Laboratory 6 (1 day): Flip-flops

Joseph Hutchinson

2024-03-28

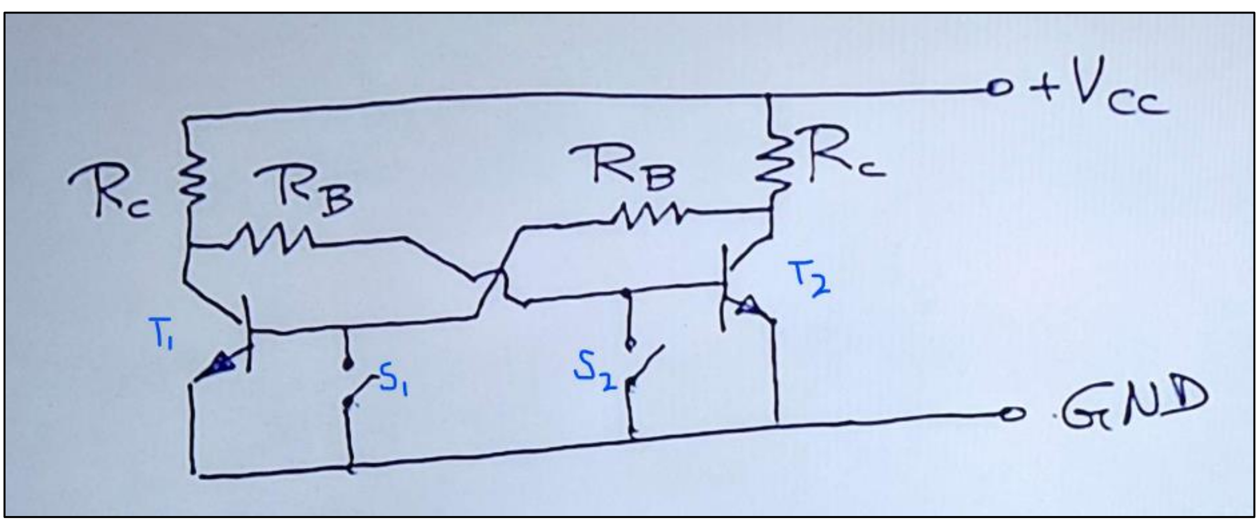
Material covered and overview:

- This laboratory has ***one session*** allocated for completion.
- Stable and astable flip-flop circuits.
- ***Stable flip-flop*** circuits can be used as a 1-bit memory cell. They are the basis of SRAM storage devices. A stable flip-flop may also be called ***bi-stable flip-flop***.
- ***Astable flip-flop*** circuits are oscillators that produce a square-wave output. Astable flip-flops can be used to generate a blinking LED circuit or a circuit that generates an audio signal.

Exercise 1

In this exercise you will design and build your own flip-flop circuit. This may be a stable flip-flop or an astable flip-flop. The following points may be considered:

Stable flip-flop:



- Choose the collector current, for example, I_C = 10 mA, and determine the values of R_C and R_B accordingly.

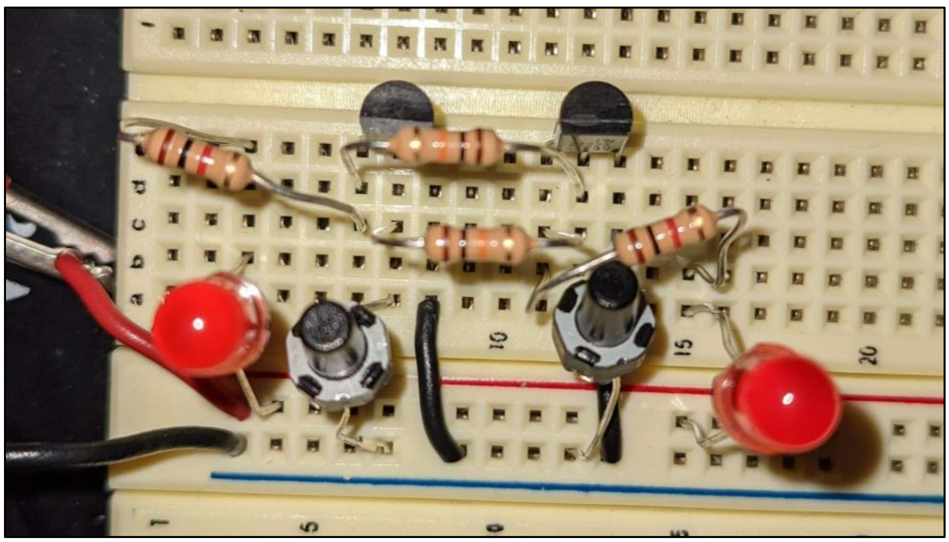
  For a collector current of $I_C = 10mA$, and a +Vcc source of 10v, we can determine R_C by using Ohm's law:

  $R_C = \frac{V_{CC}}{10mA} = 1k\ \Omega$

  We will choose a value of R_B that is 10 times R_C, so:

  $R_B = 10k\ \Omega$

- LEDs may be included in the circuit (collector branch) to indicate the logical state of the circuit. How about including an LED in each of the collector branches?

