3301ENG Practical Electronics Function generator

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Contents

1. Introduction

This document will report on the construction, design, and analysis of a function generator that is created for 3302ENG – Practical Electronics course at Griffith University. This report will detail the project lifecycle through discussion of the requirements, market analysis of the board, design and testing phases of the board, user manual and concluding analysis of the project overall.

A function generator is an important piece of electronic laboratory equipment which helps in the design and testing of electronic equipment. Circuits require reliable signal generation which will simulate normal operation of the circuit, controllable signal from low to high frequencies as well as low to high voltage ranges makes the function generator more versatile and invaluable for electronic analysis in a controlled environment.

Stated in 'Function generator and arbitrary waveform generator guidebook' by D. Peterson and B&K Precision that function generators are used where stable and repeatable stimulus signals are needed with common uses as:

- Research and development
- Stimulus/response testing
- Frequency response characterisation
- In-circuit signal injection

And used by:

- Education institutions
- Electronics and electrical equipment repair businesses
- Electronic hobbyists

Function generators of today provide a variety of signal creation such as:

- Waveforms: Pulse, square, triangle, sine, sawtooth.
- Variable frequency: less than 1 Hz to (up to at least) 1 MHz
- Variable amplitude depending on the circuit
- Adjustable DC offset
- Extra features

2. Project scope

The scope of the project was to design, create and present a printed circuit board of a chosen project within a time-frame of 4/5 weeks (Griffith University's semester 1 week 7 to week 11), the project that was chosen and submitted by this group was a function generator. This section will discuss the Project scope – the timeframe, requirements, submitted design and the changes of the design post-submission

2.1.1 Requirements

The requirements for the project were provided by the course convener via document given called 2018 Project Exemplars, within this document the function generator was chosen as an exemplar because the project met the requirement of analogue circuit complexity, mature circuits (i.e. well-tested) and the components to construct the circuits are readily available in the lab.

The circuit should produce a variety of waves – sine, triangle and pulse with adjustable amplitude and frequency. The project is broken down into stages where the first stage is an astable multivibrator, the second and third stage are both integrators. The first stage will produce square wave and thus the second and third being integrators will output triangle and sine respectively. For this project the minimum frequency is set to be 5 kHz, an amplifier will be needed to adjust the amplitude of the output signal. The demonstration for the three waveforms on the oscilloscope.

2.2. Submitted design

The design was submitted in which the function generator would generate the three waveforms required in the project exemplar however the frequency minimum was set to 5kHz with no higher limit frequency to allow for deciding the upper limit later through the development cycle, it was submitted with adjustable amplitude with no value range as the railed voltage value of V+ and V- were not chosen at the time.

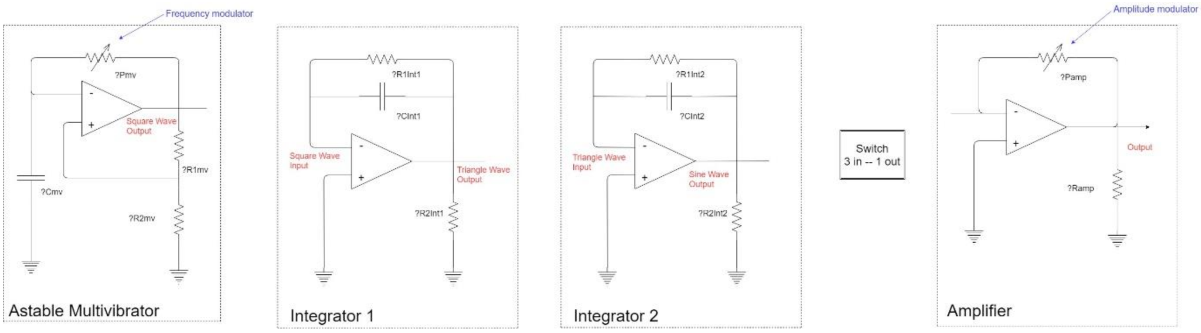

Figure 1. 'Circuit proposal' Figure from 3301ENG project submission Power Point

The values for each resistor and capacitors were not used as the values had not be calculated yet because the design and testing phase in our project had not begun as a group due to multiple university commitments leaving not a lot of time during the submission phase of the project. A later submission phase might have resolved issues of not having limits set among the circuit proposal figure seen above.

2.3. Post-review changes

These changes occurred after the review of the submitted design and before the design and testing phase, this report will reflect on all changes that occurred through-out the process of creating of the function generator later in the document.

Before the design and testing process started, 555-timer was decided to be implemented instead of the op-amp for the first stage – astable multivibrator due to an easier implementation and calculation as well as keeping a stable 50% duty cycle. The frequency range that was set for the 555-timer was to be set to 5kHz to 200kHz however due to the 555-timer not being stable after a frequency of 50kHz thus another frequency was decided on a max frequency of 20Khz and min frequency of 20Hz.

3. Market analysis

This section will discuss the pricing of current commercially sold function generators and compare the features that each price range holds over the other; the analysis of the commercially available products will be compared against the prototype that was created for this project.

3.1. Low-end price range

As an example of a low-end price range function generator within Australia, the SFG-1013 is sold at $199.00 from EMONA instruments. The specifications of the SFG-series 1000 has:

- Output function: sine, square, triangle, TTL.
    - Frequency range of 0.1Hz – 3MHz for sine and square

    - Frequency range of 0.1 – 1MHz for triangle
- Resolution: 0.1Hz maximum
- Amplitude range: 10Vp-p
- Resistance load of 50 ohm at 10% tolerance
- Duty control range 25% to 75%
- 6-digit LED display

3.2. High-end price range

As an example of a high-end price range function generator within Australia, the TG5011 is sold at $1906.00 from EMONA instruments. The specifications of the TG-5011:

- Output function: sine, exponential rise, logarithmic rise, DC, triangle, square.
    - Frequency range of 1uHz to 50MHz for sine and square
    - Frequency range of 1uHz to 500kHz for triangle
    - Frequency range of 500uHz to 12.5MHz for pulse
- Resolution: 1uHz or 14-digit
- Amplitude range: 20mV to 20Vp-p open circuit and 10mV to 10Vp-p into 50 ohm.
- Resistance load of 50 ohm
- Variable duty cycle for certain frequency ranges
- High resolution LCD
- Gaussian white noise
- Modulation: AM, FM PM, PWM, FSK, Triggered burst, Gated, Sweep, Trigger Generator.
- Interfaces: USB, LAN, USB flash drive
- Inputs: Trig in, external modulation input, ref clock input.

3.3. Prototype

The prototype costing is at base prices of single components and not at bulk sale allowing to know the maximum possible price of the board, the components will be at Australian market price however the price of the board will be sourced from a Chinese competitor within the industry since Australian prices for the boards to be made are expensive:

Table 1. Cost analysis of the current prototype

Board cost (including shipping - 1 piece): $35 (AUD)

Type:	Size:	Qty:	Cost (AUD):
Resistor	1k-ohm	2	1.3
Resistor	10k-ohm	6	3.9
Resistor	1M-ohm	2	1.3
Potentiometer	1M-ohm	7	11.55
Mylar	0.001u-F	1	0.3
Mylar	0.027u-F	1	0.3
Mylar	0.033u-F	2	0.6
Ceramic	100p-F	1	0.3
Electrolytic	100u-F	5	12
TL074	DIP-14	2	7
NE555	DIP-8	1	10.95
Switch	DIL-3	1	3.95
Diode (Zener)	4V7	1	0.5

Component cost:	53.95
Total:	88.95

The prototype designed and built during this project lifecycle was built with these possible functions:

- Output function: sine, triangle, square.
    - Frequency range of 200Hz to 20kHz for all waveforms
- Amplitude range of 4Vp-p
- Fixed duty cycle of 50%
- Ability to be run of a 9V battery

At the current price of the prototype with the cost analysis being a one-off production without any bulk purchases of components and PCB, the ratio of functionality and cost does not directly compete with current low-end competitive prices at commercial sale.

Prototype – MK II

The prototype costing is at base prices of single components and not at bulk sale, allowing calculation if the maximum possible price of the board, the components will be at Australian market price however the price of the board will be sourced from a Chinese competitor within the industry since Australian prices for the boards to be made are expensive:

Table 2. Cost analysis of the current prototype - MKII

Board cost (including shipping - 1 piece): $35 AUD

Type:	Size:	Qty:	Cost (AUD):
Potentiometer	1M-ohm	4	6.6
Resistor	1k-ohm	1	0.65
Resistor	3k-ohm	1	0.65
Resistor	10k-ohm	4	2.6
Resistor	55k-ohm	1	0.65
Resistor	100k-ohm	2	1.3
Resistor	1M-ohm	2	1.3
Electrolytic	100uF	3	7.2
Mylar	0.0033uF	2	0.6
Mylar	0.01uF	1	0.3
Mylar	0.0272uF	1	0.3
TL074	DIP-14	2	7
555 Timer	DIP-8	1	10.95
Switch	DIL-3	1	3.95
Diode (Zener)	4V7	1	0.5

Component cost:	44.55
Total:	79.55

The prototype designed and built during this project lifecycle was built with these possible functions:

- Output function: sine, triangle, square.
    - Frequency range of 200Hz to 20kHz for all waveforms
- Amplitude range of 4Vp-p
- Fixed duty cycle of 50%
- Ability to be run of a 9V battery

At the new price of the prototype (MKII) with the cost analysis being a one-off production without any bulk purchases of components and PCB, the ratio of functionality and cost does not directly compete with current low-end competitive prices at commercial sale even with a $8 dollar AUD price down, bulk sales of component prices in China could compete.

Out-sourced Chinese market

This is the price of the entire board with the Australian price value for the components within a leading manufacturer of electronic components – at the price of a board costing one-off production and the price of the board at a bulk production of 1000 boards:

Table 3. Chinese manufactured out-sourced costs of one-production and 1000 production component price per board

Board cost (including shipping - 1 piece): $35 AUD				
Type:	Size:	Qty:	Cost (1):	Cost (1000):
Potentiometer	1M-ohm	4	5.36	3.104
Resistor	1k-ohm	1	0.134	0.017
Resistor	3k-ohm	1	0.134	0.017
Resistor	10k-ohm	4	0.536	0.068
Resistor	55k-ohm	1	0.134	0.017
Resistor	100k-ohm	2	0.268	0.034
Resistor	1M-ohm	2	0.268	0.034
Electrolytic	100uF	3	2.04	0.603
Mylar	0.0033uF	2	0.83	0.222
Mylar	0.01uF	1	0.415	0.111
Mylar	0.0272uF	1	0.415	0.111
TL074	DIP-14	2	0.858	0.371
555 Timer	DIP-8	1	0.616	0.189
Switch	DIL-3	1	1.31	0.844
Diode (Zener)	4V7	1	0.59	0.106
	Component price @ 1 (AUD):			13.908
	Component price @ 1000 (AUD):			5.848

By out-sourcing the component acquirement to China as well, the cost to purchase the components have dropped in both one-off production and 1,000 productions to that of over x3 less and over x7 less respectively in terms of cost cutting resulting in a board production that could compete with low-end market for price if the function generator prototype could produce higher frequency ranges.

4. Design and testing process

Design of the project was broken down into modules which were designed separately before being bought together as a single unit for testing and packaging. The design was broken down into the following modules:

1. Power supply stabilising circuit.
2. 555 -timer circuit outputting a 50% duty cycle square wave.
3. Integrator 1- Square wave input, Triangle wave output.
4. Integrator 2- Triangle wave input, sine wave output.
5. Buffer circuits
6. Amplifier

Each of the above modules were individually designed and simulated with the use of circuitlab.com before being constructed and tested with an existing oscilloscope and function generator DS0-X 2002A from Agilent Technologies.

Two function generator prototypes have been developed from the above modules, both will be discussed below.

4.1. Power stabilising Circuit

Stable, reliable operation of the function generator requires a power sources that is both reliable and free from noise. After considering all the power sources that are available to the average potential consumer and capable of powering a circuit that produces an amplitude of 4 voltsp-p. A single 9 volt battery was chosen as the circuit's power source due to accessibility and ease of replacement by customers.

