – 2V/div

TP4 – Yellow – 2V/div

This test was conducted by saying ‘oooooooo’ in various loudness.

This test shows the smoothing effect of the peak detector.

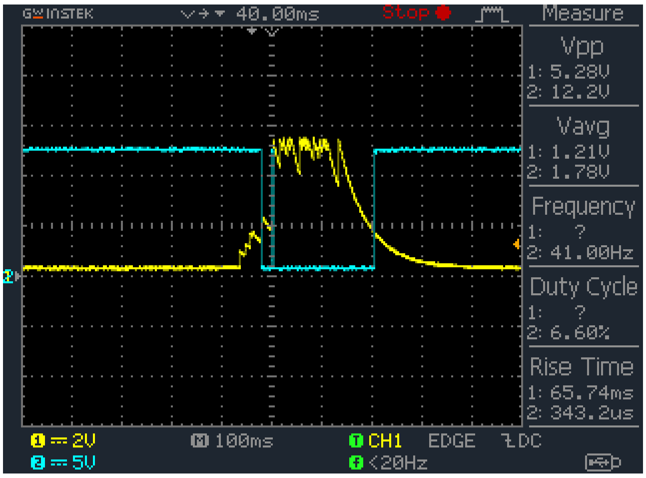


Figure 5.3.10 (100ms/div)

<u>TP4 – TP8</u>

TP4 – Yellow – 2V/div

TP8 – Blue – 5V/div

This test was conducted by blowing into the microphone.

This test shows how the output of the peak detector affects the comparator output (i.e. when the noise is loud, the comparator output is low)

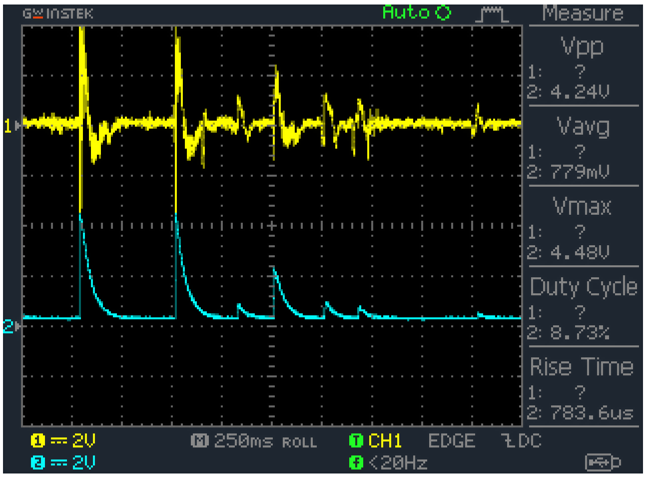


Figure 5.3.11 (250ms/div)

<u>TP3 – TP4</u>

TP3 – Yellow – 2V/div

TP4 – Blue – 2V/div

This test was conducted by blowing periodically into the microphone.

This shows the rectifying properties of the peak detector.

6 Detailed Development of the proposed solution

By relooking at the block diagram of the complete system drawn earlier (Figure 6.0.1), I found out that there are multiple ways implement an amplifier and peak detector.

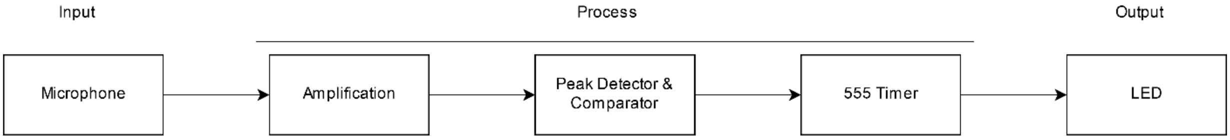


Figure 6.0.1

6.1 Advantages and disadvantages of the two amplification methods

I investigated the two methods to design the amplification circuit; using an LM358 or an LM386 to amplify the microphone signal.

The two methods to debounce the switch seem comparable. Figure 6.1.1 helps to compare the two ICs.

