Lab 3: Function Generator Design Project

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ECE 311-03
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1 Introduction

The purpose of this experiment is to successfully design and construct a function generator capable of producing square waves, triangular waves, and sinusoidal waves. This will be done by combining a Schmidtt Trigger circuit, an integrator circuit, and a wave shaper circuit.

2 Theory

To construct a function generator, it is necessary to understand its individual components. These are shown in Figure 1.

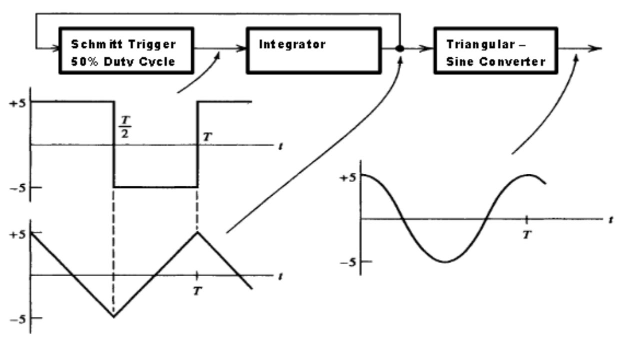

Figure 1: Block Diagram of Function Generator

As shown above, the output of the Schmidtt Trigger is used as the input to the integrator circuit. The output of the integrator is then fed back into the input of the Schmidtt Trigger and is also used as the input to the wave shaping circuit. A Schmidtt Trigger by itself is a comparator type circuit that switches the output to a negative value when the input passes upward through a positive reference voltage. It then uses positive feedback of a negative voltage to prevent switching back to the other state until the input passes through a lower threshold voltage. This is accomplished using the circuit shown in Figure 2.

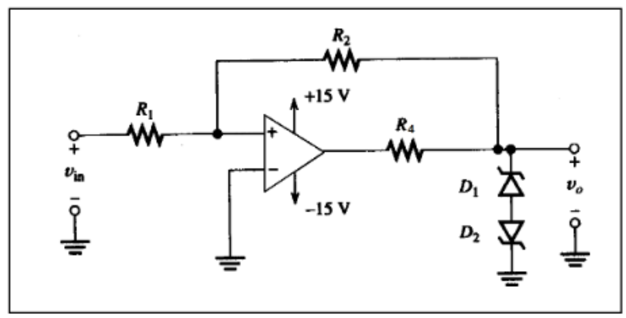

Figure 2: Schmidtt Trigger Circuit

The integrator circuit is designed so that the output signal will be the integration of the input signal. It is shown in Figure 3.

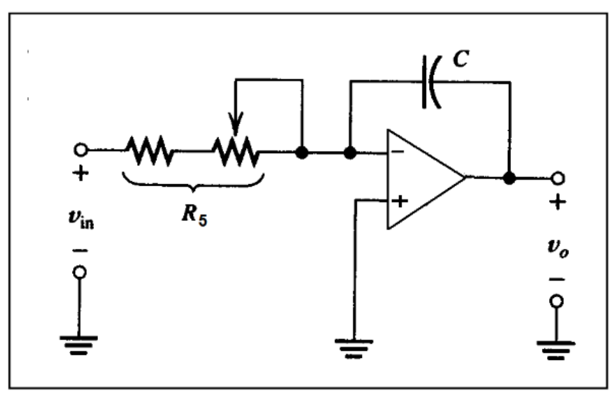

Figure 3: Integrator Circuit

If there is a constant positive voltage to the input, the op-amp output will fall negative at a linear rate. Conversely, a constant negative voltage at the input will result in a rise at a linear rate. The output voltage rate of change will be proportional to the value of the input voltage. The formulas for determining the voltage output are:

$$\frac{dV_{out}}{dt} = -\frac{V_{in}}{RC}$$

$$V_{out} = \int_0^t -\frac{V_{in}}{RC}dt + C$$

The Triangular-Sine Converter is shown in Figure 4.

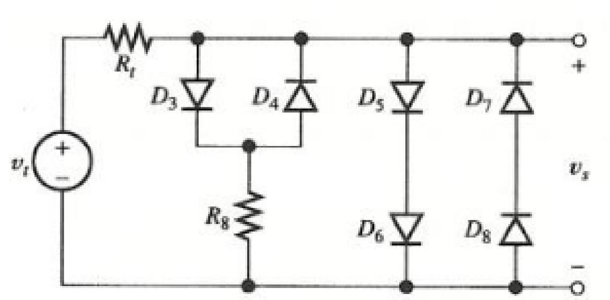

Figure 4: Triangular-sine Converter

This circuit uses a series of diodes so that the top of an input triangle wave is clipped to look more like a sine wave. They are paired so that both the positive and the negative portions of the wave are clipped to ensure that the entirety of the wave is transformed.

