ECE 312: Threshold Detection (07/24/2017)
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Summary

This lab involved designing an integrator and Schmitt trigger circuit as part of a system to implement specific waveforms for threshold voltage level detection. By using a Schmitt trigger and integrator circuit, triangle waves and square waves can easily be produced. By changing the saturation voltages through alteration of resistors, the time that a signal "turns on" within a single period can be increased or decreased. The values that are chosen to represent "on" and "off" are easily altered by the rails of the system.

Procedure

This lab involved designing a system that would produce the three waveforms as shown in Figure 6.1. By simply looking at the waveforms, it can be seen that each will require different designs with different parameters. Among the design constraints illustrated by these Figures, the following constraints were also provided:

1. Amplifier power supply should be between ±6-10V.
2. System output resistance should be within 10% of 50Ω
3. The output voltage waveform should be within ±0.5 volts of the limits

For the first waveform, a few things can be seen immediately. With a period of 1ms for all three, the frequency is simply 1/T, or 1khz and will be the frequency of the input signal for all cases that require it. Also, for this case, it can be see that the values that the signal is "on" and "off" are ±6V, which means that these are going to be the rails for the op-amp. Looking at the system, 0V is meant to be the switching point. If this is the case, the circuit would simply be the circuit shown in Figure 6.2. When Vin is above 0, it will quickly jump to Vcc+, and when it is below it will jump to Vcc-. For this system, any Vin can be chosen since it will spend exactly half of the time above and below 0V, so 6V was used.

However, having one switching point does not use the concepts of hysteresis and thus makes the system less stable. Instead, a hysteresis for positive and negative saturation can be chosen to be half the period, which means they will be set at ±3. To accomplish this a resistor is put in line with Vin and across the feedback. The equation for calculating at what Vin the switch will occur is:

$$Vin = -R1/R2(Vo)$$

So, knowing that Vo is going to be set to ±6V, it can easily be seen that having a 1:2 ratio of resistors will cause Vin to switch at ±3, and thus a more stable circuit of waveform 1 is designed. Vin can once again be set at any values between the stated ±6-10V, since it will cross the ±3V threshold at the same time.

For waveform 2, you will need a Schmitt trigger in series with an integrator. The switching values for the triangle wave remain at ±6V. Just like we said in waveform 1 with hysteresis, resistor values are chosen based on Vo and the Vin value that we want the switch to occur. In this case, 10V was chosen as the rails for the Schmitt trigger with Rin = 600Ω and Rf = 1kΩ. Now, because this circuit relies on feedback to generate the waveform, an input signal is not needed and the value of RC needs to be chosen to create a period of 1mS before the integrator circuit will get to the next triggering value. So, the following equation is used to calculate RC:

4*Vswitch / T = Vin / RC → 4*6 / 1*10^-3 = 10/RC → RC = 10*(1*10^-3) / 24 → RC = 416 * 10^-6

With 10uF capacitors on hand, R = 416 * 10^-6 / 10 * 10^-6 → R = 4160 Ohms.

For the third waveform, a non-symmetric Schmitt trigger needs to be used. This is done because the time that the square wave is on is less than half of the period. This time, the rails are also set differently to 4V and 0V to match the output required. Because the time that the Schmitt trigger is active is not given, it can be estimated to see what would cause a period of less than 0.5mS. So, the range of thresholds should be much closer to create a smaller time of being active. The circuit in Figure may be used to design a non-symmetric trigger. If the thresholds are set equal as said before, there is no hysteresis. However, it is easy to create a circuit where the threshold is a single value because then resistance values do not need to be calculated, merely a reference voltage should be connected for the trigger point, R1 should be shorted and R2 should be open (or any relatively high resistance).

A hysteresis buffer may be added by giving a resistance value to R1. If R1 is 750Ω, R2 is 10kΩ, and Vref = 3.5V, a buffer between 3.5V and 3.8V is created. The waveform looks almost identical to the previous one, albeit slightly wider due to the slightly different thresholds. If noise is introduced, this setup would not randomly trigger like the previous circuit though.

Conclusion

Schmitt triggers were successfully used to create square waves and triangle waves from either a sinusoidal input or from feedback within the system. It can be seen by analyzing a single period that the transition from “off” to “on and vice-versa does not happen as instantaneously as is implied, and there is a noticeable ramp-up time. When multiple periods are looked at, this distortion tends to disappear. The time “on” for each of the waveforms did not always meet exactly what was desired, but was within region. This is expected due to errors in rounding resistances, tolerances within the devices, and internal resistances of the op-amps that all effected the hysteresis. Also, sometimes the rails of the op-amps had to be altered so that the desired “on” and “off” voltages could be reached, which is probably due to the fact that these op-amps are not ideal.

