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Lab 9: Comparators and Oscillators

Introduction

Previously we explored the amplifying properties of op-amps in negative feedback configurations; in this lab, we constructed comparator, Schmitt trigger, and oscillator circuits by incorporating positive feedback as well. Rather than outputting a scaled copy of the input signal, these circuits only output values of +15v or -15v. The former two circuits compare an input signal to a certain threshold voltage to determine their outputs, while the latter circuit oscillates its output with no input required.

Methods

The first circuit we examined was the comparator shown in Figure 1 below. The non-inverting input is maintained at 0v, while an oscillating signal is applied to the inverting input. When the signal voltage is positive, the op-amp outputs -15v; similarly, a negative signal voltage causes an output of +15v. In this configuration, there is no feedback between the output and inputs, so the circuit simply detects when the signal crosses the threshold set at the non-inverting input.

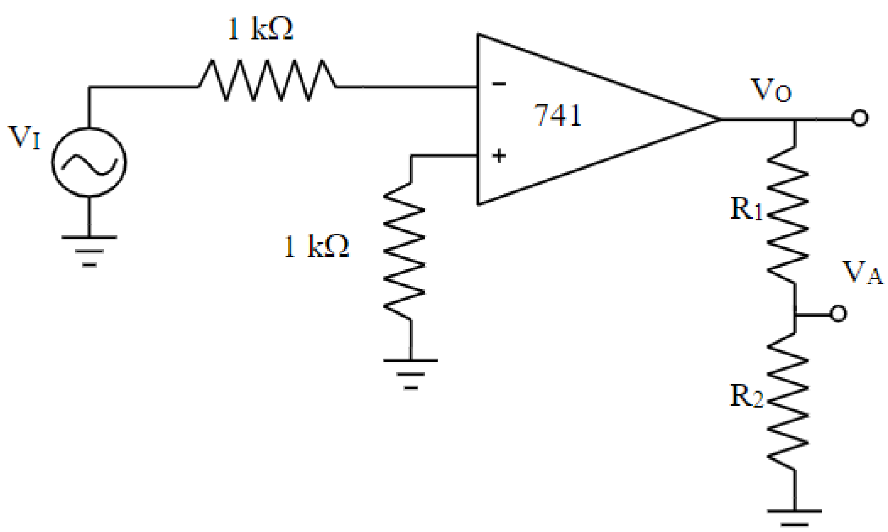

Figure 1

Comparator circuit used in the first part of the lab (taken from the lab handout). The Schmitt trigger is constructed by attaching a 100kΩ resistor between V_O and the non-inverting input.

Connecting the output to the non-inverting input through a resistor introduces positive feedback to the system, creating a Schmitt trigger circuit. When the output is at 15v, the feedback resistor pulls up the threshold voltage to a positive value; if the signal surpasses this threshold, then the output switches to -15v, pulling down the threshold to a negative value. As a result, a buffer region is created around 0v, making the circuit less sensitive to small voltage fluctuations.

In the second part of the lab, we added a resistor between the output and inverting input, introducing negative feedback. In addition, we removed the input signal and inserted a capacitor, as shown in Figure 2 below. When the output is at 15v, the positive feedback resistor again sets the threshold at a positive value; meanwhile, the negative feedback resistor allows the capacitor to begin charging. At some point the capacitor voltage surpasses the threshold, and the output flips to -15v. The process now reverses, discharging the capacitor and then charging it in the opposite polarity until its voltage exceeds the new threshold, causing the cycle to repeat.

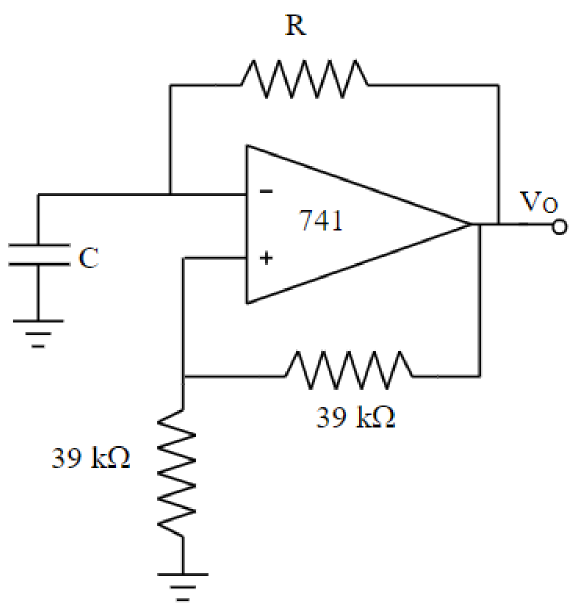

Figure 2

Oscillator circuit used in the second part of the lab (taken from the lab handout).

The net result is that the circuit outputs a 15v-amplitude square wave with a period proportional to the time constant $\tau = RC$, as given by the following equation:

$$T = 2\ln(3)RC$$

The most apparent use of this circuit is the production of a square wave; however, by measuring the frequency of the output signal, this circuit can also be used to measure capacitances.

Results

Our plots for the comparator, Schmitt trigger, and oscillator circuits, which are included on the attached pages, agreed perfectly with our expectations. The comparator plot shows the sinusoidal input signal 180° out of phase with the square wave output.

For the Schmitt trigger, instead of a voltage-versus-time graph, we plotted the output voltage against the input voltage. The resulting graph shows that the output switches polarity at the positive and negative thresholds, which occur near +0.15v and -0.15v on the horizontal axis. This agrees well with theory; given the resistor values we used, the voltage at the non-inverting input should be a hundredth of the output voltage, or about 0.15v.

For the oscillator circuit, we again used a voltage-versus-time plot to show the voltages at the output and the inverting input. As expected, the output was a square wave, while the input was composed of alternating segments of positive and negative exponential decay.

In addition to our qualitative observations, our measurements and calculations appeared to be in reasonable agreement. The following tables present our expected and measured values for the oscillation period and the capacitance.

Table 1: Measured and predicted values for the oscillation period.

$T_{measured}$	$T_{predicted}$
0.630 s	0.514 s

Table 2: Calculated and expected capacitance values.

C_{rated}	$C_{calculated}$
5 μF	6.13 μF

Our calculated capacitance is close, but still significantly off from the value listed on the capacitor. Capacitors can have fairly large error tolerances, but we were unable to find the exact tolerance value of this particular component. A 20% tolerance would allow for a capacitance of 6μF, which is slightly short of our calculated value, but still reasonably close. Despite lacking the tolerance or a direct measurement of the capacitance, our results still seem to agree well with theory.

Conclusion

This lab demonstrated that op-amps are very versatile tools capable of much more than signal amplification. Incorporating positive feedback resulted in discrete output values of +15v and

-15v, and pairing it with negative feedback caused the output to oscillate as a square wave. In addition, we used the theoretical relationship between the RC time constant and the period of oscillation to calculate the value of our capacitor, which was only about 1μF above its rated value of 5μF.