This power source needs to power both the positive and negative rails of all op-amps in the function generator as well as supply positive and negative power to the 555-timer. To produce the required noise free positive and negative power the following circuit was created.

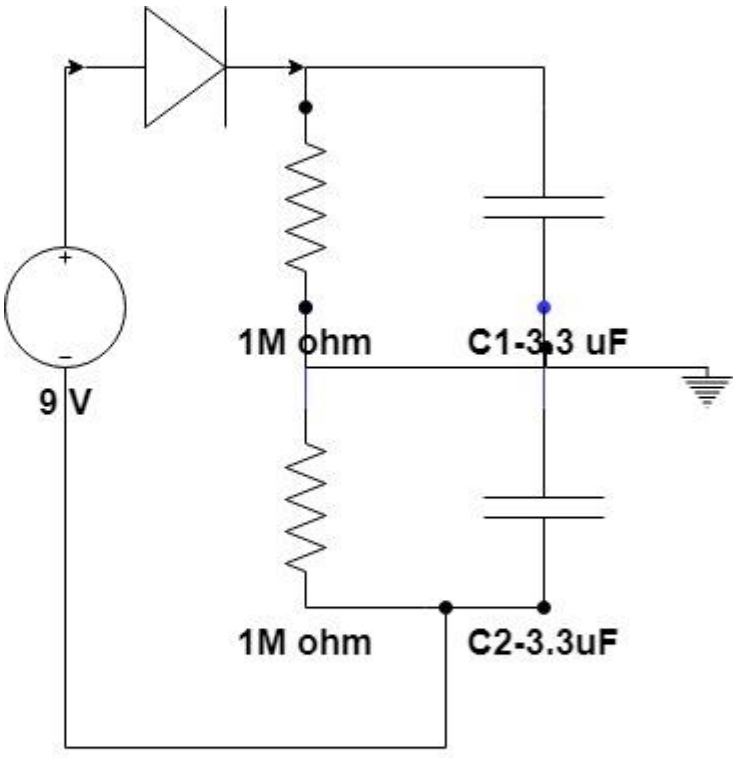

Figure 2. Power Supply Circuit

The above circuit is a simple resistor divider created with two equal resistors. A large value of 1 Mega-ohms was chosen for these resistors to minimise the current flowing through the resistor divider, instead of powering the other modules of the function generator. According to ohms law the voltage drop across both of these equal resistors would be equal. The middle point of the resistors is deemed to be the common ground point of the circuit. Initial testing of this module showed resulting voltage levels had high degrees of noise and fluctuation. To combat this noise D1, C1 and C2 were added to the circuit.

4.2. 50% Duty Cycle 555-timer

The 555-timer module is the basis of the function generator and produces a square wave, this square wave is applied to the integrators which produce the triangle wave and sine wave outputs. The signal produced from the 555-timer needs to be vary in frequency from 200Hz to 20KHz yet maintain a 50% duty cycle for all of these frequencies.

The following circuit was adapted from https://www.electronics-tutorials.ws/waveforms/555_oscillator.html

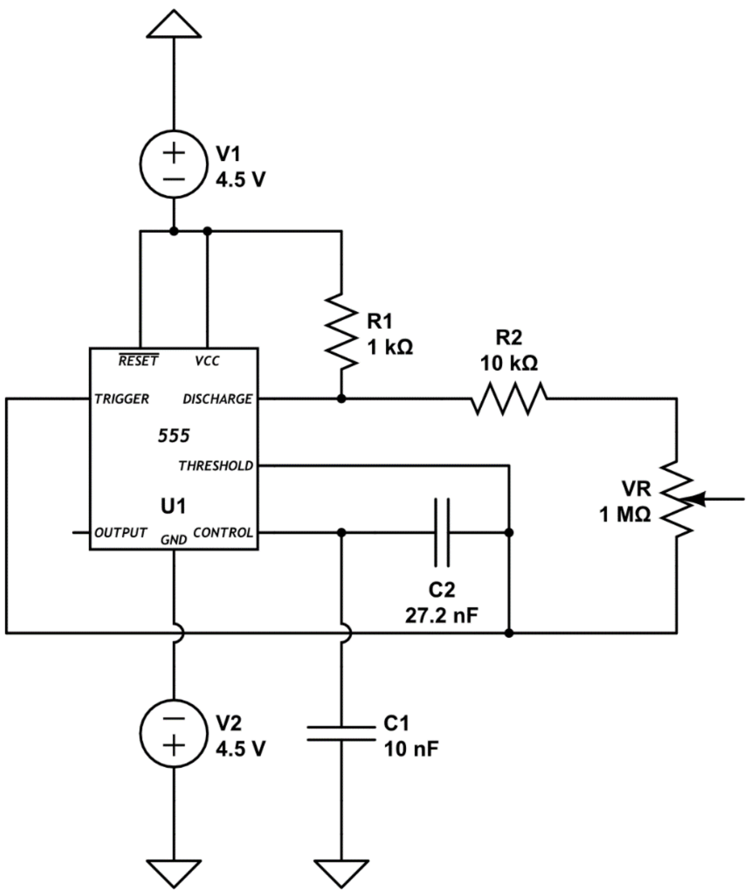

Figure 3. 555-Timer Circuit for 50% Duty Cycle Square Wave

The above circuit produces a square wave that has a 50% duty cycle as long as the resistor leading to the potentiometer is 10 times larger than the resistor that is connected to the VCC and Discharge pin-outs on the 555-timer proved by this equation:

$$\frac{(R1 + (R2 + VR))}{(R1 + 2 * (R2 + VR))}, \qquad VR = 0$$

$$therefore, \qquad \frac{1 + 10}{1 + 2 * 10} = \frac{11}{21} = approx. 50\%\ duty\ cycle.$$

4.3. Integrators

In addition to the square wave produced by the 555-timer circuit the function generator needs to produce triangle and sine waves. Taking a square wave and integrating results in a triangle wave while integrating this triangle wave results in a sine wave. This integration can be achieved by the following circuit.

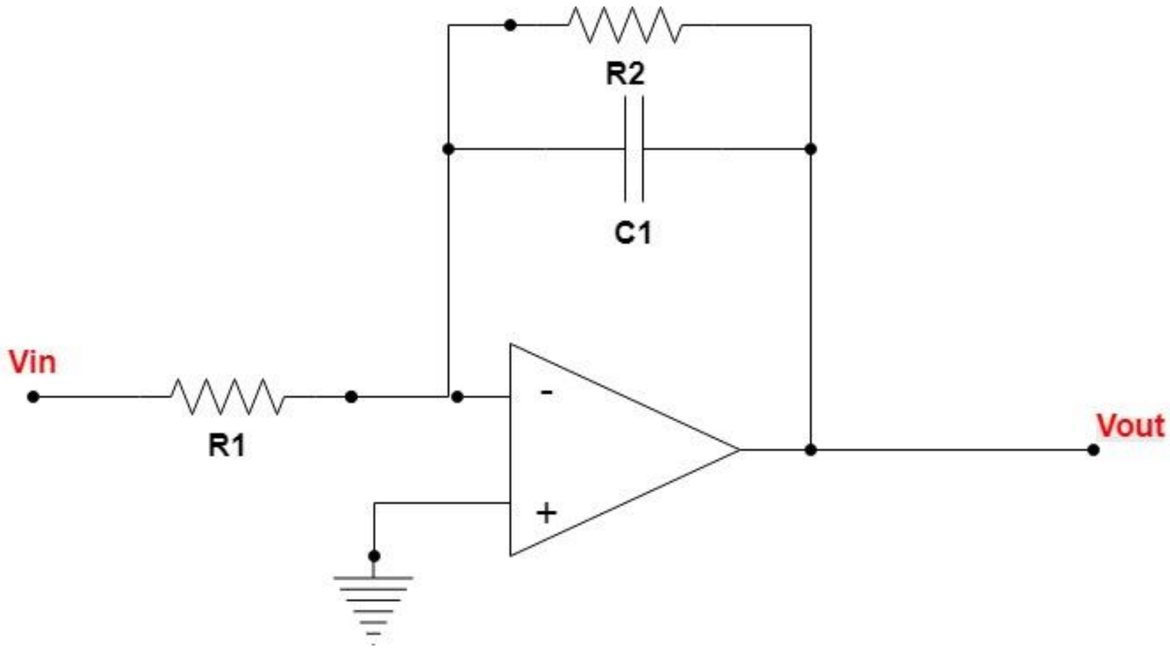

Figure 4. Integrator Circuit

This integrator is dependent on the time constant created by R2 and C1. With the output of the circuit (Vout) being given by the following equation. $Vout = -\frac{1}{j\omega R2C1} \times Vin.$ Consequently the gain of the above circuit reduces to a level were the output is no longer large enough to measure or so high that the signal clips when the input is outside a narrow frequency range.

To solve this problem R1 was replaced with a Variable resistor, by adjusting variable resistor the gain of the integrator can be adjusted when input frequency is adjusted to result in the desired output. The two integrators used in the function generator are identical with the output of integrator 1 being a triangle wave inputting this triangle wave into integrator 2 results in a sine wave output.

4.4. Integrator-Prototype 1

Prototype 1 featured a variable resistor in the place of R2 as well as in the place of R1. This was an attempt to increase the frequency range for which the integrator produced undistorted outputs for as large a range as possible. Integrator 1 proved to be unreliable and resultant outputs exhibited large amounts of noise.

4.5. Integrator-Prototype 2

It was found by using a fixed resistor in the place of Prototype 1’s VR2 had no effect on the frequency range for which the integrator was effective. Additionally this circuit was seen to be more reliable and the output exhibited less noise.

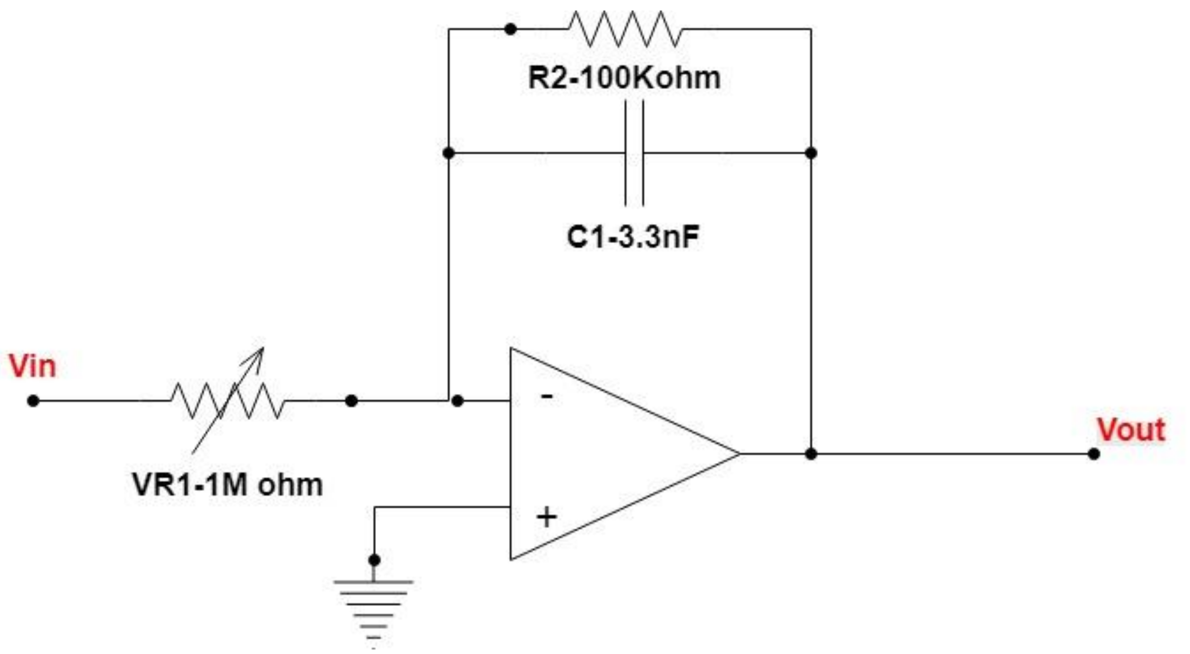

Figure 5. Prototype 2-Integrator Circuit

Figures 6 and 7 show simulated integrator results.

