10 The Triangular and Square Wave Oscillator

10.1 Objectives

- To learn Schmitt Trigger and usage for Triangular and Square WaveOscillator
- To learn “Slew Rate” concept for op-amp.

10.2 Introduction and Theory

A Square Wave Oscillator can be realized with a cascade connection of an “Integrator” and a Schmitt trigger circuit.

Schmitt Trigger:

The Schmitt trigger is essentially a comparator in which the reference voltage is derived from a divided fraction of the output voltage. **As in a comparator, the output is forced to either a positive or negative saturation limit whenever the magnitude of V_I exceeds that of the reference voltage**. Unlike the comparator, the Schmitt trigger ”remembers” its most recent positive or negative output and hold its output voltage even when the input voltage returns to zero.

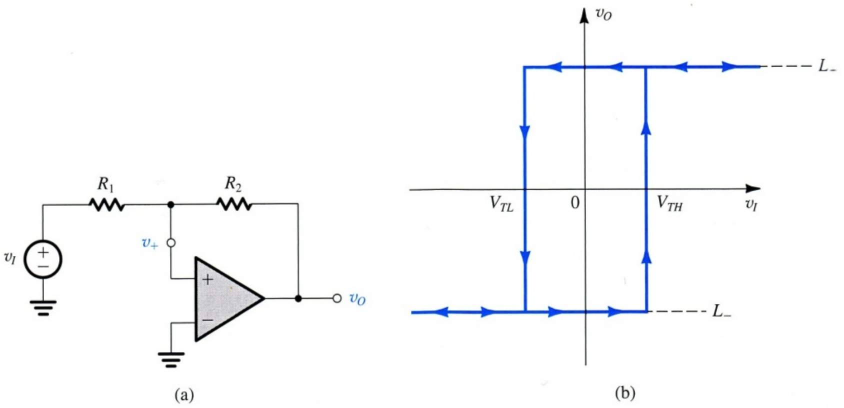


Figure 1

We can see in figure 1 the Schmitt trigger configuration as well as its transfer characteristic. The important reference voltage is given by:

$$V_{TL} = -L_{+}(R_1 / R_2),$$

$$V_{TH} = -L_{-}(R_1 / R_2),$$

where L_- and L_+ are the negative and positive saturation voltages of the opamp, respectively.

Cascade Connection

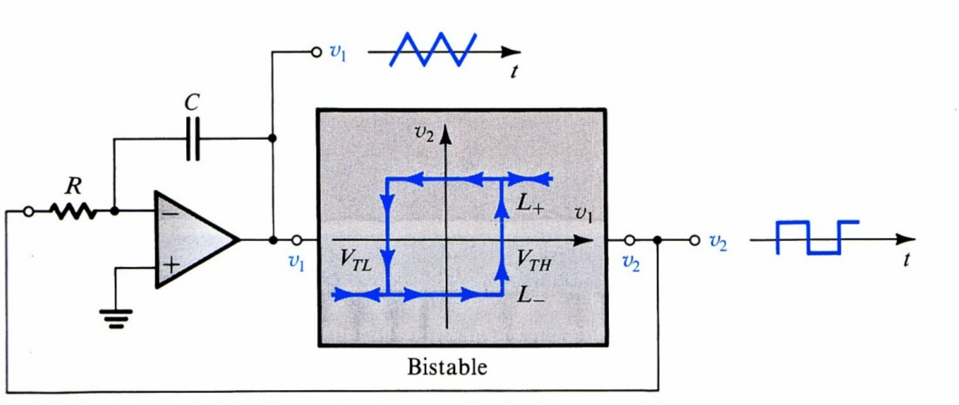


Figure 2

Since the output of the Schmitt trigger will be at either saturation levels $V_2= L_-$ or $V_2=L_+$, it causes a current flow through R and C. If V_2 is at L_+ level, the current flow through R and C increases Vc and causes V_1 to decrease. As soon as V_1 reaches $\mathbf{V_{TL}}$ level, the Schmitt trigger toggles its saturation level to $V_2=L_+$. Then the charged capacitor reversely discharges through R and V_1 starts to increase. After V_1 reaches $\mathbf{V_{TH}}$ the whole cycle starts again and that yields an oscillation, where V_1 has a triangular form and V_2 has a square-wave form.