LM358	LM386
Advantages: • Able to control bias • Cheap	Advantages: • Requires minimal components
Disadvantages: • Requires more components • Harder to configure	Disadvantages: • Limited output power • Output requires 100-ohm load

Figure 6.1.1

In order to amplify the signal, the LM358 needed bias resistors to bias the reference + pin and set the amplification value. However, I found that it was difficult to properly bias the signal in a way that the output will not clip. The LM386 automatically amplifies the input signal with minimal external components. Thus, I chose to use the LM386 integrated amplifier.

6.2 Advantages and disadvantages of the two peak detectors

Figure 6.2.1 helps to compare the two methods of implementing a peak detector.

Opamp based	Simple diode
Advantages: • Precise	Advantages: • Requires minimal components
Disadvantages: • Requires more components • Requires negative voltage supply	Disadvantages: • Only good for rough estimates and lacks high precision • Prone to leakage and lack precision • Voltage drop across the diode

Figure 6.2.1

One major factor in deciding whether to use an opamp-based or diode-based peak detector is the availability of components and complexity of the design. Since it is difficult to generate a negative supply rail and it is easier to troubleshoot simpler design, I decided to use a simple diode peak detector.

6.3 Enhancements

- The LED sign should remain on for a specific time
- An audio bar graph can be implemented and can be used to calibrate the noise threshold

6.4 BJT base resistor calculations

Assuming (2N2222),

$V_{BE(sat)}$ = 0.6V

$\beta_{DC(min)}$ = 35

$V_{CE(sat)}$ = 0.3V

V_F of LED = 2V

V_{in} = 12V

$$\begin{aligned}
I_{C(sat)} &= \frac{V_{cc} - V_{CE(sat)} - V_F}{R_L} \\
&= \frac{5 - 0.3 - 2}{220} \\
&= 0.0122727A \\
I_B &= \frac{I_{c(sat)}}{\beta_{DC(min)}} \\
&= \frac{0.0122727}{35} \\
&= 3.506485714285714 \times 10^{-4}A \\
R_B &= \frac{V_{in} - V_{BE}}{I_B} \\
&= \frac{12 - 0.6}{3.506485714285714 \times 10^{-4}} \\
&= 32{,}511.18335818524306071063076464
\end{aligned}$$

Therefore, I choose to use a 30 kΩ Resistor from the E24 Series.

6.5 Description of the proposed solution

In my investigations, circuit simulation software was used to investigate how to connect an LM386 so that it can amplify the signal from the microphone. Additionally, I simulated the peak detector circuit, 555 Timer circuit, comparator circuit and the bar graph enhancement.