Now it is important to understand the function generator's operation. Assume that at time $t = 0$ the outputs of the Schmidtt trigger and the integrator are both +5V. This means that for $0 < t < T/2$, the input to the integrator will be a constant. The integral of a constant is always a ramp function. Since the output of the integrator is fed back into the input of the Schmidtt trigger, and since the integrator being implemented inverts the signal, Figure 1 shows that the Schmidtt trigger flips to -5V when its input, or the output of the integrator, is -5V. The input to the integrator then becomes negative, thus the output of the integrator is positive. At time $t = T$, the output of the integrator becomes positive, thus flipping the ramp function. Using the Schmidtt Trigger, a square wave is generated. Using the combination of the integrator and Schmidtt trigger, a ramp or triangular wave is generated, but a sine wave must also be generated for the completion of the function generator. As discussed before, the output of the integrator, a ramp function, is then transformed via non-linear elements such as diodes in the circuit of Figure 4. This completes the function generators design.

3 Procedure

The equipment used in the lab was:

- Breadboard
- DC Power Supply
- Function Generator
- Oscilloscope
- $1\mu F$ Capacitor

- $1k\Omega, 10k\Omega$, and $100k\Omega$ resistors
- Voltage regulator
- Diodes
- 741 Op-Amp Chip
- Wire

It was decided that since the function generator could be broken down into smaller sub-circuits, it would be beneficial to construct each of these sub-circuits one at a time, test their functionality, and then combine them together. The first sub-circuit constructed was the Schmidtt Trigger shown in Figure 2. Once constructed, its transfer function was then tested for verification. This is shown in Figure 5.

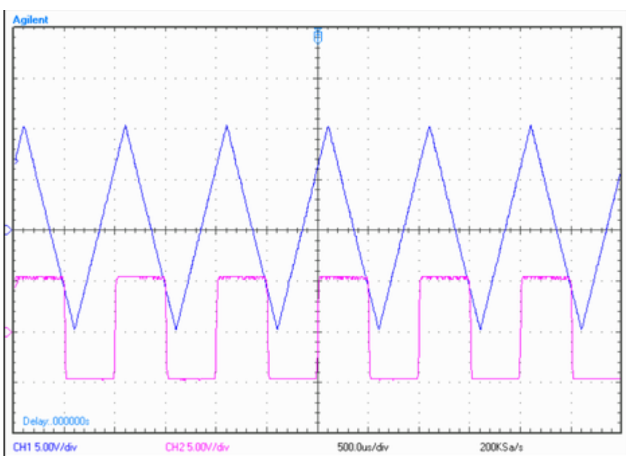

Figure 5: Schmidtt Trigger Transfer Function

After this, the integrator shown in Figure 4 was built. The transfer function was then tested. This is shown in Figure 6.

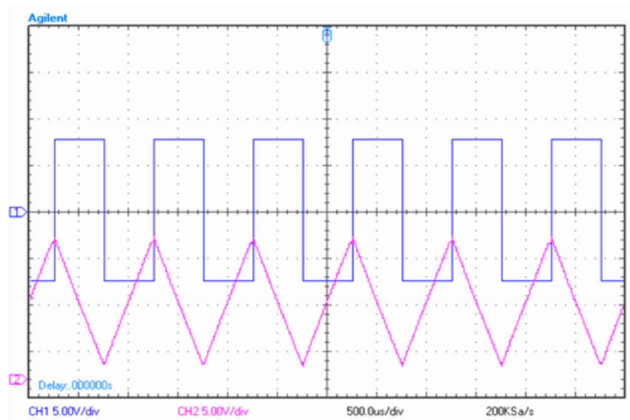

Figure 6: Integrator Transfer Function

Once the output was verified, the Schmidtt Trigger and the integrator were then combined as discussed in Section 2. The last sub-circuit to be constructed was the wave shaping circuit shown in Figure 4. Once completed, all three sub-circuits were combined as shown in Figures 7 and 8. The oscilloscope was then utilized to show the characteristics of the Fast Fourier Transform. This is shown in Figures 9 10.

