1. Introduction

This design will include the use of a buck converter along with a PI controller and a voltage divider to achieve a fixed output voltage. The desired output voltage must be between 2.4V and 9.6V as it's 20% to 80% of the desired input voltage; 12V being the desired input voltage. The PI controller will be the same controller that was created in lab 6 when a feedback system along with a PI controller was implemented for the buck converter. A stable feedback system is important for health and safety as instability of a high voltage circuit can cause a lot of damage to its environment if instability were to occur.

2. Background

In a DC/DC converter a feedback loop is important to maintain a fixed desired output voltage for a buck converter. To achieve this, an error reading will be taken from the desired output and fed back into a summing junction to allow the system to correct itself. As a result, the equation in figure 2.1 has been utilised to create a close feedback system.

$$negative\ feedback = \frac{forward}{1+foward}$$

Figure 2.1

To compensate for the feedback instability a PI controller will be implemented. Additionally, the PI controller will remove steady state error as it reduces the system type. This is a result of introducing a pole at the origin and a finite zero to the feedback loop. To further develop this project a voltage divider will be implemented so that the output voltage of the buck converter can be changed between 20% to 80% of the input voltage.

3. Schematic

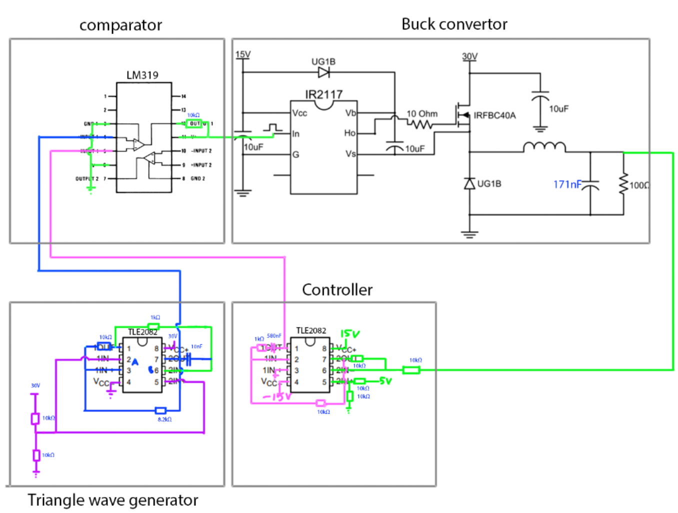

Figure 2.1: schematic of the system without the physical mechanism

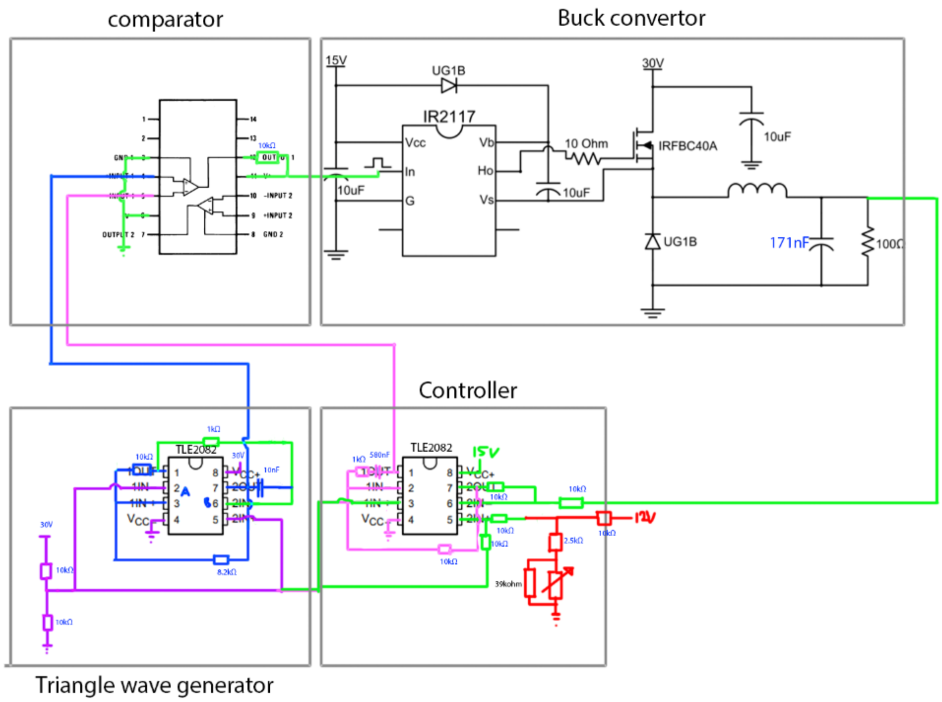

Figure 2.2: new schematic without negative rails and physical mechanism

4. Methodology