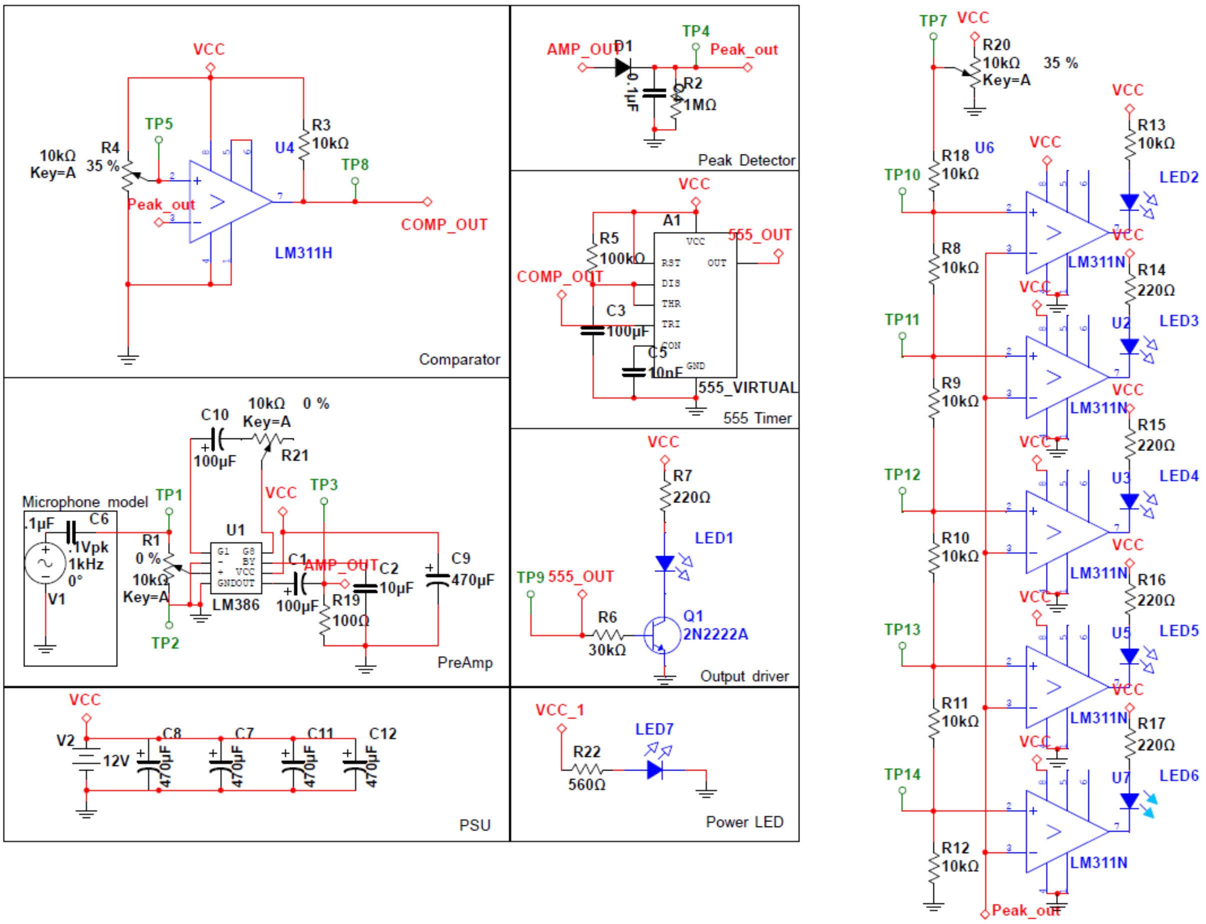


Figure 6.5.1 (see Section 1.1 for enlarged version)

Here, I connected all the subsystems together in Multisim as shown in Figure 6.5.1 From the diagram, the small electrical signal generated by the microphone is amplified by the subsystem 'PreAmp' which consists of a variable gain LM386. This is then fed through the 'Peak Detector' subsystem. From here, the signal is split between the bar graph subsystem and the 'Comparator' subsystem. The 555 Timer takes the output from the comparator subsystem and produces a fix pulse width pulse which drives an output BJT and lights up the LED sign. Capacitors were added across the power rails to smooth out any fluctuation in the voltage. A capacitor was also added as close as possible to the LM386 to minimise noise in the output of the amplifier.

After testing that circuit works as expected with the computer simulation, I went on to build the actual circuit which took a few weeks.

7 Details of the proposed solution

7.1 Bill of materials

S/N	Components	Value	Type	Quantity	Remarks
1	Resistor	10kΩ	Carbon Film	7	5%, 0.25W
2	Resistor	100kΩ	Carbon Film	1	5%, 0.25W
3	Resistor	30kΩ	Carbon Film	1	5%, 0.25W
4	Resistor	560Ω	Carbon Film	1	5%, 0.25W
5	Resistor	220Ω	Carbon Film	1	5%, 0.25W
6	Resistor	1MΩ	Carbon Film	1	5%, 0.25W
7	Resistor	100Ω	Carbon Film	1	5%, 0.25W
8	Capacitor	0.1µF	Ceramic	1	50V
9	Capacitor	33µF	Aluminium Electrolytic	1	50V
10	Capacitor	470µF	Aluminium Electrolytic	5	50V
11	Capacitor	100µF	Aluminium Electrolytic	2	50V
12	LED Diode			3	
13	LED Diode			3	
14	LED Diode			2	
15	LM311		IC	1	
16	LM386		IC	1	
17	NE555			1	
18	Diode	1N4004		1	
19	Microphone	9mm	Electret	1	
20	Multi-turn potentiometer	50kΩ		2	
21	Potentiometer	10kΩ		2	
22	2N3904	BJT	NPN	1	

