EE2301: Lab Report 4

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1 Objective

To build a 1 Hz Oscillator.

2 Theory

2.1 Schmidt Comparator

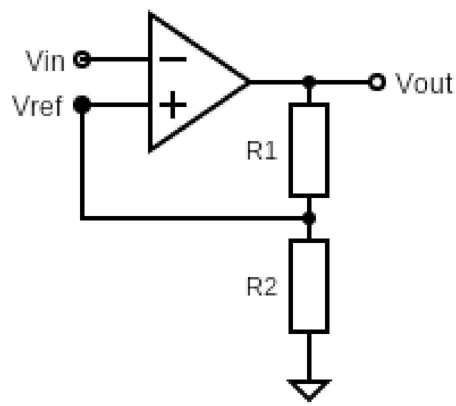

Figure 1: A Schmidt Comparator

A Schmidt Trigger is a comparator circuit which uses positive feedback. As the Op-Amp is in positive feedback configuration, the output of the Op-Amp will hence be saturated at $+V_{cc}$ or $-V_{cc}$. When the output of the opamp is $+V_{cc}$, the voltage at the non-inverting terminal of the opamp (V_{ref}) will be, using KCL,

$$\frac{V_{cc} - V_{ref}}{R_1} = \frac{V_{ref}}{R_2}$$
$$\implies V_{ref} = \frac{R_2}{R_1 + R_2} V_{cc}$$

When the output of the opamp is $-V_{cc}$, the voltage at the non-inverting terminal of the opamp (V_{ref}) will be, using KCL,

$$\frac{-V_{cc} - V_{ref}}{R_1} = \frac{V_{ref}}{R_2}$$
$$\implies V_{ref} = -\frac{R_2}{R_1 + R_2} V_{cc}$$

Define, $\beta = \dfrac{R_2}{R_1 + R_2}$.
Thus, the voltage of the non-inverting terminal of the opamp will either be $-\beta V_{cc}$ or βV_{cc}.
Hence, when the voltage at the inverting terminal of the opamp (V_{in}) goes above βV_{cc} (i.e., $V_+ - V_- = \beta V_{cc} - V_{in} < 0$), the opamp will flip its state and the output of the opamp goes to $-V_{cc}$. Similarly, when the voltage at the inverting terminal of the opamp goes below $-\beta V_{cc}$ (i.e., $V_+ - V_- = -\beta V_{cc} - V_{in} > 0$), the state of the opamp flips again and the opamp will now output $+V_{cc}$.

2.2 Oscillator Circuit

Consider the following Circuit,

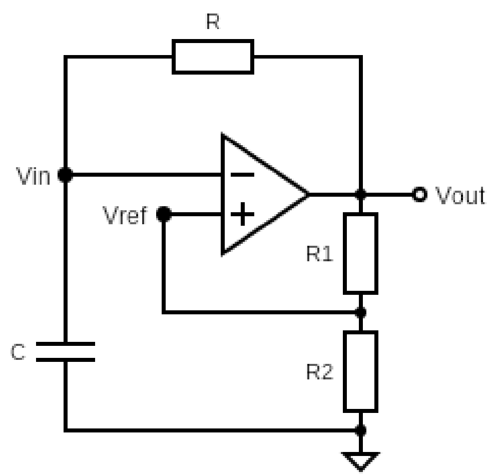

Figure 2: Oscillator Circuit

We add a capacitor and a resistor to the previous Schmidt Comparator circuit, to sustain oscillations and generate square waves.
Consider the capacitor to be uncharged initially, and the output of the Op-Amp to be saturated at the positive voltage ($+V_{cc}$). The capacitor is connected to the output of the Op-Amp, through the resistor R. The capacitor will now start charging. When the capacitor is charging, at some moment, the voltage at the inverting terminal (V_{in}) of the Op-Amp will reach a voltage which is equal to the voltage at the non-inverting terminal ($V_{ref} = \beta V_{cc}$) of the Op-Amp. After this moment, the output of the Op-Amp will flip and will now be saturated at the negative output ($-V_{cc}$), because now the difference ($V_+ - V_- = V_{ref} - V_{in} < 0$), which will make the output

of the opamp $-V_{cc}$. This cycle would continue and the output of the opamp would flip every t_0 seconds, which would resemble a square wave.