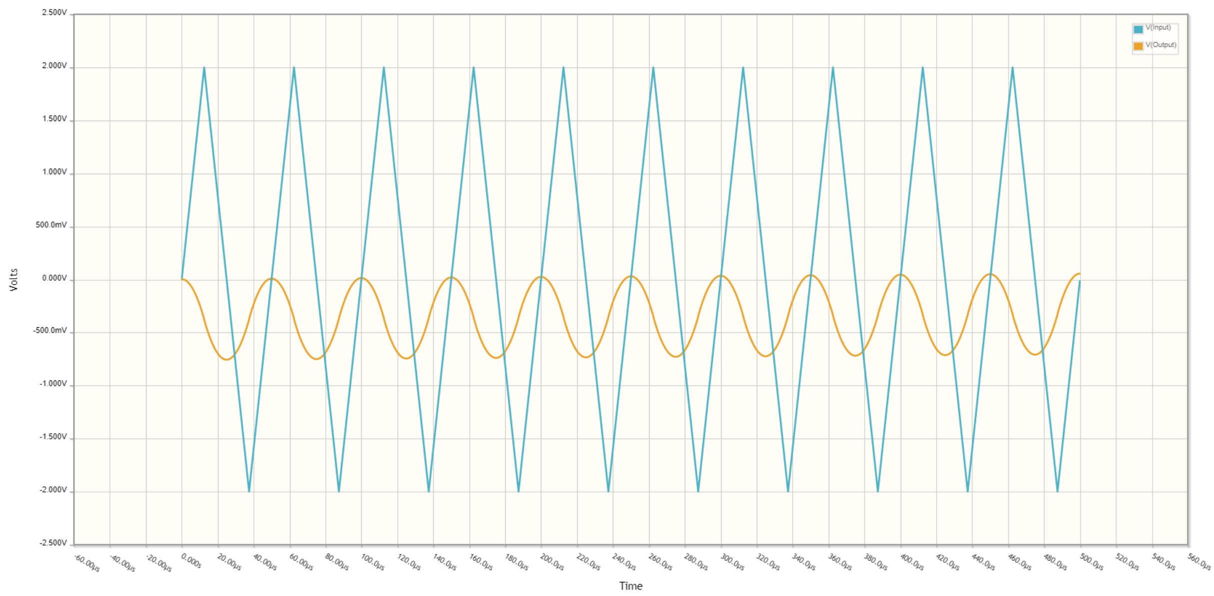

Figure 6. Simulated integrator Response(Triangle wave Input)

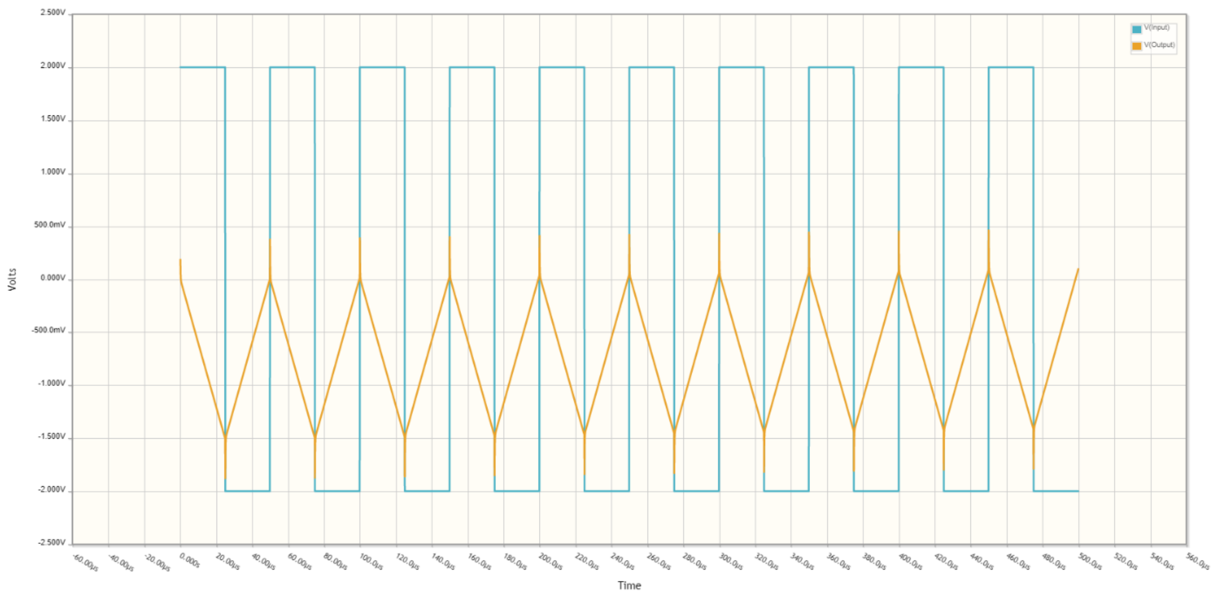

Figure 7. Simulated Integrator Response (Square Wave Input)

4.6. Buffer Circuit

Upon construction of the 555-timer circuit the resulting square wave exhibited large amounts of ringing once applied to the integrator circuit the resulting triangle wave exhibited large amounts of distortion. To reduce this distortion the following buffer was created.

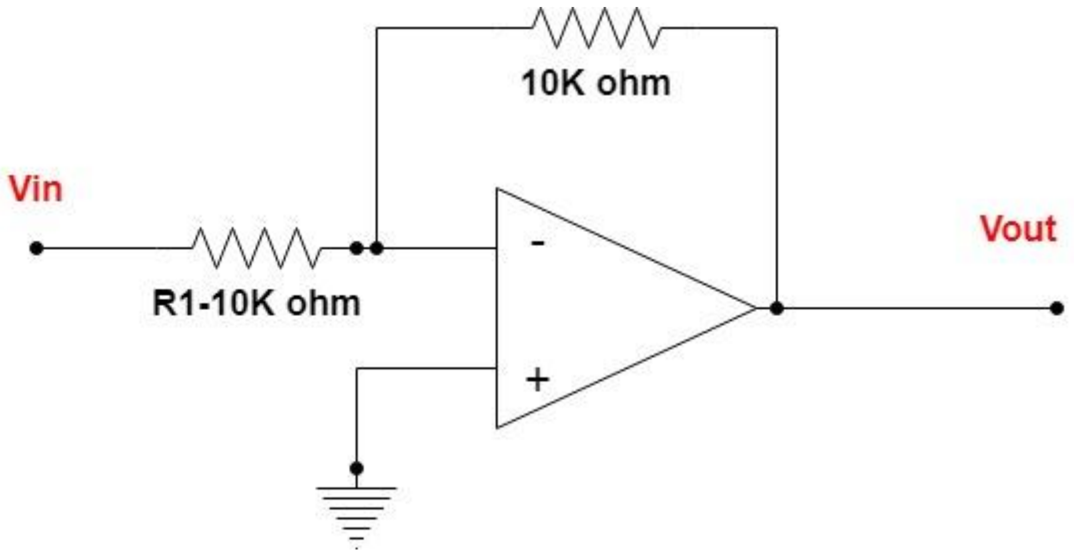

Figure 8. Buffer Circuit

Upon cascading of integrator 1 and integrator 2 it was seen that both outputs were far below the expected amplitude due to the loading effect of integrator 2 on integrator 1. Consequently it was deemed necessary to implement the above buffer between the integrator modules.

4.7. Amplifier

The output of the function generator is required to be of variable amplitude as well as of variable frequency. An amplifier stage has been used for amplitude modulation. This amplifier needed to be capable of producing gain of greater than one and less than one (increase and decrease the amplitude of the signal). To best achieve this goal an inverting amplifier was chosen due to its ability to provide gains of less than one. The following circuit provides the function generator with amplitude modulating ability.

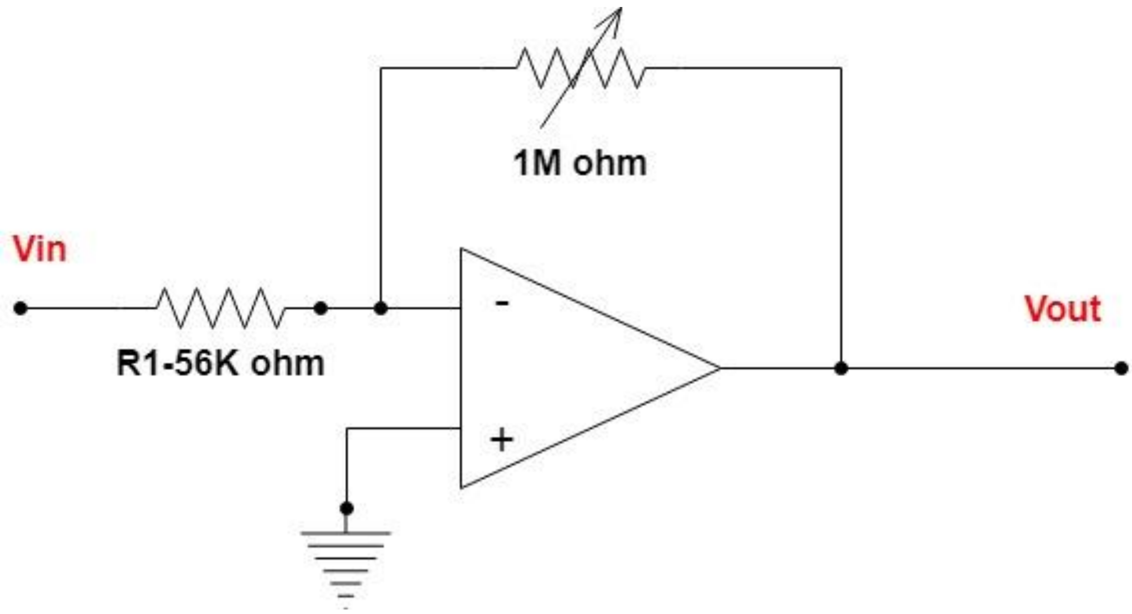

Figure 9. Amplifier Circuit

4.8. Prototype 1

Prototype 1 was completed by cascading the simple circuits described in the last five sections together. Flow diagram for prototype 1 is shown in figure 10, while complete circuit schematic is shown in figure 11.