The recommended design procedure requires us to test one section of the PI controlled buck converter at a time. Furthermore, we have built and tested the triangle wave generator first before continuing the build. Additionally, the same process was done for the comparator where an input was connected to a 5V supply to simulate the effects of a PI controller while the other input is a triangle wave (figure 4.1). This resulted in a square wave signal. This square wave will be fed into the buck converter's mosfet for the switching frequency which in turns supports the buck converter.

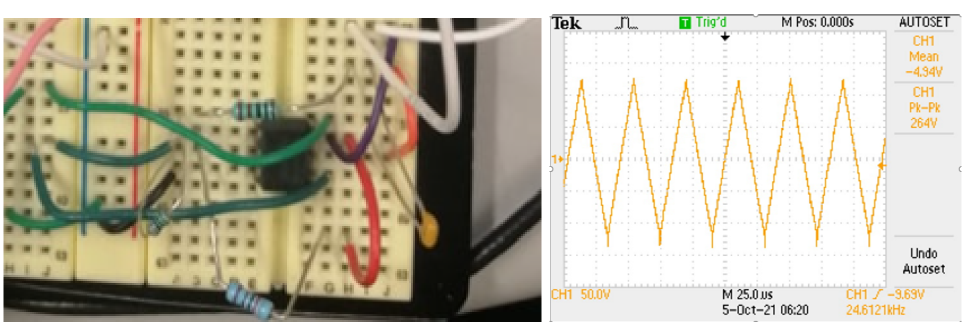

Figure 4.1: Image of the triangle wave generator and the oscilloscope reading

Testing of each section should be done before final assembly to allow for easier diagnostics if future mistakes were to be created. As a result, a PI controller was simulated on another breadboard before an attempt was made on the original circuit (figure 4.2). There were some issues when following the original schematic due to not having enough resources to give a negative rail so a different reference point was provided for the subtractor circuit. This will be the same Vc used for the triangle wave generator as can be observed in figure 4.3.

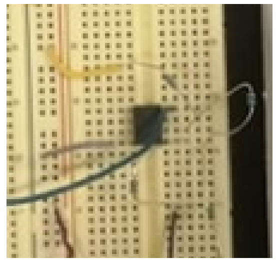

Figure 4.1: attempted PI controller

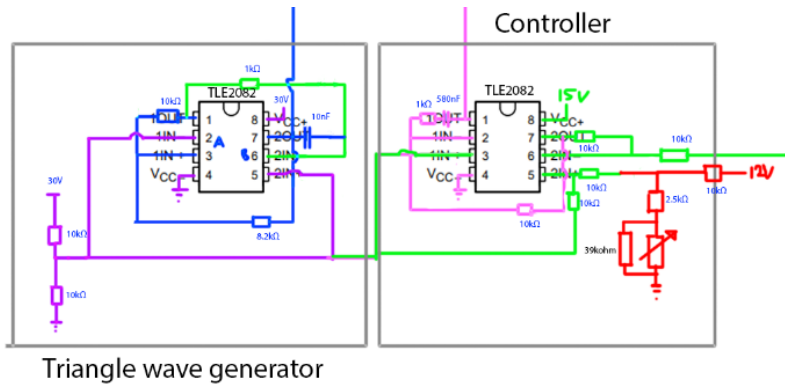

Figure 4.2: new triangle wave + controller schematic. Controllers using the same Vc as triangle wave generator rail will provide a different voltage reference point.

Once the PI is connected to the comparator, it should provide us an error reading for the system to which it can be processed by the comparator. The output of the PI controller may result in +/- voltage before going back down to 0. The output of the PI will be fed into the comparator so that it may act as a feedback error input.