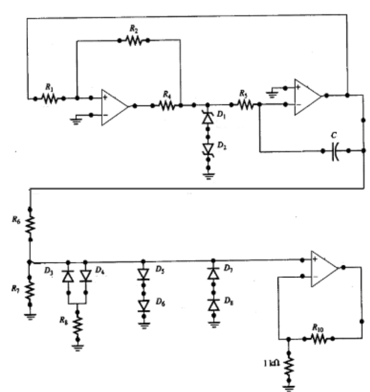

Figure 7: Function Generator Circuit Diagram

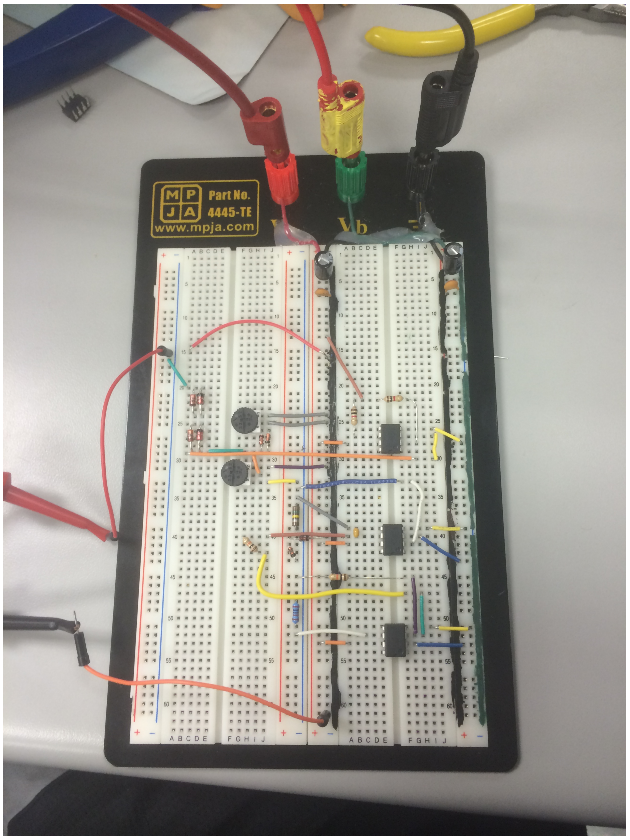

Figure 8: Implementation of Function Generator Circuit

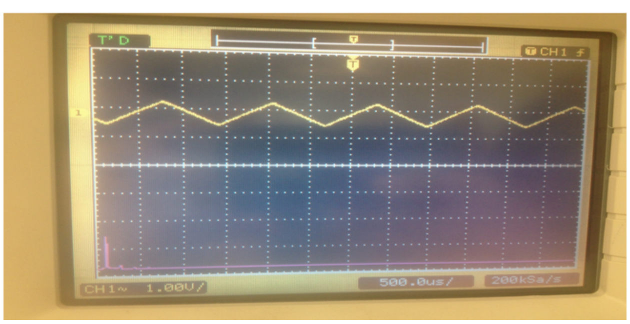

Figure 9: Low Setting of Voltage Regulator

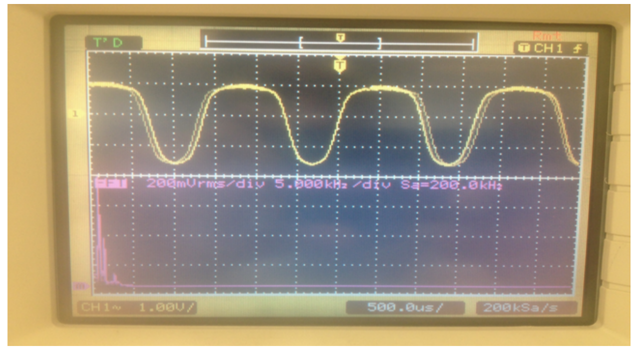

Figure 10: High Setting of Voltage Regulator

4 Interpretation

The expected result of each sub-circuit accurately matched up with each experimental result obtained in lab. Consequently, the combination of each sub-circuit (the function generator as a whole) produced the expected outputs from the original design problem.

5 Conclusion

Overall, this lab was a success. By dividing the main problem into several sub-problems, the overall goal was obtained efficiently and effectively. Furthermore, the FFT theorem was tested and verified using a voltage regulator. Through the confirmation of the functionality of the Schmidtt Trigger, Integrator Op-amp circuit, and with the effective use of diodes, it is clear how a function generator can be designed and constructed.