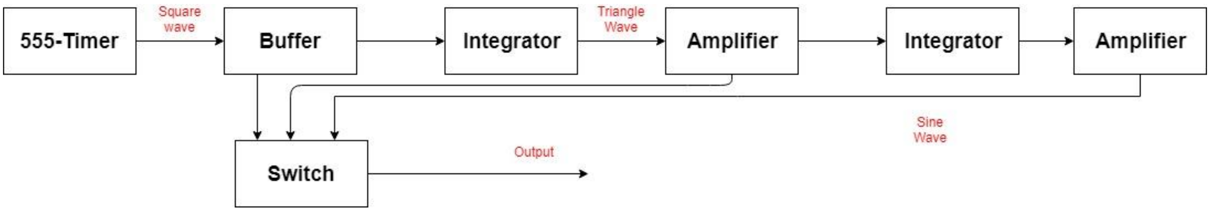

Figure 10. Prototype 1- Block Diagram

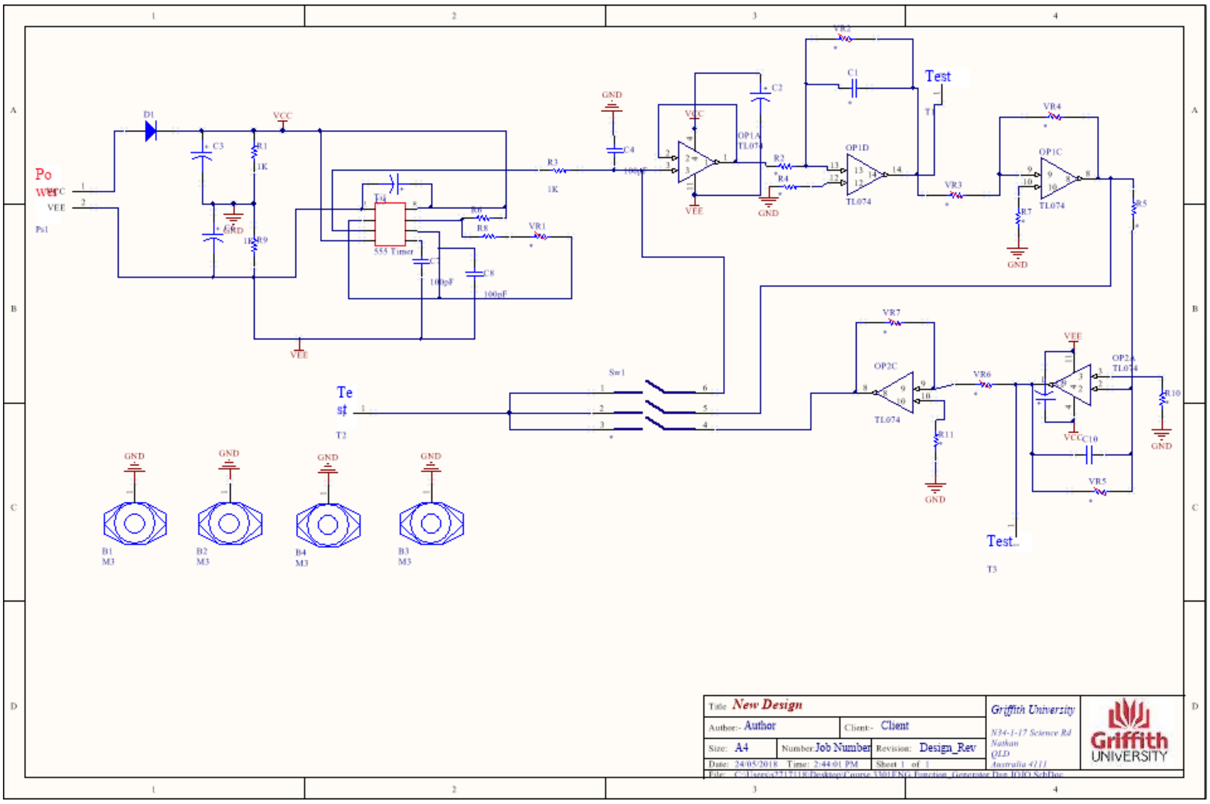

Figure 11. Prototype 1- Schematic

Capacitors 4,5,2 and 9 in the above circuit are decoupling capacitors and have been implemented to reduce noise.

4.9. Prototype 2

Prototype 2 was completed by cascading the simple circuits described in the last five sections together. Flow diagram for prototype 2 is shown in figure 12, while complete circuit is shown in figure 13.

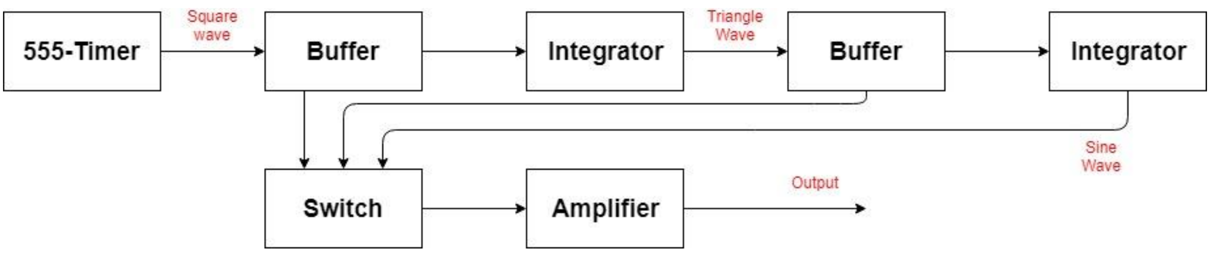

Figure 12. Prototype 2- Block Diagram

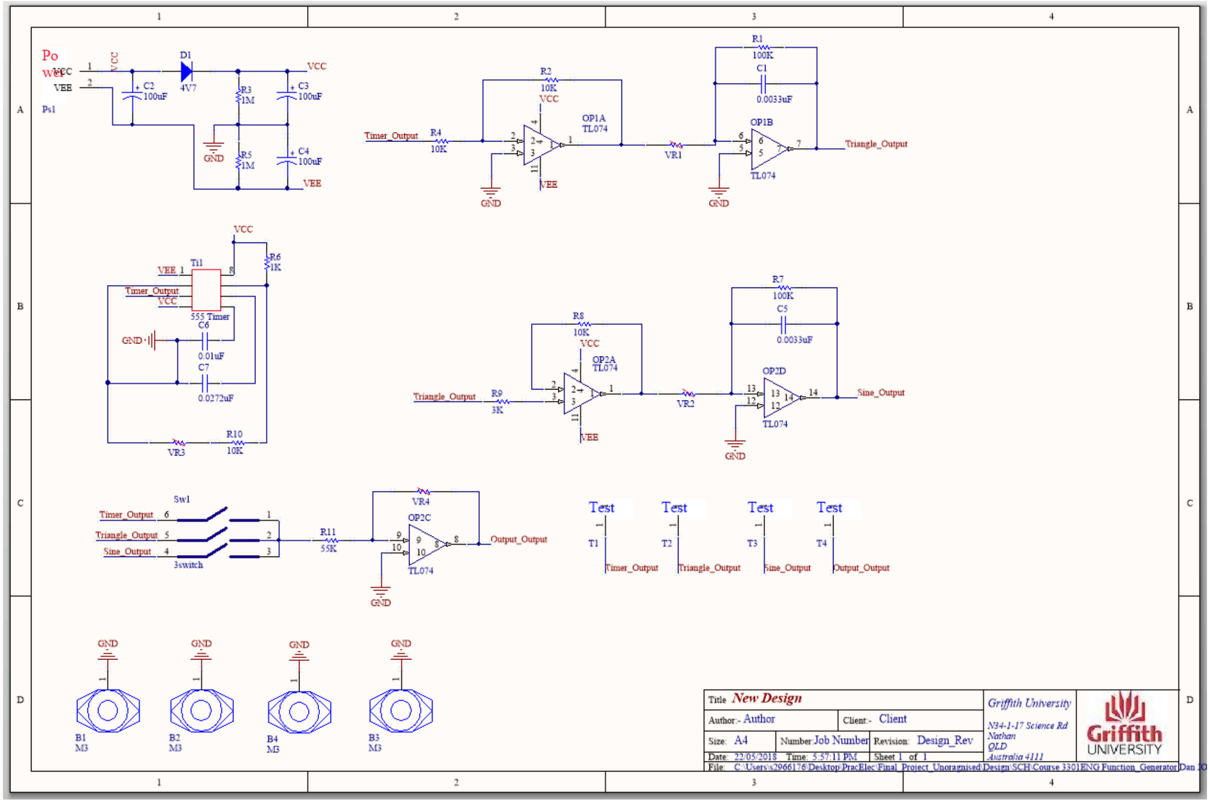

Figure 13. Prototype 2- Schematic

5. Circuit Performance

5.1. Power Supply

The power supply circuit illustrated in figure 2 provides stable unvarying voltage. Measurements obtained with the use of Agilent technologies U3401A multimeter show the created positive rail to be 4V and the negative rail to be -4V

5.2. 555-Timer

555-Timer from figure 2 is capable of producing a 50% duty cycle square wave between 250Hz and 24KHz. Figures 14 and 15 show 555-Timer circuit outputs at maximum and minimum achievable frequency.

