LEDs and comparators

1 What this project is about

Many of us have issues studying OpAmps as they seem almost intangible as they are usually more hidden within electrical structures without an apparent use from the point of view of the student. This project is about constructing a simple OpAmp circuit to make the device a little more approachable.

2 Components and circuit scheme

2.1 Components

- 2 LM741 OpAmps
- 2 150 Ohm Resistors
- 2 Potentiometers
- 2 LEDs

2.2 Circuit Scheme

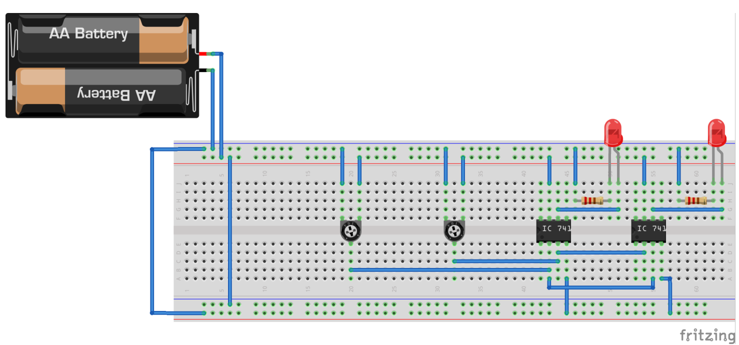

Figure 1: OpAmp comparator circuit [1]

3 How it works

The circuit is based on two differential OpAmps which serve as comparators. An OpAmp compares the voltages on the 10K resistor and outputs the difference multiplied by the gain of the OpAmp. If the voltage output is positive, it will cause the LED to light up and because one of the OpAmps is inverting and the other is not, they will each produce voltage of opposite signs, causing one LED to light up while the other is not.

4 Why it works

4.1 Differential OpAmp

To explain in greater how an OpAmp works, the function of a bipolar junction transitior must be cleared up first.

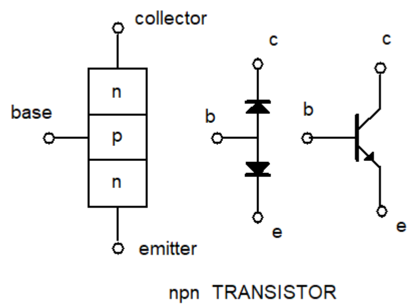

Figure 2: Bipolar Junction Transistor

A BJT is composed of two pn-diodes back-to-back, creating an npn bridge. The device itself work when a small current is injected in to the base which causes a large current to flow from the collector to the emitter. What is happening in terms of electrons is that when a positive terminal is connected to the base, electrons will move from the emitter to the base and only a very few electrons will combine with the holes, the rest will jump to the collector layer due to their kinetic energy.

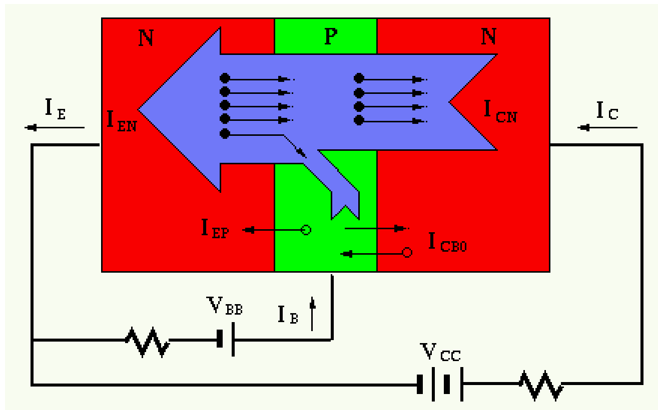

Figure 3: Current and Electrons in a BJT [2]

The current on the collector is given by the relationship

$$I_C = \beta I_B$$

Beta is a parameter of the particular component as is given in a range, e.g. 40 - 800.

$$I_E = I_C + I_B$$

For most cases

$$I_E \approx I_C$$

Now that the function of an OpAmp is known, it is time to move on to the OpAmp itself.

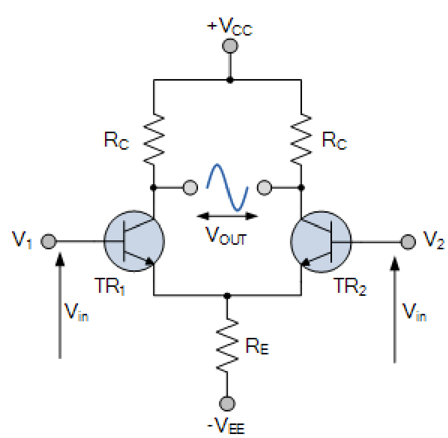

Figure 4: Differential OpAmp circuit [3]

Two important things are going on in here. First, the current coming from Vcc has to split into two according to the Current Div Rule. Second, there are different currents injected in to the bases of the transistors causing the two collector currents to be different.

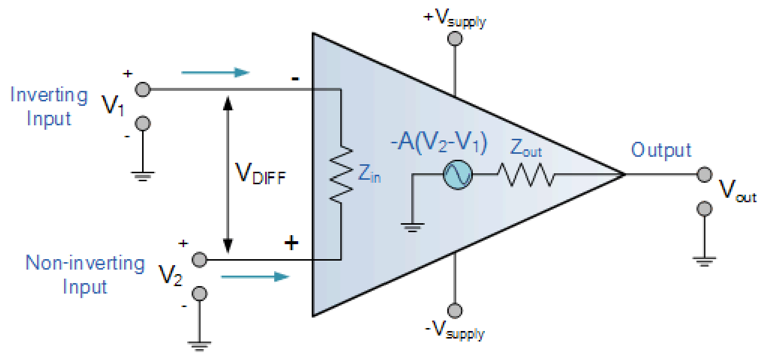

Figure 5: Differential OpAmp abstracted scheme [3]

This is a simplified model of an OpAmp. A couple of things to note: Z_{IN} is infinite, Z_{OUT} is zero and the gain is governed by the relation

$$V_{OUT} = A_V(v_+ - v_-)$$

A_V is the gain and is the ratio between V_{OUT} and V_{IN}.

5 Conclusion

In this project, a comparator circuit was constructed to make OpAmps more approachable and to explain the function of the differential amplifier. Feel free to leave any feedback.

6 Sources

References

[1] Dark and Light Indicator Circuit using OpAmp IC LM358,
https://circuitdigest.com/electronic-circuits/dark-and-light-indicator

[2] Bipolar Junction Transistor (BJT),
http://fourier.eng.hmc.edu/e84/lectures/ch4/node3.html

[3] Operational Amplifier Basics,
http://www.electronics-tutorials.ws/opamp/opamp_1.html