7.2 System diagram

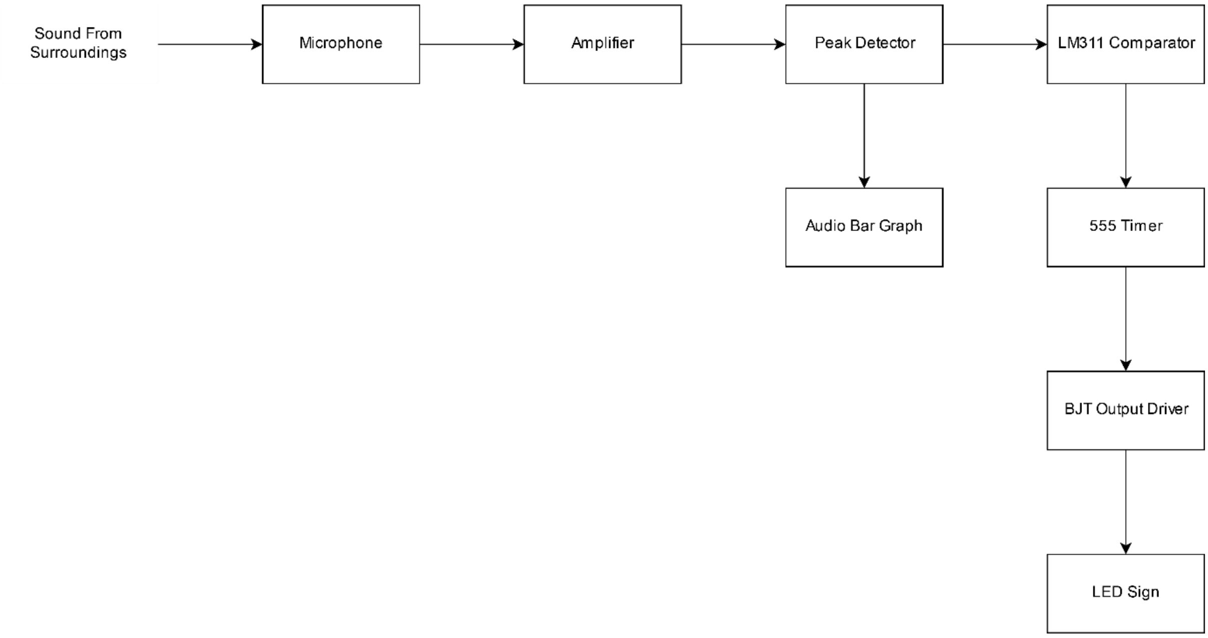


Figure 7.2.1

7.3 Completed circuit