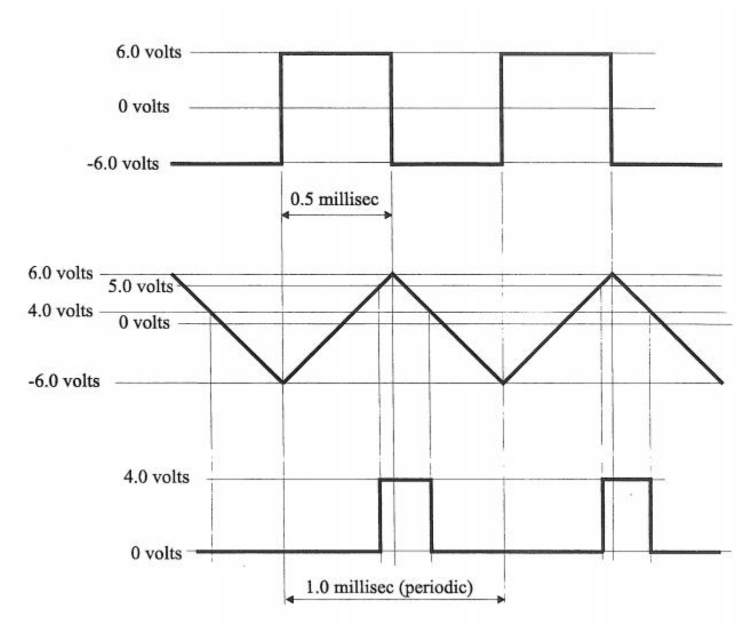

Figure 1: Waveforms to be created

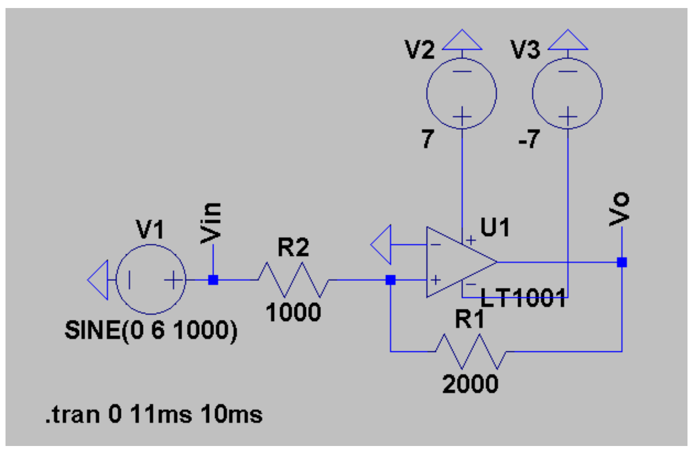

Figure 2: Waveform 1 Simulation Circuit

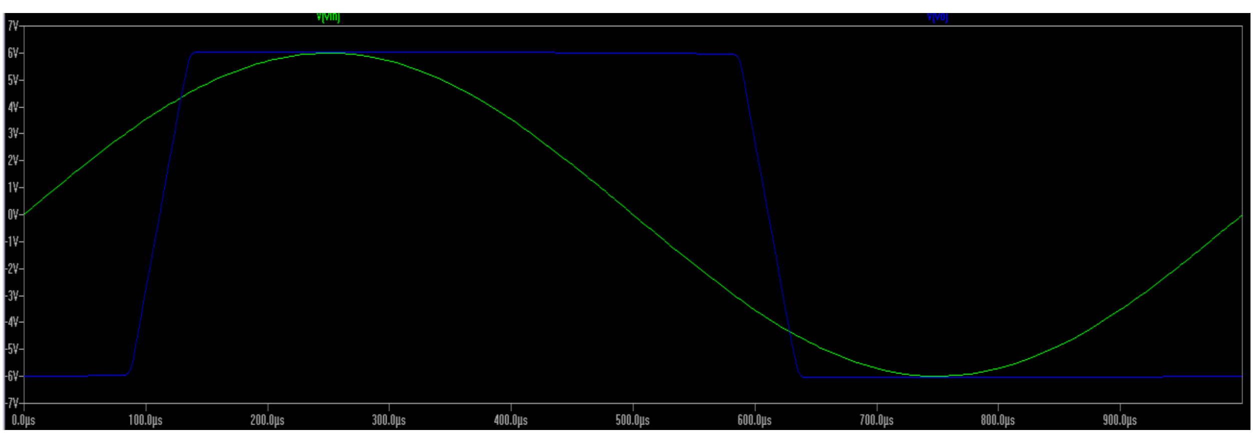

Figure 3: Waveform 1 Simulation