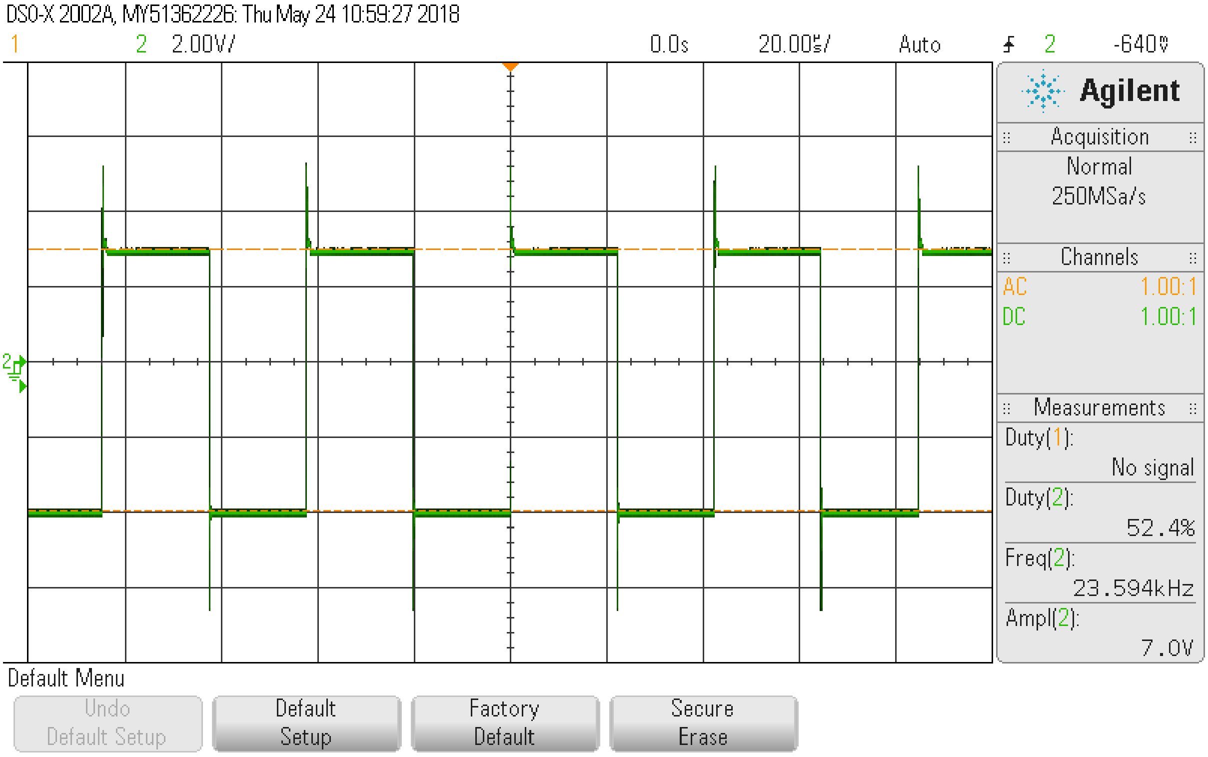

Figure 14. 555-TImer Circuit output at Max Frequency

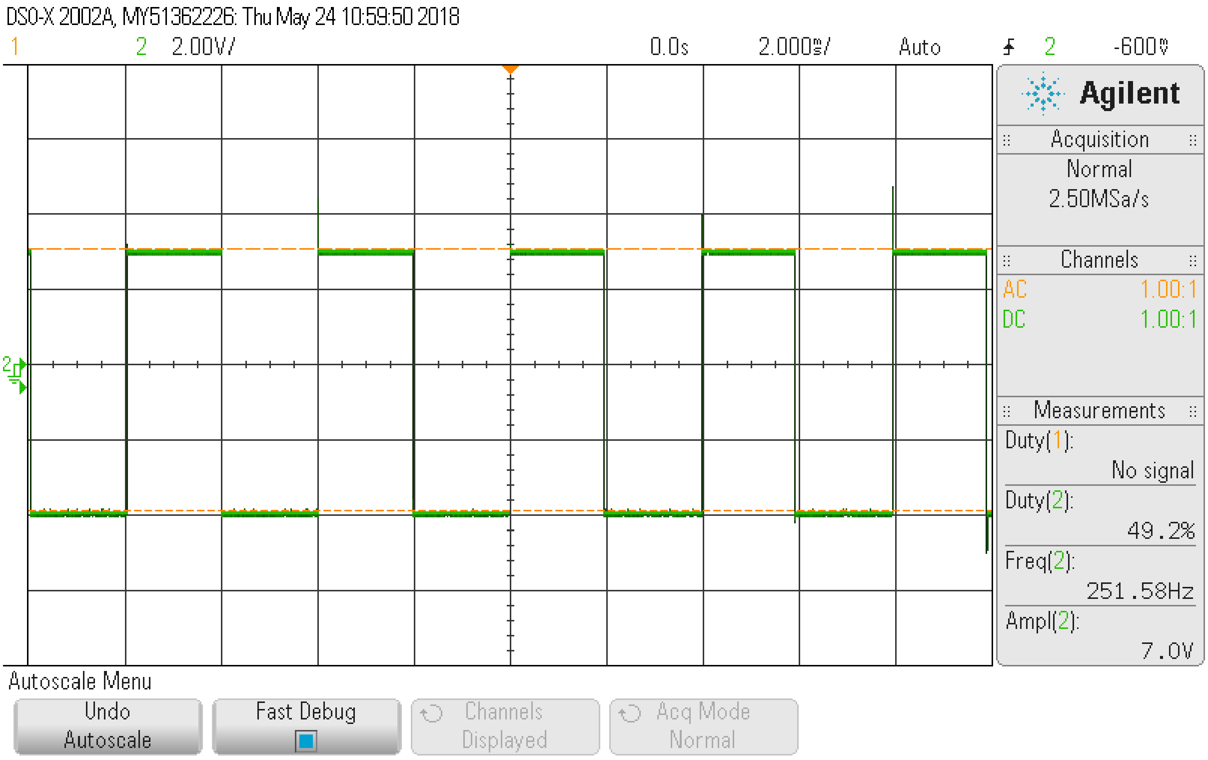

Figure 15. 555-Timer Circuit output at MIn Frequency

5.3. Buffer

The Buffer illustrated in figure 8 has proven to be effective in reducing noise from the 555-Timer. Figure 16 shows the 555-Timer output before and after the buffer at the maximum frequency were noise was most prevalent.

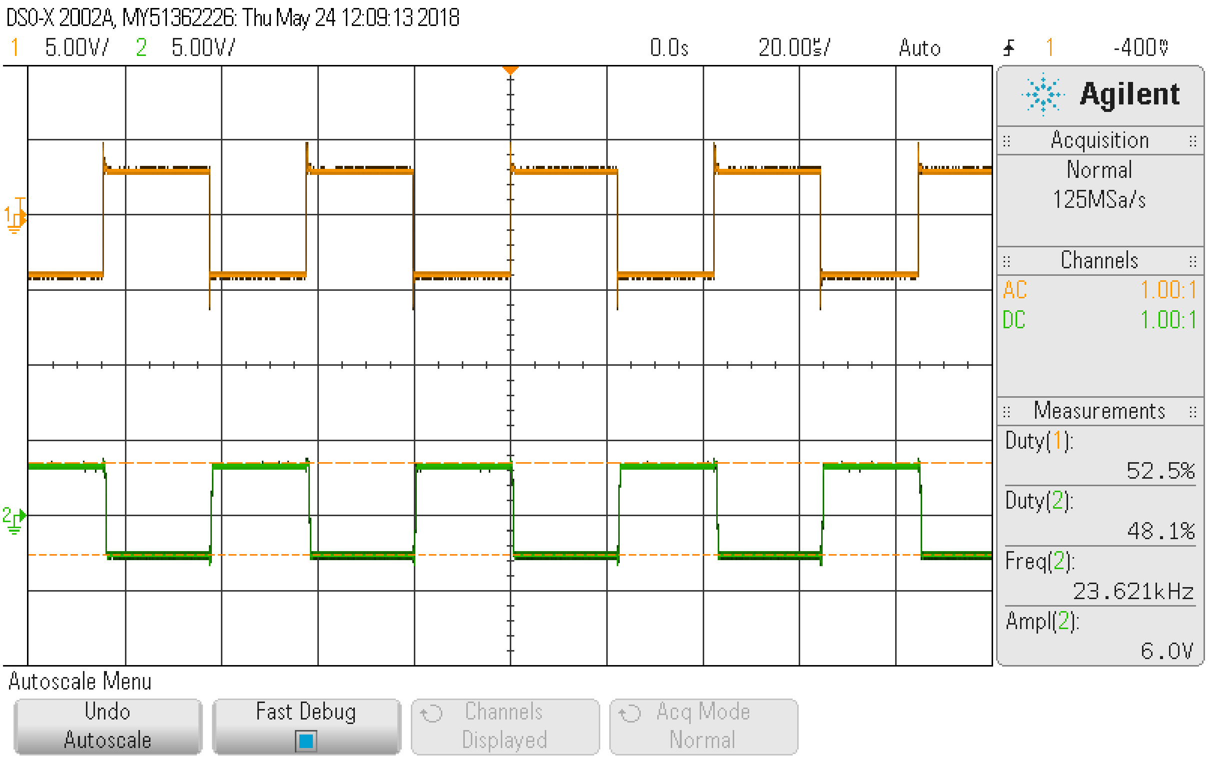

Figure 16. Square Wave Output Before Buffer (Yellow) and after Buffer Circuit (Green)

5.4. Integrator

Integrator circuit from figure 5 yields the expected undistorted waveforms when operating at a frequency 2 KHz to 24 KHz. These undistorted outputs are shown in figures 17 and 18.

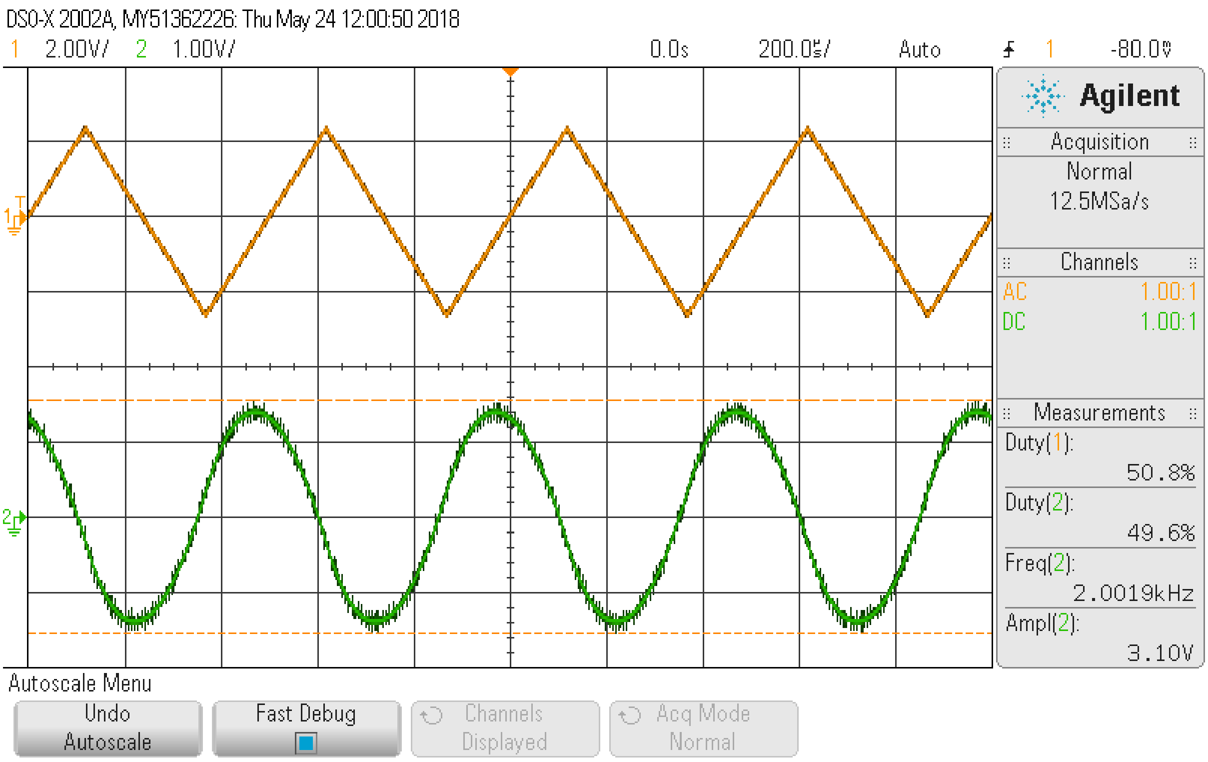

Figure 17. Integrator Output (Green) from 2 KHz Triangle wave input (Yellow).

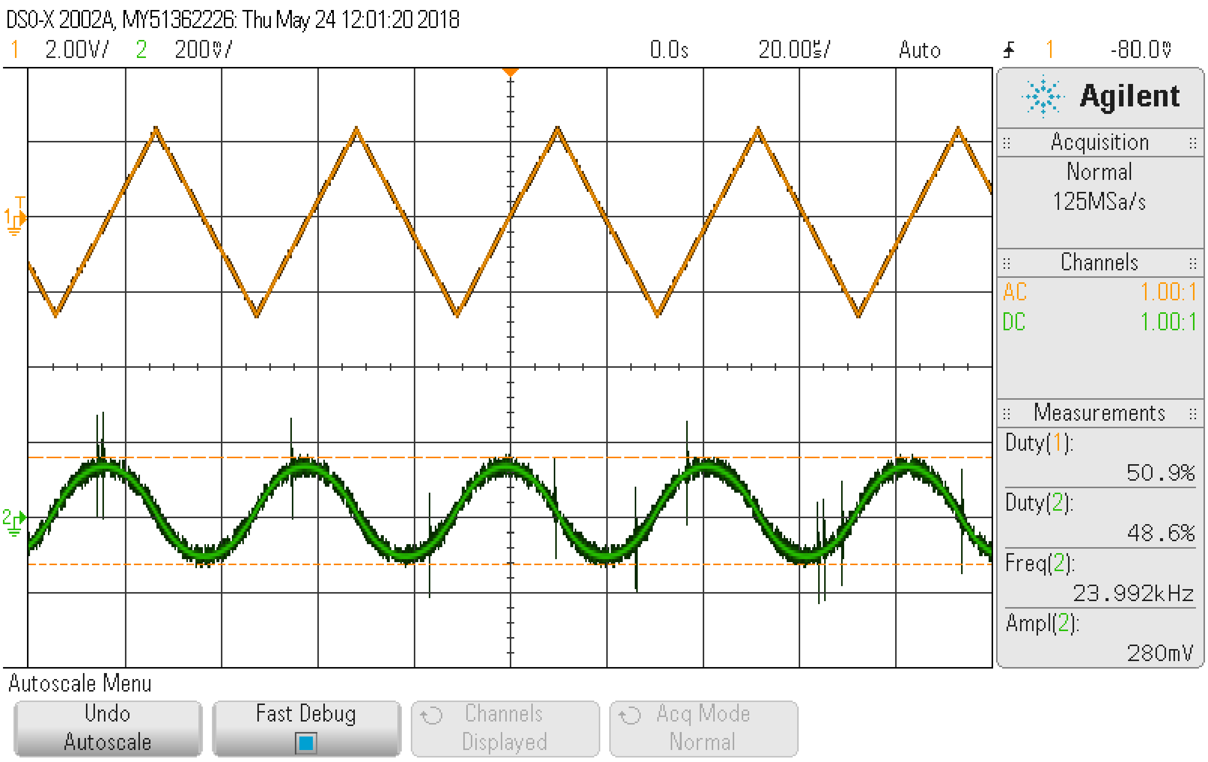

Figure 18. Integrator Output(Green) from 24 KHZ Triangle wave input (Yellow).

However outside of this frequency range the outputs receive some distortion. Output quality is summarised in table 2.

Table 4. Integrator performance

Input	Frequency(Hz)	Output	Distortion
Square	500	Triangle	low
Square	1000	Triangle	none
Square	2000	Triangle	none
Square	4000	Triangle	none
Square	8000	Triangle	none
Square	12000	Triangle	none
Square	16000	Triangle	none
Square	20000	Triangle	none
square	24000	Triangle	none
Triangle	500	Sine	low
Triangle	1000	Sine	low
Triangle	2000	Sine	none
Triangle	4000	Sine	none
Triangle	8000	Sine	none
Triangle	12000	Sine	none
Triangle	16000	Sine	none
Triangle	20000	Sine	none
Triangle	24000	sine	none

5.5. Amplifier

Utilisation of amplifier illustrated in figure 9 successfully gave prototype 2 amplitude modulation. The amplitude modulation has varying ranges across the different wave forms and frequency outputs. The resultant amplitude modulation range can be seen below in table 3.