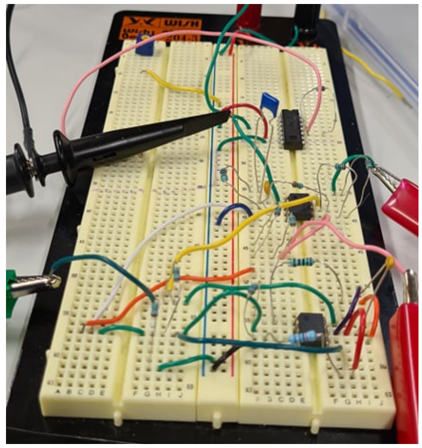

Figure 4.3: finished controller with comparator and triangle wave generator, buck converter assumed finished

To test this step of the design, 5V was imputed as the desired output for the subtractor circuit (pin 5) while pin 6 is a varying voltage to simulate as a feedback before proceeding with the next step. This will ensure that the PI system works before a potentiometer is cascaded onto the controller. Furthermore this will cross out the PI controller as a fault for future errors.

Final step of this design was to implement a physical mechanism that will alter the voltage input between 20% and 80% of its original voltage. This physical mechanism will include a trimmer, and 2 x 10kΩ resistors that will cascade onto the positive terminal of the differential amplifier. When the trimmer is at its max resistance value we can expect the voltage reference to be 80% of the 12V as it is the desired input voltage. Whereas, when the trimmer is at its lowest resistance value we can expect a voltage reference to be 20% of 12V. Using the voltage divider equation.

$$V_{ref} = \frac{R_2}{R_2+R_2} * V_{in}$$

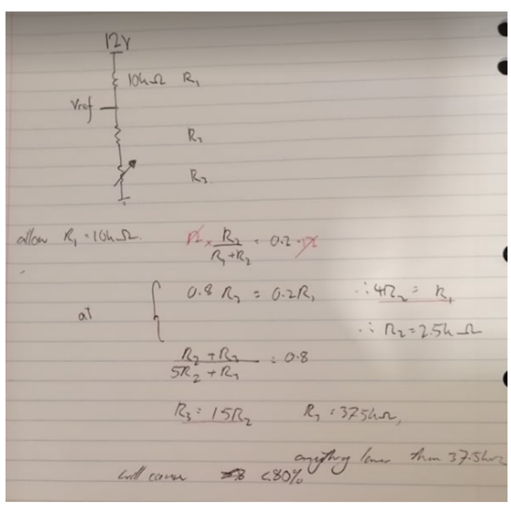

Figure 4.4: calculations for voltage divider (physical mechanism).

With this physical mechanism we can achieve a voltage range of 2.4V (low potentiometer resistivity) to 9.6V (high potentiometer resistivity) for the output of the buck converter without the alteration of the power supply (20% to 80% of the input voltage). This range of voltage input would be the desired output for the buck converter since the output of the buck converter will constantly be compared to the desired range of voltage. Since a 1MΩ potentiometer was the only available variable resistor, a parallel resistor must be attached onto it to allow a 80% of the voltage input at the maximum resistor value. If this wasn't in place a maxed out 1MΩ potentiometer will cause 99.9% of the 12V input voltage to become the output.

The parallel resistor was calculated to be 39kΩ to provide a rail to ground when the potentiometer maxes out to 1MΩ. The user can now alter between 2.4V and 9.6V depending on the resistivity of the potentiometer.

$$37.5k\Omega = \left(\frac{1}{1000000} + \frac{1}{x}\right)^{-1} \therefore x = 39k\Omega$$

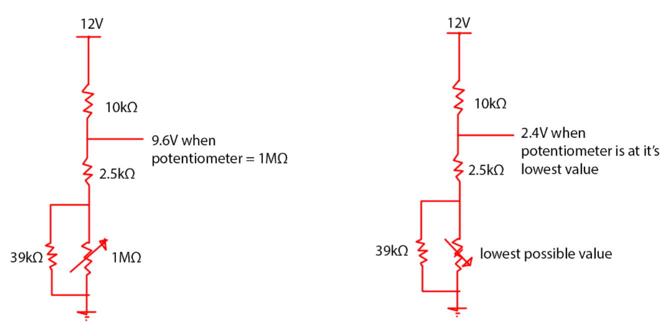

Figure 4.5: example of attached physical mechanism (potentiometer/ voltage divider)

5. Results

When the comparator was connected with the triangle wave signal and the PI controller the output resulted in a flat line. However this was overcome by feeding both inputs through a signal generator and a varying voltage to test the comparator. As a result of this trouble shooting, the comparator was working once more. When a buck converter was connected to the output of the comparator it would be a PWM which would change according to the feedback.