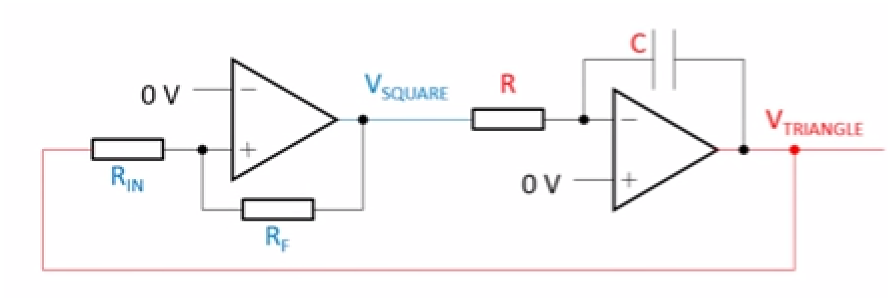

Figure 4: Waveform 2 Circuit Design

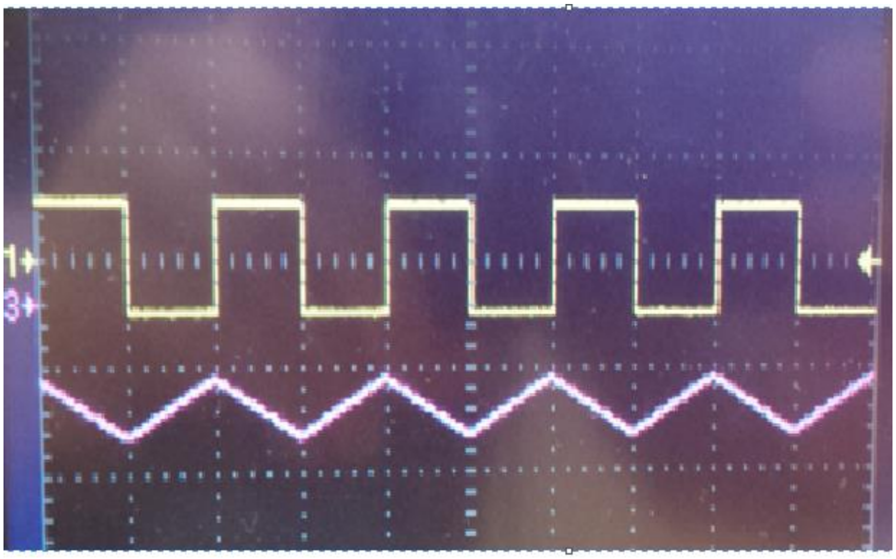

Figure 5: Waveform 2 Output

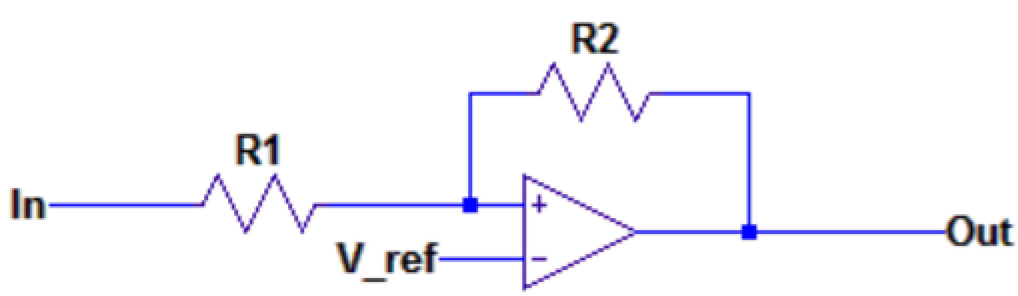

Figure 6: Waveform 3 Circuit Design