5.6. Prototype 1 Performance

Prototype 1 successfully produced the three desired waveforms (square, triangle and sine), however the output proved to be unreliable and would be lost due to small disturbances. Prototype 1 also had limited amplification modulation ability.

5.7. Prototype 2 Performance.

Prototype 2 produces reliable square, triangle and sine wave outputs with amplitude and frequency modulation ability. Sample Square, Triangle and Sine Wave outputs are shown in figures 19, 20 and 21 respectively.

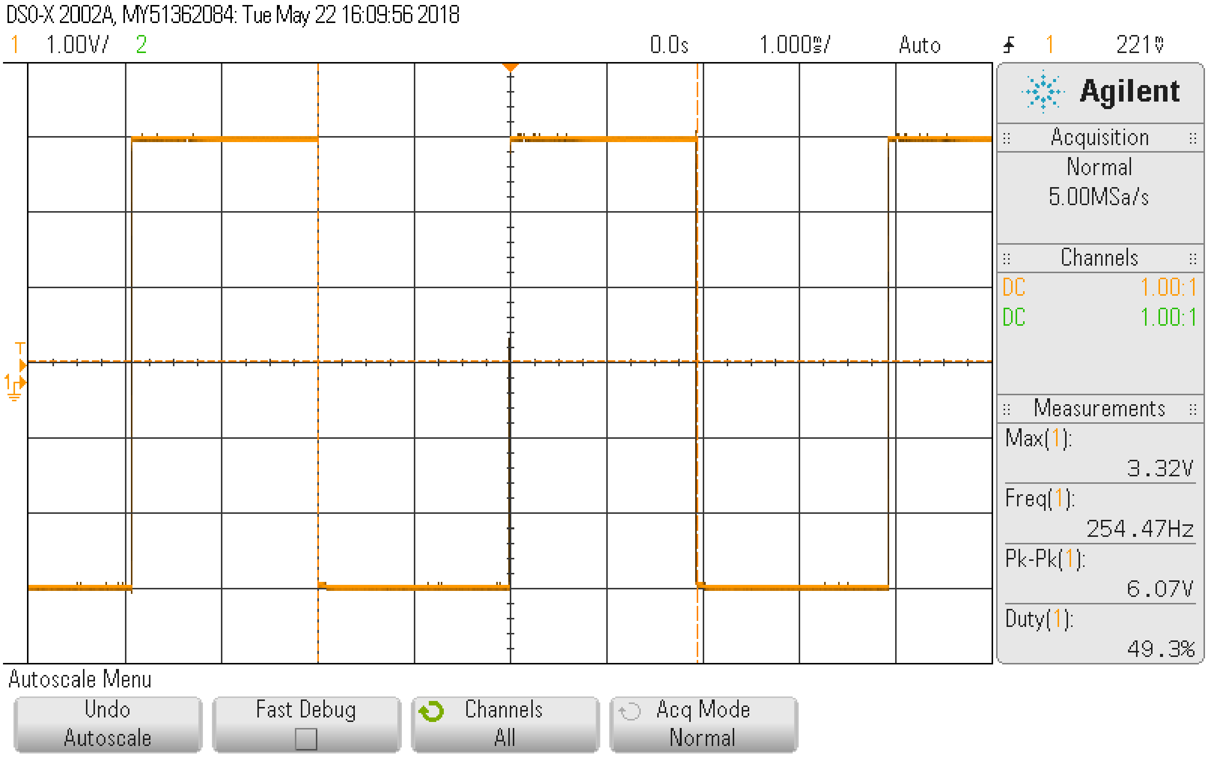

Figure 19. Prototype 2- 250 Hz Square Wave Output

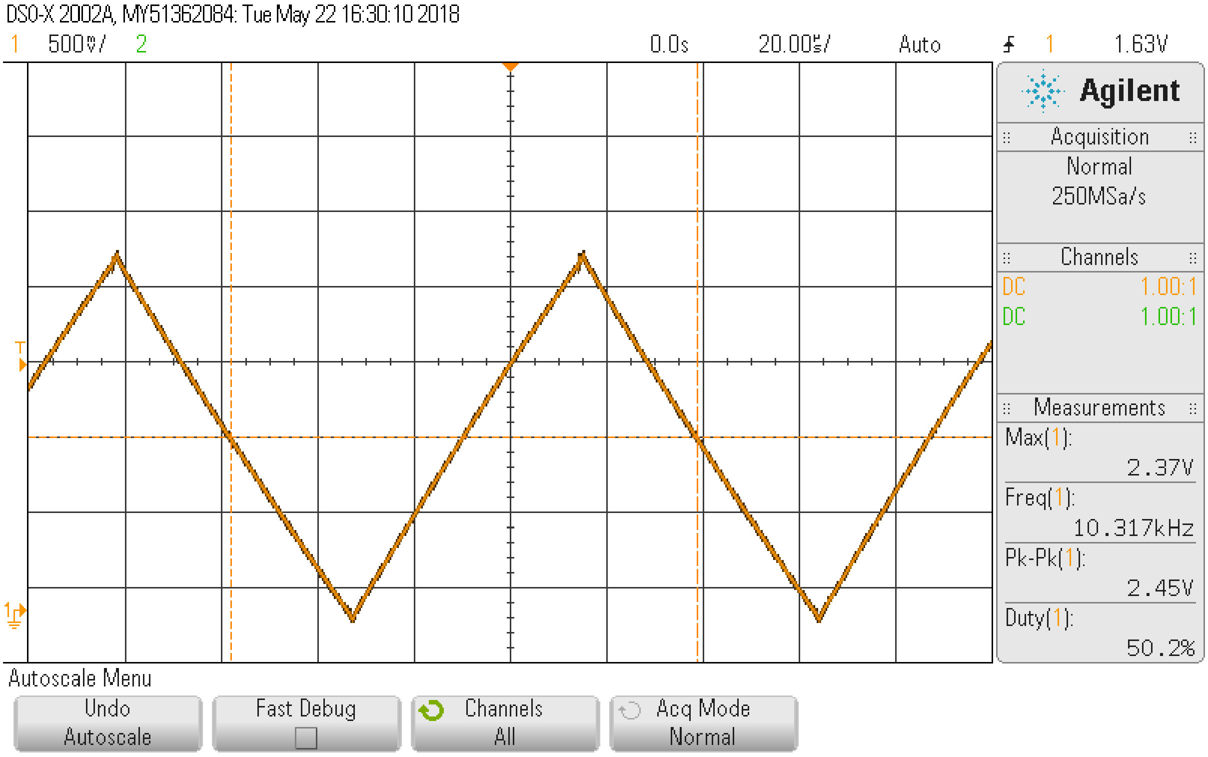

Figure 20. Prototype 2- 10 KHz Triangle Wave Output

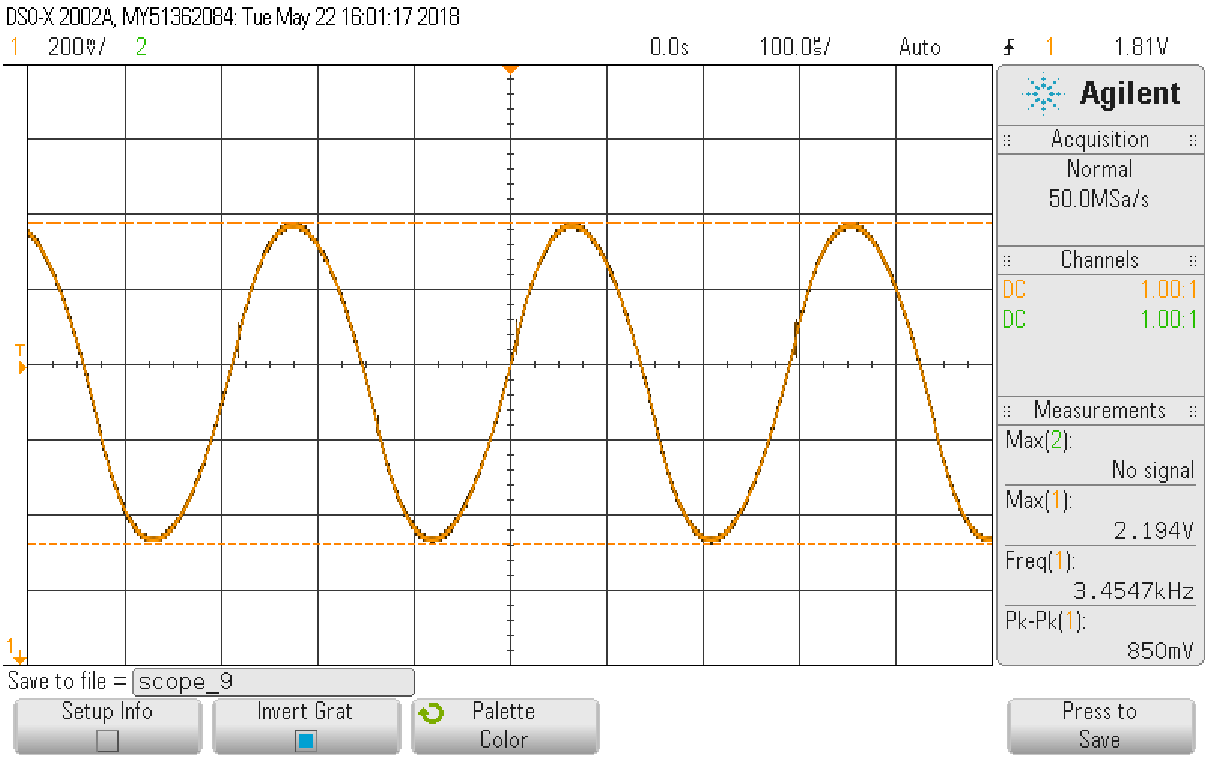

Figure 21. Prototype 2- 3.5 KHz Sine Wave Output

The output quality and capabilities of prototype 2 are summarised in table 3.

Table 5. Prototype 2 - Output characteristics

Frequency	Square Wave	Distortion	Max-PP(V)	Min-PP(V)
500	Square Wave	none	6.5	0.15
1000	Square Wave	none	6.5	0.15
2000	Square Wave	none	6.5	0.15
4000	Square Wave	none	6.5	0.15
8000	Square Wave	none	6.5	0.15
12000	Square Wave	none	6.5	0.15
16000	Square Wave	none	6.5	0.15
20000	Square Wave	none	6.5	0.15
24000	Square Wave	none	6.5	0.15
500	Triangle	High	5.9	0.15
1000	Triangle	Low	5.6	0.15
2000	Triangle	none	5	0.15
4000	Triangle	none	4.1	0.15
8000	Triangle	none	3	0.15
12000	Triangle	none	1.75	0.15
16000	Triangle	none	1.6	0.15
20000	Triangle	none	1.6	0.15
24000	Triangle	none	1.5	0.15
500	Sine	low	5.7	0.15
1000	Sine	low	3.5	0.15
2000	Sine	none	2.2	0.15
4000	Sine	none	0.72	0.15
8000	Sine	none	0.2	0.1
12000	Sine	low	0.12	0.04
16000	Sine	low	0.12	0.04
20000	Sine	high	0.06	0.04
24000	Sine	extreme	-	-

5.8. PCB Performance-Prototype 1

PCB design contained errors, consequently the PCB of prototype 1 failed to yield any successful outputs. Design errors include C7 and C8 connected to negative power rail instead of ground and C7 respectively.

Further errors were created from installation and correction of a faulty 555-Timer IC. Consequently multiple copper tracks were damaged and unable to be successfully repaired.

The malfunctioning PCB is shown below in figures 21 and 22.