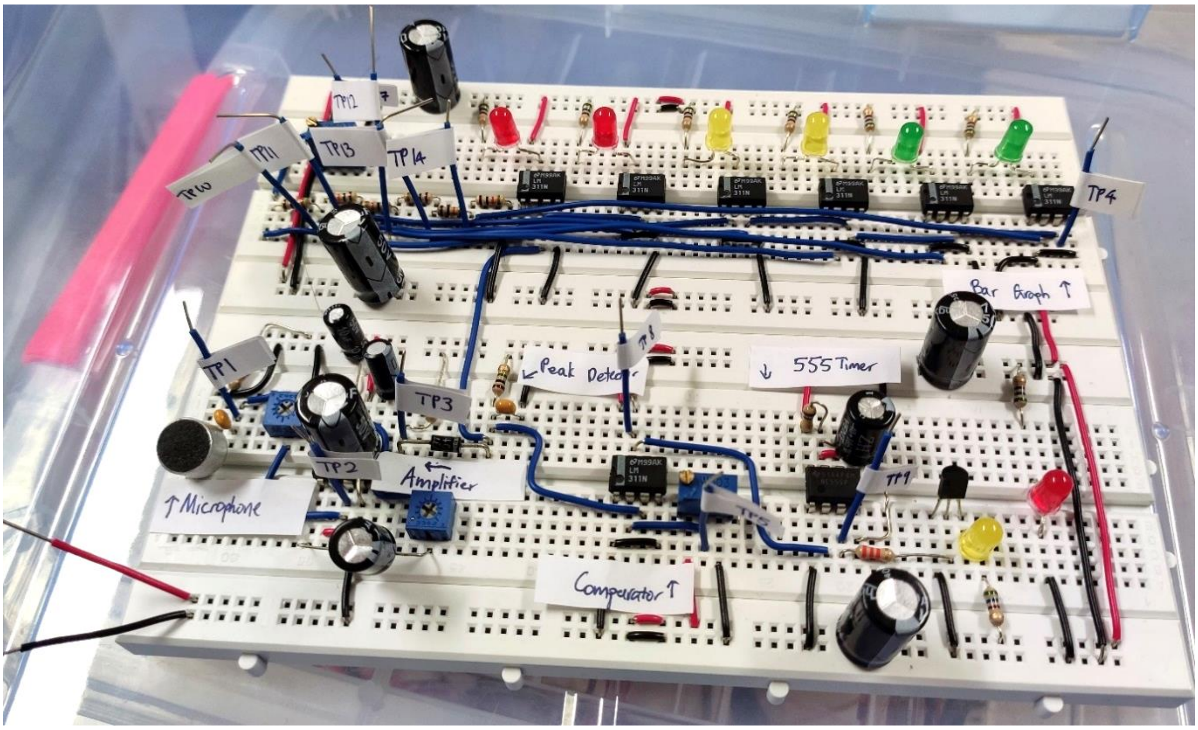
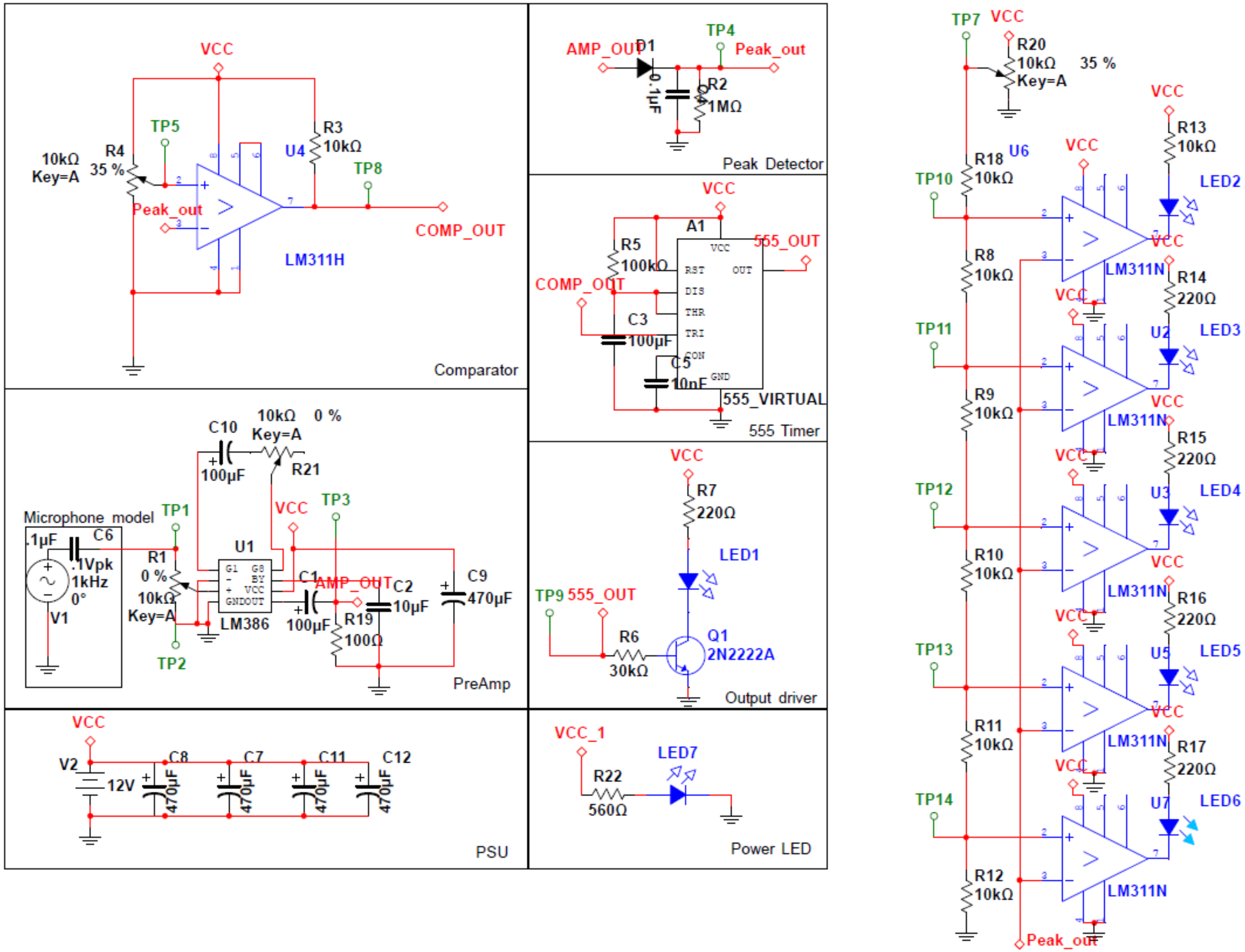