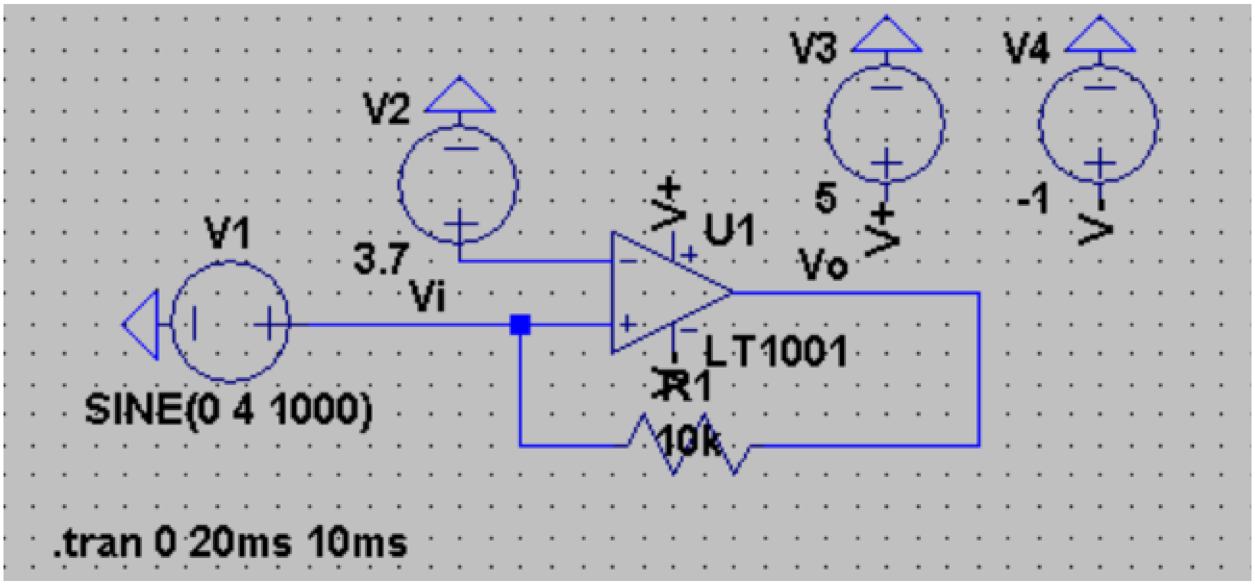

Figure 7: Waveform 3 Simulation Circuit

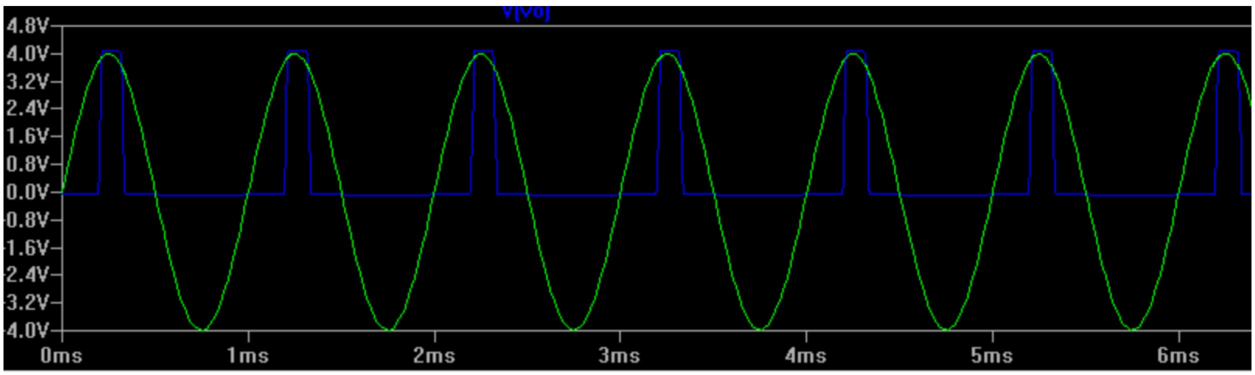

Figure 8: Waveform 3 Simulation Results

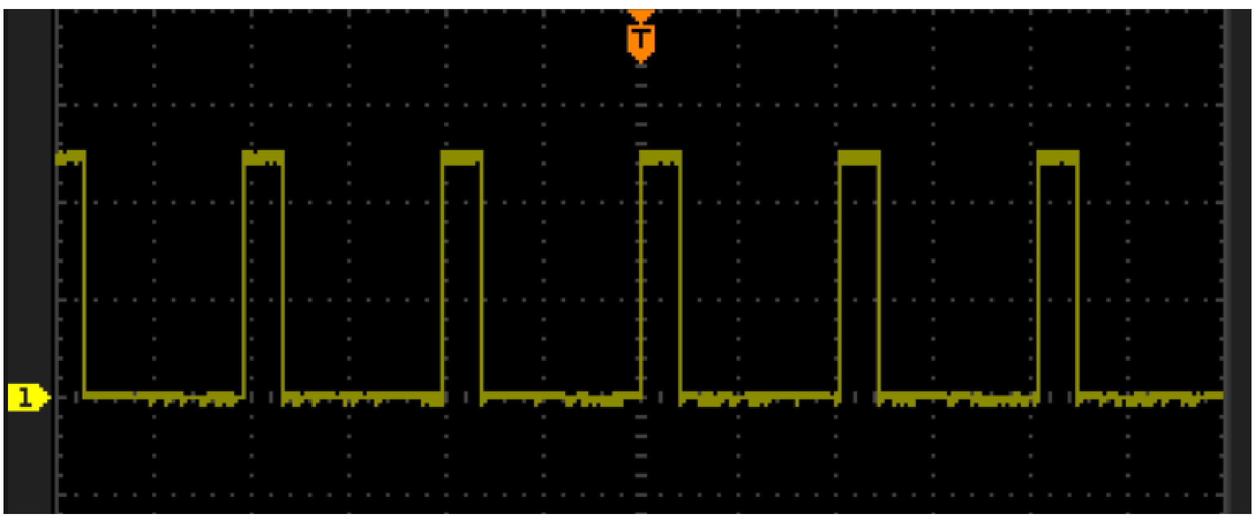

Figure 9: Waveform 3 Output