Figure 23. Prototype1 –Top View

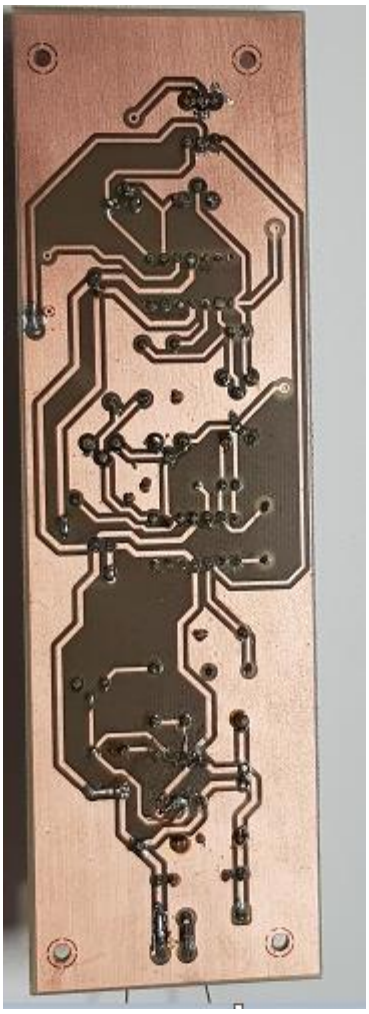

Figure 22. Prototype2- Bottom View

5.9. Prototype 1 Vs Prototype 2

Prototype 2 has proven to be more reliable than prototype 1 and the output wave forms exhibit less noise than prototype 1. Due to the reduced noise the triangle and sine waves also prove to have less distortion. The addition of an amplifier module after the output selection switch has also proven to provide more effective amplitude modulation to the circuit. Additionally the reduction in variable resistors from seven to four results in a circuit that is both easier to operate and cheaper to construct.

6. User manual

This section will be a user manual direction on how to manipulate the prototype function generator to acquire the outputs needed for each type of wave.

6.1. General information

This manual will provide an overview on how to control the prototype for each waveform output, safety, maintenance and trouble-shooting the prototype.

6.2. Safety

The prototype was designed to function off a 9-volt battery with exposed board for manual tuning of the waveforms, safety is of the highest priority and the prototype must not be used by anyone who does not have the required knowledge of how electronics, electricity and a function generator works.

- Keep board within a secure area while in use and not in use.
- Check over board before and after use for any damage.
- Check connection wire to the prototype – Do not use if wires are damaged; replace damaged wires if needed.
- Do not over-supply board with more than 9V battery.
- Careful when tuning board with screw-driver – preferable material for tuning is plastic.
- Do not bend circuit board.

6.3. Controlling the prototype

System overview

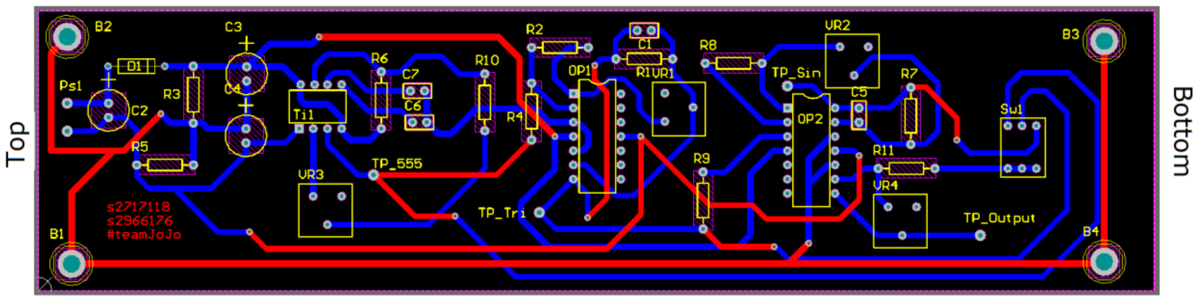

Figure 24. Figure of the PCB of each component position on the board as well as tracing on the bottom layer (blue) and the top layer (red).

Table 6. Controllable parts on the board and action associated.

Controllable Part	Part Code	Action
Potentiometer	VR3	Changes frequency of 555-timer

Potentiometer	VR1	Controls the gain of the signal leading in the first integrator module
Potentiometer	VR2	Controls the gain of the signal leading in the second integrator module
Potentiometer	VR4	Altering the gain of the output signal
Switch	Sw1	Controls which signal is read at the output testing point (TP_Output)

Table 1. Tabular form of the controlling parts of the board and the actions.

NOTE: On the board you can see text in which has TP_name – these points on the board are testing points – 555 is the square wave, Tri is the triangle wave, Sin is the sine wave where Output is the output of the board using the switch to control which signal can be fed from the board.

System functionality

Connection the power to the board:

To power the board, attach a 9-volt battery to the battery attachment located at the top of the board.

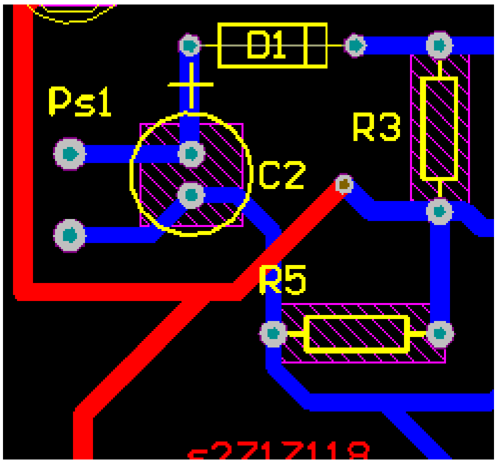

Figure 25. Figure of the power supplying circuit of the PCB (Ps1) are the pin holes that power will be supplied to the board - a battery connector will be connected to this point to attach a 9V battery

Figure 26. 9V battery connector that will along 4.5V-positive and 4.5V-negative to be supplied to the board

Location of output:

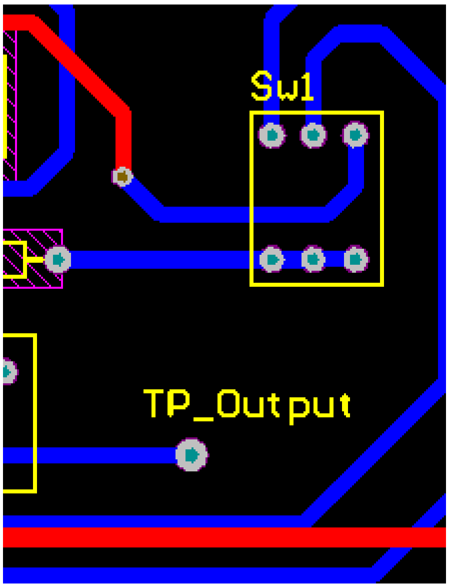

Figure 27. TP_Output is the testing point for the final output pin on the board

Positioning the board in the same way shown in the figure above will allow you to match the lay-out. Highlighted in the figure is the output section of the board, the output pad which is a 0.8-millimetre hole is left for use preference to what attachment the user wants. The active line (usually a red cord) should be attached to the output's attachment and the inactive line (usually a black cord) should be attached to the ground plane of the board (the copper plate that covers the board.

Controlling the Square-wave:

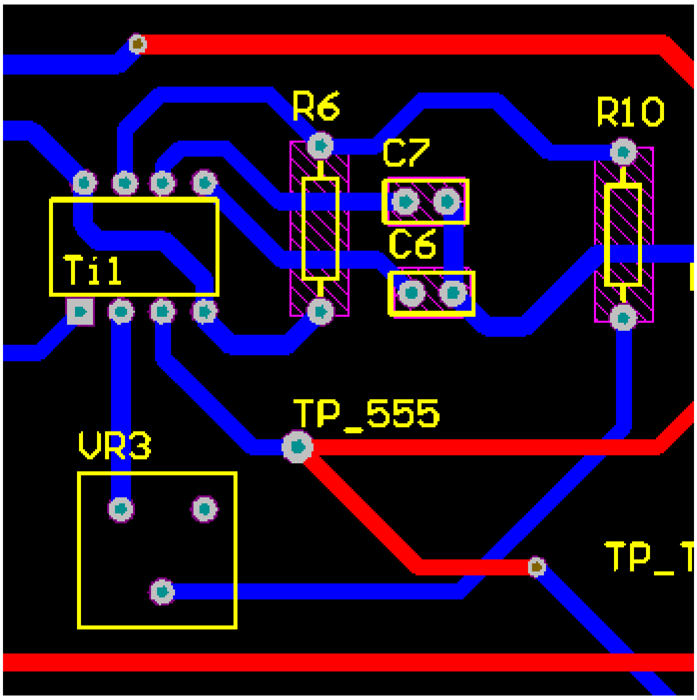

Figure 28. 555-timer circuit shown, VR3 is the potentiometer that changes the frequency of the signal

In the highlighted section of the figure above, this is the layout of the 555-timer generating the square wave. Within this section you will notice a part labelled VR3 – this is the potentiometer / variable resistor, in the middle of this potentiometer is a grooved section that will allow a flat-head screwdriver to rotate in a clockwise and counter-clockwise position, this is the method in which the generated square wave will changed in frequency specifically from 200 Hz to 20,000 Hz, TP_555 is the testing point for the 555-timer which is a square wave.

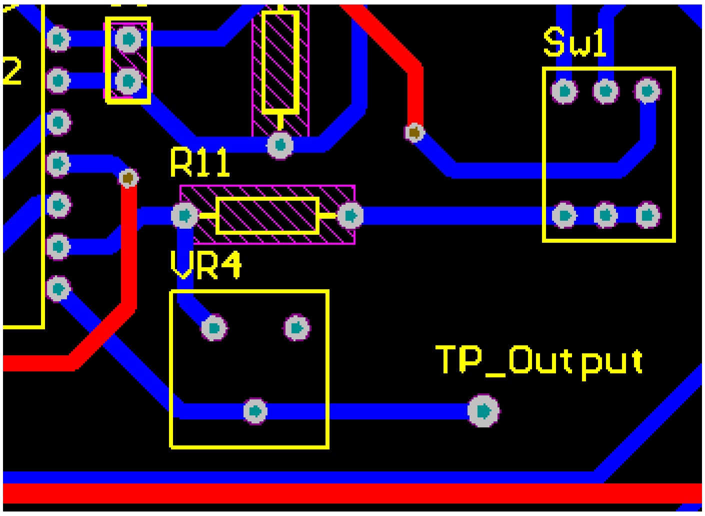

Figure 29. Circuit of the final amplifier after the switch (Sw1) with the TP_Output being the testing point for the output of the board's signal being fed by the switch

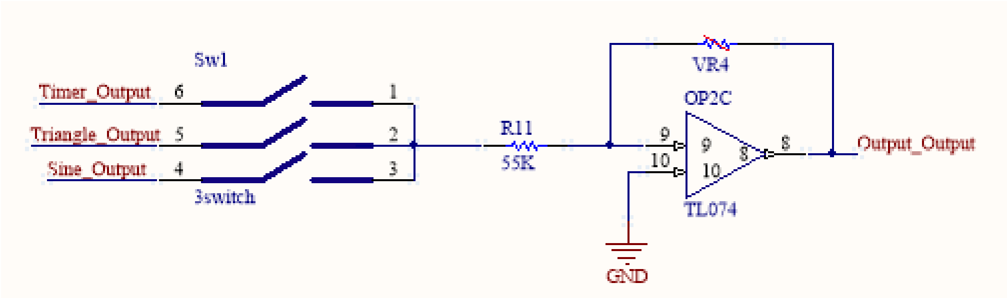

Figure 30. Circuit of the switch (Sw1) to amplifier in a schematic form - the switch physically labelled to match which on/off will output which signal (Square wave is linked to 1, Triangle wave is linked with 2, Sine wave is linked with 3)

In the highlighted section of the figure above, this section controls the gain of the generated output, via VR4. Rotating potentiometer VR4 will control the gain of the output.

Note: The wave can be truncated if needed although it is recommended to not exceed the voltage rail input which is 4.5V+ and 4.5V- (this is created by the 9V battery).

