In this experiment we will examine some applications of operational amplifiers in non-linear circuits.

We will use the same \( \mu A741 \) operational amplifier board as in Experiment 11. Please note that it is possible to burn out the op amp by applying an input voltage that exceeds the voltage of the power supply.

1. Construct the voltage comparator circuit shown below. For \( v_2 \), use sine waves with an amplitude of about 4 V peak-to-peak. Keep \( f \leq 200 \) Hz. Use the \( \pm 5 \) V power supply for \( V_1 \). Observe what happens to \( V_{out} \) as you adjust \( V_1 \) up and down. Write a brief explanation of what the comparator circuit does. For some value of \( V_1 \) (say \( V_1 = 1.5 \) V) make a sketch showing the input voltages and \( V_{out} \).

2. Construct the latch circuit shown below with \( R_i = 1 \) k\( \Omega \) and \( R_f = 25 \) k\( \Omega \). Use the \( \pm 5 \) V power supply for \( V_{in} \). Describe what happens to \( V_{out} \) as you adjust \( V_{in} \) up and down. Determine the values of \( V_{in} \) at which the latch switches states. The latch circuit “remembers” the polarity of the last input pulse by “latching” to either the positive or negative saturation voltage. Explain what the resistor \( R_f \) does in this circuit.

![Comparator and Latch Circuits](image)

3. The circuit diagram of a logarithmic amplifier is shown below. The output voltage from this amplifier should be given by:

\[
V_{out} = -\alpha \ln(V_{in} / I_0 R).
\]

Before you begin, set up the linear amplifier of Expt. 11, part 1 and carefully adjust the zero off-set of the op amp. Then construct the log amp circuit using a silicon diode and a 10 k\( \Omega \) resistor. Using the \( \pm 5 \) V power supply and two DMM’s, measure and tabulate \( V_{out} \) as a function of \( V_{in} \).
Start at $V_{in} = 5$ mV and work up to $V_{in} = 5$ V, increasing $V_{in}$ by roughly a factor of 2 at each step. Make a plot of $V_{out}$ vs $V_{in}$ on semi-log paper. Over what range is the amplifier logarithmic? What value do you get for $\alpha$ from your graph?

4. For the exponential amplifier shown below the output voltage should be given by:

$$V_{out} = -I_\text{d}R \exp(V_{in}/\alpha).$$

![Logarithmic Amplifier and Exponential Amplifier](image)

Construct the amplifier using a silicon diode and a 20 kΩ resistor. Measure and tabulate $V_{out}$ as a function of $V_{in}$ starting at $V_{in} = 0.3$ V and going up in 0.025 V steps until $V_{out}$ reaches saturation. Plot the results on semi-log paper and extract a value for $\alpha$. How does the result compare with the value of $\alpha$ you obtained in step 3?

5. Construct the two oscillator circuits shown below. For each circuit sketch $V_{out}$ and $V_C$ (the capacitor voltage). Measure the period for each and compare your results with the expected values ($T = 2.2 R_f C$ for the relaxation oscillator and $T = 2\pi \sqrt{LC}$ for the resonant oscillator). Write a brief explanation of how each oscillator works.
Relaxation Oscillator

Resonant Oscillator