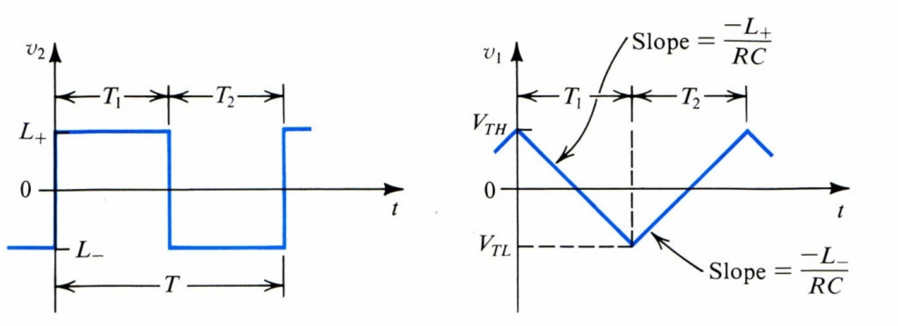


Figure 3

The frequency of the oscillation

Using $I = C\dfrac{\Delta v}{\Delta t}$, we can write,

$$\frac{-L_+}{R} = -C\frac{V_{TH} - V_{TL}}{T_1} \tag{1}$$

$$\frac{-L_-}{R} = -C\frac{V_{TH} - V_{TL}}{T_2} \tag{2}$$

To obtain a symmetrical square wave, we should have

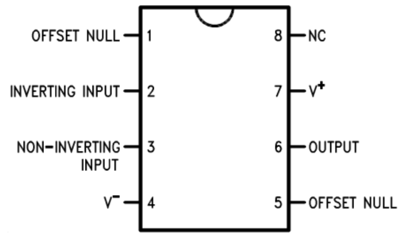
$$L_+ = -L_- = L \quad \text{and} \quad T_1 = T_2 = T/2 \ ,$$

Then, we can find:

$$f = \frac{1}{T} = \left(\frac{R_2}{4R_1}\right).\frac{1}{RC} \tag{3}$$

10.3 Experiment Equipments

- KL2101 Linear Circuit Lab
- Oscilloscope
- 741 Operational Amplifier
- Resistors: 1k, 4k7, 47k
- Capacitors: 220nF, 470nF