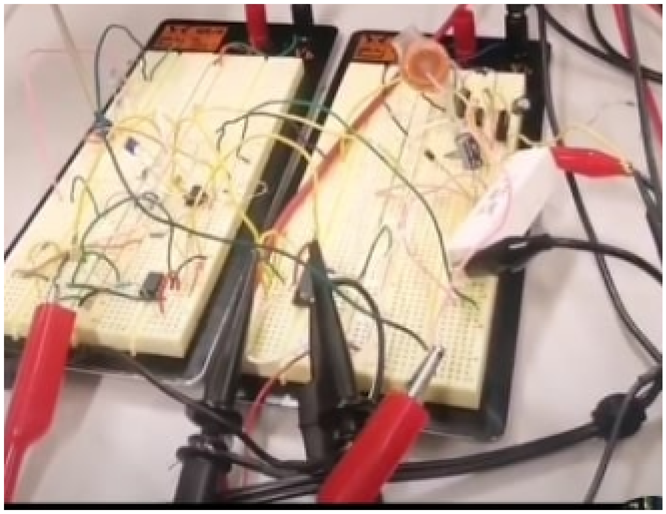

Figure 5.1: fully implemented schematic on a breadboard, PI controller, triangle wave generator, buck convertor and converter.

A major issue that we came across was the triangle wave peak to peak was too high for the LM319 voltage rails as a result a capacitor was employed in series with the triangle wave. This also resulted in the triangle wave generator IC heating up. Additionally, the voltage inputs of the triangle wave generator have been reduced to fit inside the comparator's voltage range. An issue that occurred involves the physical mechanism that if the potentiometer was to be cranked up too fast it will cause the PI system to go unstable before resetting itself.

Although a potentiometer voltage divider was an effective method in providing a form of error feedback it can be quite power intensive at high voltages. Hence, it may not be recommended for higher voltages. This is a result of the resistors heating up causing a loss of power thus resulting in loss of energy making it energy inefficient.

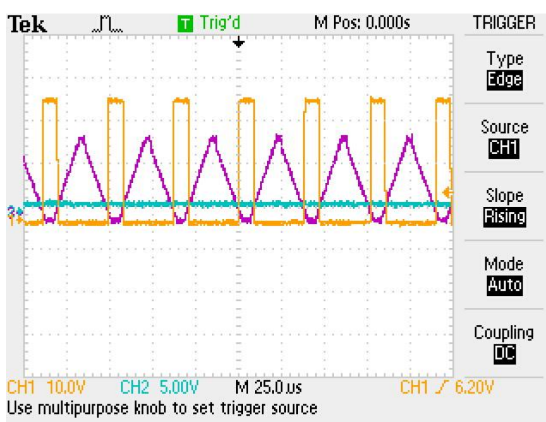

Figure 5.2: comparator output (orange), triangle wave generator (blue), error feedback (purple)

An alternative to a potentiometer voltage divider by the subtractor circuit was limiting the width of the square wave inside the gate driver. This can be achieved by attaching a potentiometer in a way that it can limit the width, which will lead to a cascade of events that will limit the average output voltage so that it will range between 20% to 80% of it. However, this can come at a cost of simplicity which is the benefit of using a voltage divider.

6. Conclusion

In conclusion, Systematically testing each component has proven to be an effective method to make trouble shooting in future points of the project much easier. This is a result of having checkpoints in a project. For example it would've been harder to diagnose if the subtractor had a false error reading due to not being able to go up to 80% of the 12V voltage input. In addition, Although a buck converter is useful it should also be used in conjunction with a voltage divider and a PI controller to achieve a fixed output voltage. Furthermore, it is important to take correct design procedure when it comes to feedback loops and high voltage circuits as a mistake can cause instability in the feedback and will result in great amounts of damage and may potentially be fatal.