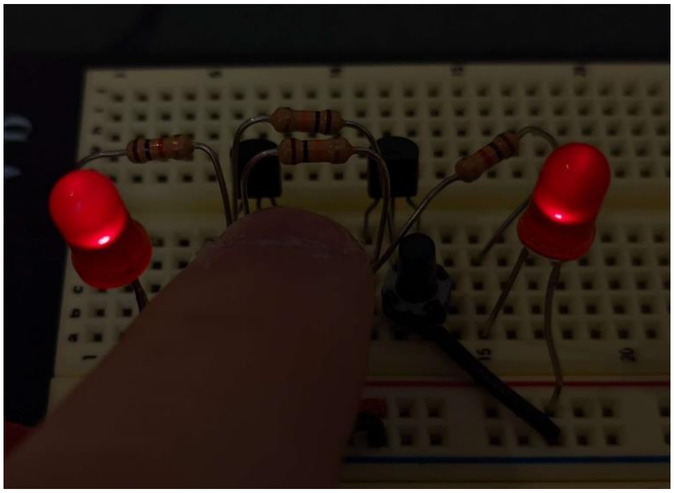


- How about including two push-button switches that allow you to set the flip-flop to its logical "0" and "1" state?

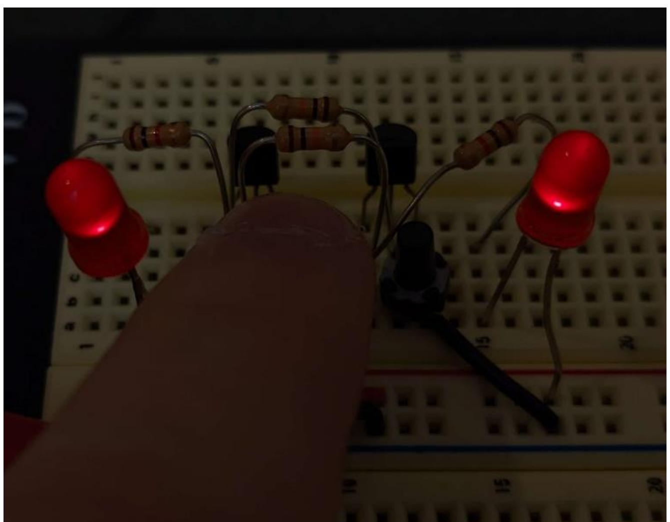
Upon testing the circuit with 10v, the pushbuttons DID correctly alter the state of the flip-flop. When the Base1 switch was pressed, the LED for Collector2 would go high, while the LED for Collector1 would go low. Similarly, when the Base2 switch was pressed, the LED for Collector1 would go high, while the LED for Collector2 would go low. This matches our expected behavior.

For the purpose of taking the pictures, I used a lower Vcc of ~3.4v, since at higher voltages the difference in brightness of the LEDs is not as visible.

With neither switch pressed:

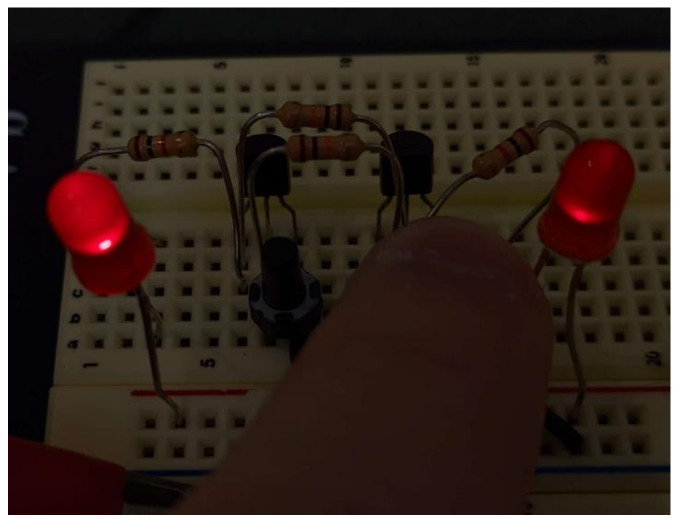


With only Switch 1 pressed:



Note that LED1 is dimmer, LED2 brighter

With only Switch 2 pressed:



Note that LED1 brighter, LED2 dimmer

No matter the configuration, there was still some leakage through the LED which should have been off at any given state. The LED meant to go off would become much dimmer, but still be "ON". I altered the resistor values to attempt to correct this, as well as swapped the LEDs for one with a different forward voltage. But ultimately, there was still leakage. In an ideal scenario, the current flow through one branch would be close to ZERO while the other branch is active.

The measured current at the voltage source ranged from 2 mA to 12 mA total, as we changed resistors or pressed the buttons.

Overall, we proved that the concept of a bi-stable flip-flop using BJTs is indeed functional.

Astable flip-flop:

- Choose the collector current, for example, I_C = 25 mA, and determine the value of R_C.
  The base resistor R_B may be chosen to have a ten times higher resistance than the R_C.
- How about choosing an R_BC time, for example 10 ms, and then determining the relevant R and C values?
- A speaker (or headphones) may be included when building an astable flip-flop working in the audio frequency range. Should the speaker (or headphones) be connected between collector and ground? You may want to include an emitter-follower amplifier for impedance matching.
- If no speaker (or headphones) are available, you may want to connect your circuit to an oscilloscope to see the square wave.