10.4 Procedure

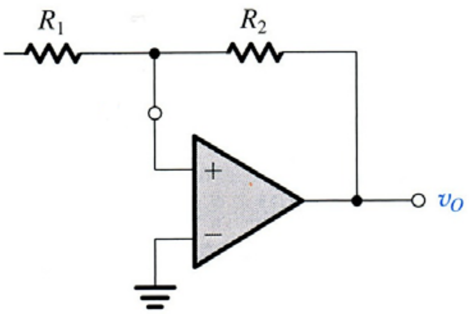


Figure 4a

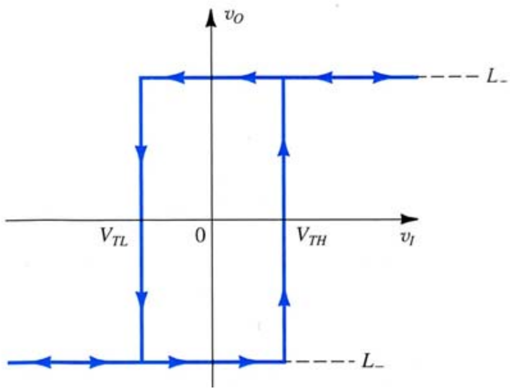


Figure 4b

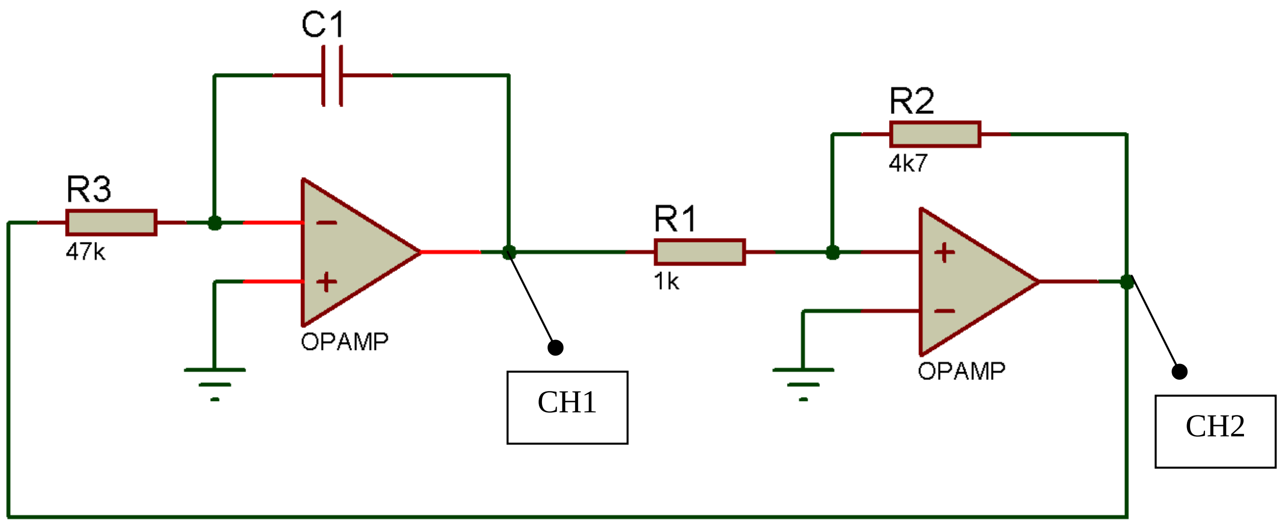
Part 1 - Schmitt Trigger

1. Setup the circuit shown in Figure - 4a for **R1=1k, R2=4k7** (Supply Voltage = +/- 12V).
2. Connect function generator to R1 terminal as input. Apply triangular wave @ 200 Hz.
3. Connect oscilloscope channels **(CH1 = Input, CH2 = Output)**
4. Adjust oscilloscope to **XY mode** .
5. Adjust input voltage amplitude so that you can see the plot as in Figure - 4b.
6. Measure and record threshold voltages.

V_{TL} (Low Threshold)= ____________ **V_{TH} (High Threshold)= ____________**

Part 2 – Oscillator circuit

7. Disconnect and turn-off function generator.
8. Set-up additional circuit shown below. (Note that right side is already done!!)



9. Take C1=220nF.

10. Observe the output signal through channels as shown and record waveform types.

CH1 (Integrator Output) T = ____________

CH2 (Schmitt Trigger Output) = ____________

11. Measure and record the frequency and compare with theoretical value.

Theoretical Frequency = ____________

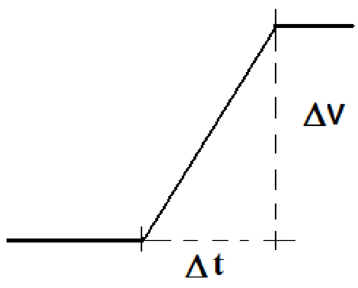
Measured Frequency = ____________

12. Change C1 to 470 nF and repeat steps (10,11)

Part 3 – Slew Rate Measurement

13. Turn off CH1 so that only CH2 is visible.(You should only see a square wave now)

14. Adjust voltage and time divisions so that you can clearly see the transition from low to high values as shown.



15. Calculate Slew Rate given by:

$$SR = \frac{0.8\Delta V}{\Delta t}$$

10.5 References

1) Sedra-Smith, Microelectronic Circuits. Oxford University Press., 5th edition