To find the Time period (T) of the Oscillator circuit, we consider the discharging of the capacitor from βV_{cc} to $-\beta V_{cc}$. Assume, it takes t_0 seconds for this to happen.
For a discharging RC circuit we know,

$$V(t) = V_f + (V_i - V_f)\, e^{-t/RC}$$

Here, $V_f = -V_{cc}$ because the capacitor tries to reach $-V_{cc}$ if there were no comparator and $V_i = V_{cc}$ which is the initial charge on the capacitor. The capacitor will keep on discharging till the voltage is $V(t_0)V_+ = -\beta V_{cc}$ and the time is t_0.

$$\begin{aligned} -\beta V_{cc} &= -V_{cc} + (\beta V_{cc} + V_{cc})\, e^{-t_0/RC} \\ 1 - \beta &= (\beta + 1)\, e^{-t_0/RC} \\ \implies t_0 &= RC \ln\left(\frac{1+\beta}{1-\beta}\right) \end{aligned}$$

Similarly, for the capacitor to charge from $V = -\beta V_{cc}$ to $V = \beta V_{cc}$, the time taken would be t_0 seconds. Hence, the time period is,

$$T = 2t_0 = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$$

3 Observations

The values of R_1 and R_2 were chosen such that the logarithm term in the expression becomes 1, for easier calculations. Here, $R_1 = 68k\Omega$ and $R_2 = 56k\Omega$, such that $\beta = 0.4516$ and $\ln\left(\frac{1+\beta}{1-\beta}\right) = 0.97 \simeq 1$.
Also, the value of R chosen was $820k\Omega$ and the value of the capacitor C chosen was $0.64\mu F$. Hence, the time period of the oscillator for the given values for the components is,

$$T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right) = 2 \times 820 \times 10^3 \times 0.64 \times 10^{-6} \times 0.97 \simeq 1.021\ s$$

Hence, the frequency is,

$$f = \frac{1}{T} \simeq 0.98\ Hz$$

The output of the circuit is,

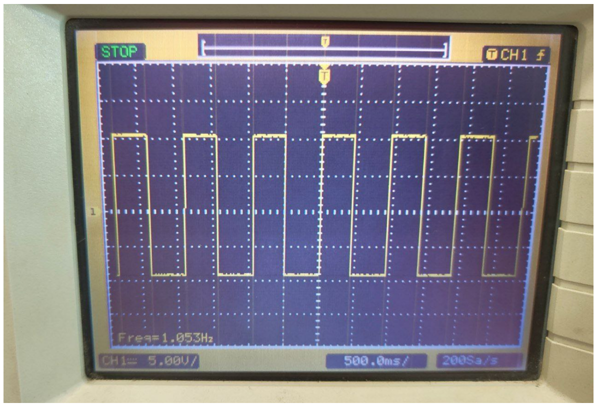

Figure 3: Square Wave Oscillations at 1 Hz

The circuit built in the lab is,

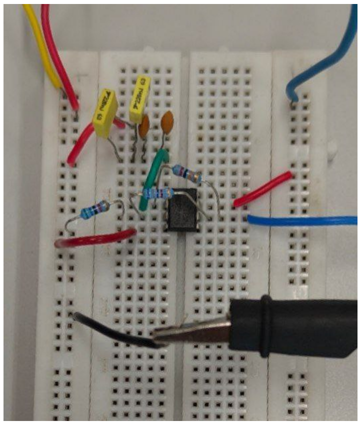

Figure 4: Circuit Built

4 Sources of Error

The impedences of the breadboard and of the wires caused the circuit to behave in an unintended manner. Also, the error in the measurement of resistances and capacitances, cause the oscillations to be at slightly different frequencies, instead of being exactly at 1 Hz, as anticipated.

5 Conclusion

A 1 Hz Oscillator was successfully built.