Controlling the Triangle-wave:

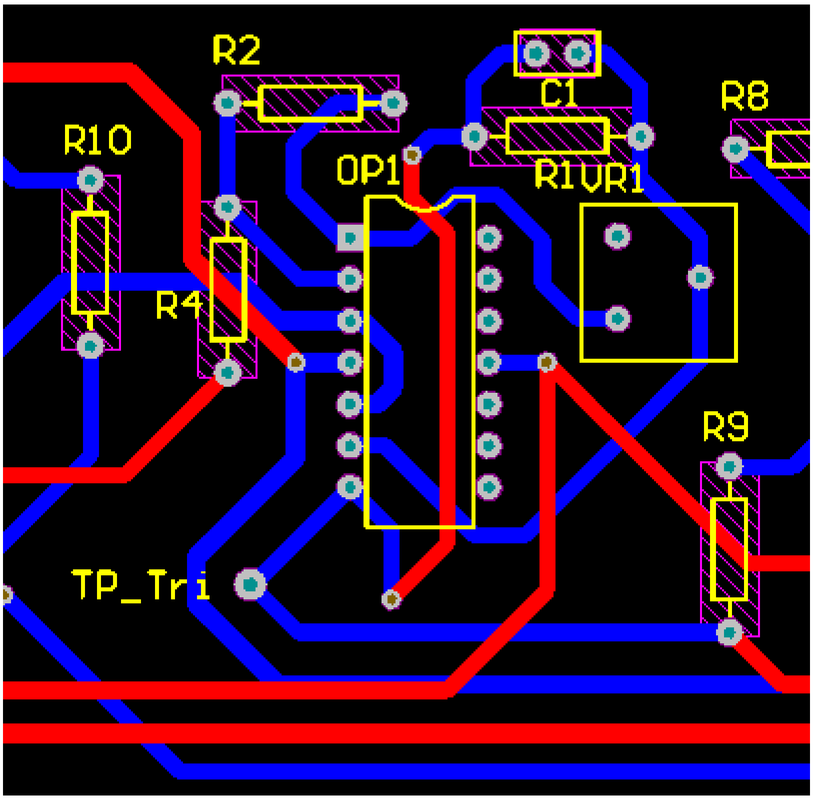

Figure 31. Triangle integrator circuit shown, VR1 is the potentiometer that changes the gain of the signal leading into the integrator

In the highlighted section of the figure above, is the layout of the first stage integrator that will manipulate the inputted square-wave and outputs a triangle-wave, the potentiometer labelled as VR1 will control the signal gain for the triangle integrator, TP_Tri is the testing point for the Triangle wave.

Note: Check "Controlling the Square-wave" for the figures and a text in controlling the output gain.

Controlling the Sine-wave:

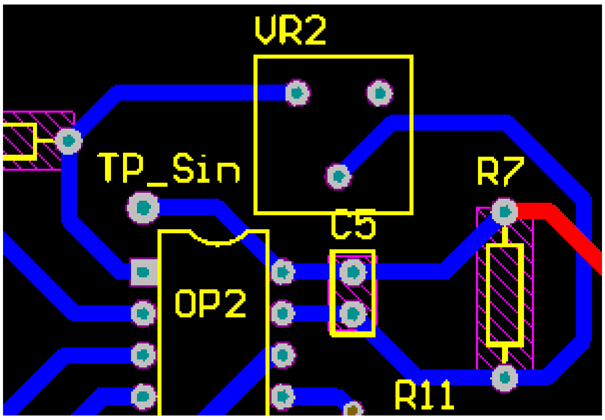

Figure 32. Triangle integrator circuit shown, VR2 is the potentiometer that changes the gain of the signal leading into the integrator

In the highlighted section of the figure above, this is the layout of the first stage integrator that will manipulate the inputted triangle-wave and outputs a sine-wave, the potentiometer labelled as VR1 will control the signal gain for the sine integrator, TP_Sin is the testing point for the generate sine wave.

Note: Check "Controlling the Square-wave" for the figures and a text in controlling the output gain.

6.4. Maintenance

Upkeep for the board is minimum, every six months check the connections between each component via testing of resistance values as well as searching for any signs of damage to the components along the copper traces.

6.5. Troubleshooting

Function Generator Produces No Output

In the event the function generator produces no output:

- Ensure positive and negative power supply are securely connected at 9V. Ensure the function generator is correctly connected with the negative terminal connected to the ground plane and the positive terminal connected to the output pin. If still no output- connect positive terminal of oscilloscope to test point 1.
- Measure voltage between drop across R3 and R5. If voltage drop across either resistor is less than 3.5V or more than 4.5V check resistor connections are secure and no shorts are

present. If Connections are secure and voltage drop still falls outside of 3.5V-4.5V range R1 or R2 need replacing.

Function Generator Powered correctly-No Output

- If above checks reveal no errors the issue arises from the 555-timer circuit. Perform checks on all connections in the 555-timer circuit. If all connections are secure and not shorted and still no output occurs on test point 1. 555-timer chip is damaged and needs replacing. Alternatively if Output isn't a square wave C7 may need replacing.

No frequency Modulation

- In the event the function generator functions normally with the exception of frequency modulation, VR3 connections are either unstable or VR3 is damaged and needs replacing.

No Amplitude Modulation

- In the event the function generator functions normally with the exception of Amplitude modulation, VR4 connections are either unstable or VR4 is damaged and needs replacing.

Square Wave and Triangle wave Outputs Functioning-Sine wave error

- In the event triangle wave and square wave outputs function normally but an error occurs in the sine wave output, the issue can be isolated to the integrator 2 circuit. Ensure the triangle wave output is functioning correctly, then without altering VR3 and VR1 slowly adjust VR2 through its full range of values while checking output.
- If at no time during the above steps the sine wave output produces an output OP-AMP2 connections are compromised or OP-AMP2 is damaged and needs replacing.
- If variation of VR2 has no effect on outputted wave form connections to VR2 are compromised or alternatively VR2 is damaged and needs replacing.
- If variation of VR2 produces a change in the outputted wave form but waveform is not a sine wave, connections to C5 are compromised or alternatively need replacing.

Square Wave but Triangle and Sine wave error

- In the event the square wave functions normally but errors occur in the triangle and sine wave an issue is present in the integrator 1 circuit. Alter VR1 through its full range of values while monitoring triangle wave output. If an output signal exists but variation of VR1 has no effect on the output, VR1 connections have been compromised alternatively VR1 is damaged and needs replacing.

- If altering VR1 effects the triangle wave output but doesn’t produce a triangle output C1 connections are compromised or alternatively C1 is damaged and needs replacing.
- If at no time during the above process an output signal is present at the triangle wave output OP-AMP1, connections are compromised or alternatively OP-AMP1 is damaged and needs replacing.

7. Analysis

Sensitivity of heat application of the soldering iron to the through-hole legs of op-amps can cause problems if the soldering iron's temperature is too high and left to long against the op-amp leg, the heat transfer could damage the op-amp, this case is especially problematic if the op-amp needs top soldering thus resulted in replacement of the most expensive component within this project's first prototype at approx. $11 AUD with the cost on par with the potentiometers at $11.55 AUD for 7 and electrolytic capacitors at $12 AUD for 5. The potentiometers where used in controlling gain and electrolytic capacitors were utilised to prevent DC parasitic effects and noise via decoupling capacitors. However two are needed to create a voltage differential that will allow the board to be run off a single battery instead of needing a dual power supply.

8. Conclusion

The failure of the first prototype caused a redesign which resulted in the construction of the latest prototype-MKII and the reduction of potentiometers and electrolytic capacitors; implementing the lessons learned from the failed construction of the PCB illustrated in section 5.8 the following PCB has been designed.

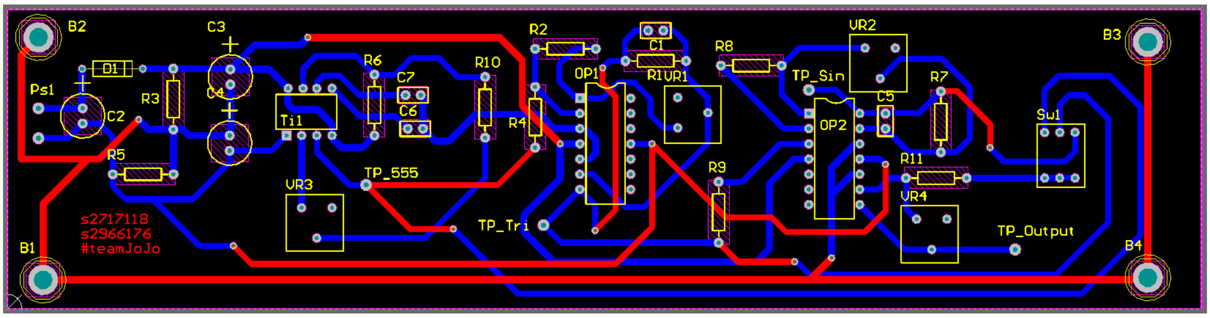

Figure 33. PCB board pre-polygon pour with all trace visible

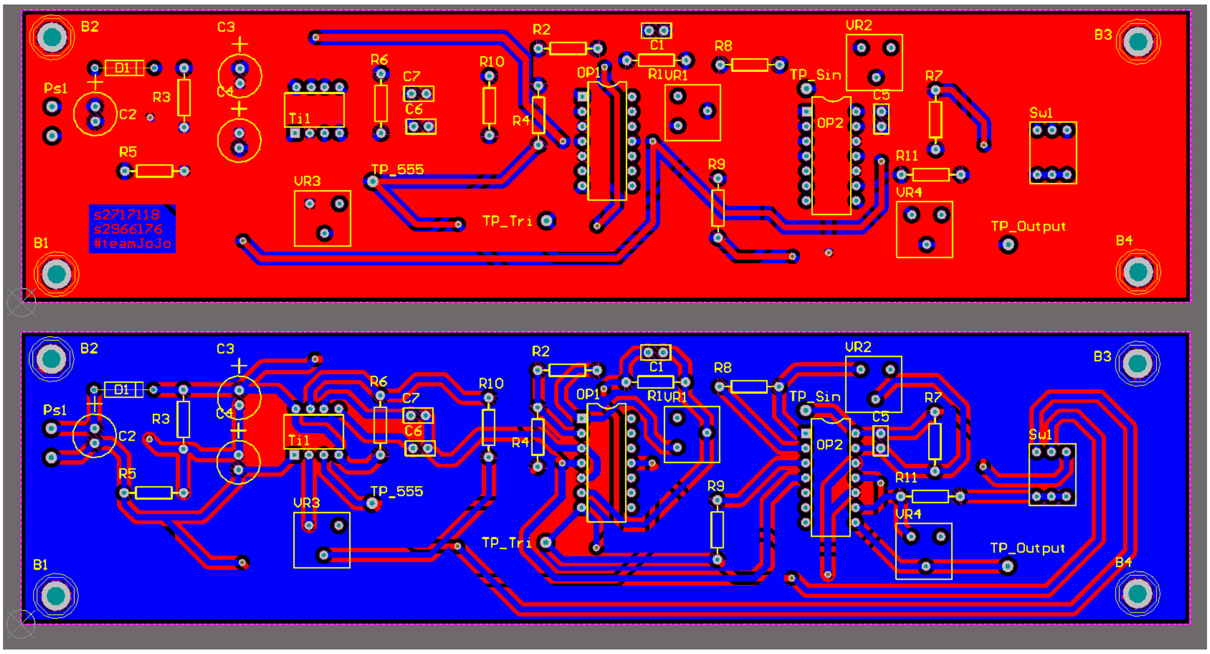

Figure 34. Polygon pour showing both top (red) and bottom (blue) layers

Breadboard construction of Prototype 2 has produced waveforms that are both less distorted and more reliable than those created by Prototype 1. Prototype 2 also has the benefits of being slightly simpler than Prototype 1 and needs three less variable resistors to control the output. Consequently Prototype 2 is cheaper and easier for potential customers to use however without utilising larger manufacturer distributing electronic components from overseas the price was not reduced significantly from the prices in Market Analysis section under Out-sourced Chinese market.

9. References

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