Figure 7.3.1

7.4 Schematic



8 Evaluation

These are my learning points from my project:

- I have learnt how to do research better. When researching, I learnt that I should always record the location and author of the source so that I can cite them in my report.
- I also learnt how to read datasheets better. I have learnt that datasheets not only provide the technical details of the IC; it also provides applications notes and example circuits that I can use.
- I have learnt how to record and document my findings. Documenting my finding that I encounter doing my project allows me to be more efficient at drafting my report instead of going back and remeasuring the test points. Documenting ideas is also important as you might forget that idea after a few days if it is not written down.
- I have learnt how to plan my time. When starting out on this coursework, I thought I could finish my project before the June holidays. However, I did not account for delays such as examinations and school holidays.
- I have learnt how to write a proper coursework report.

8.1 Challenges faced

- The main challenge faced was troubleshooting. A single bad connection can cause a whole circuit to fail. While performing research for my project, I learnt that there are actually a few ways to find out common faults like power supply not being connected properly; it could be as simple as adding a power indicator. That will be the first thing I will add for future circuits that I build. For loose connections, a Multimeter is a great tool to quickly check if two points are connected or not. Probing can be repeated quickly for many pairs of points.
- The peak detector did not work as expected. Initially, it only worked as expected when the oscilloscope probe was connected. I overcame it by doing additional research online into why this problem occurred and experiments such as adding resistors across the capacitor.
- For my main simulation file in Multisim, the simulation speed was terribly slow (1µs / second). I overcame this by splitting the individual subsystems into their respective files.
- My initial prototype was powered on a 5V PSU. However, when the input from the microphone got too loud, the LM386 output began to ‘clip’ (crest of sine wave became flattened). I overcame this problem by switching to a 12V PSU.
- Multisim did not have some components (microphone, LM386) that I wanted to use, so I had to make my own custom components or improvise with similar components.

8.2 Strengths

- The project has met basic requirements – It can light up a sign when the noise level is above an adjustable threshold.
- I have built this circuit using proper techniques explained in the textbook such as colour coding the wires and trimming the wires and components to the correct lengths to avoid unintentional short circuits.
- The project is reliable.
- The project is neat, and subsystems are clearly labelled.
- The device is modular, with subsystems clearly separated.
- The device is relatively compact, taking up only two breadboards.

8.3 Weaknesses

- When the sound source is far away from the microphone, the microphone sometimes will not pick up the signal.
- The surrounding's volume is not directly proportional to the voltage generated by the microphone. Thus, soft sounds do not activate the circuit.
- The amplification adjustment is very sensitive and difficult to adjust to the correct amplification value.
- The components are easily pulled out if the device is not handled carefully.
- The 12V required for the device makes it not as portable as one powered from 9V.
- A screwdriver is required for calibration of the noise threshold.

8.4 Possible improvements

- A possible improvement is to have a counter that counts the number of times the circuit is triggered and display that number on a seven-segment display
- Another possible improvement is to have the sign blink when it is triggered within a period of time. However, I did not have enough time to build it.
- Make a fully backlit sign with the words 'Please Keep Quiet'. However, I did not have enough time to build it.
- Improve the faint sound detection by changing the microphone for a better microphone.
- Make the circuit run from a 4.5V PSU (3 AA Batteries) for better portability.
- Replace the mini trim potentiometer with a larger multi-turn rotary potentiometer for easier calibration.
- Include an integrated adjustable noise source (buzzer) to simulate a noisy environment and make calibration easier.
- Make the 'on' time of the sign adjustable with a trim potentiometer.

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