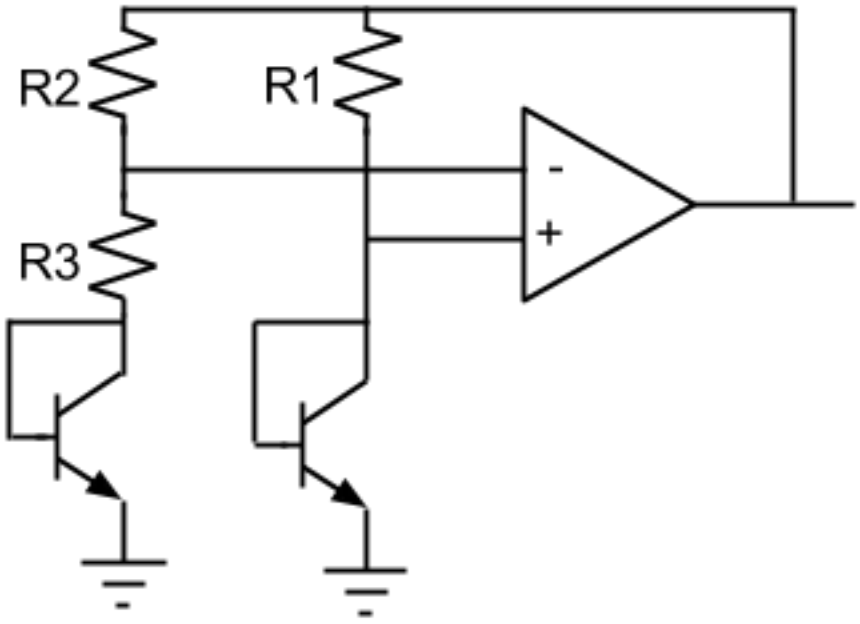

Figure 1: Band gap reference circuit.

In this lab we will build a band gap reference and compare its performance to simpler references. The learning goals are listed below:

- Observe bias fluctuations with power supply variation.
- Observe bias fluctuations with temperature variation.
- Practice calcuations for band gap references.

1 Build and Measure References

1. Build three references: a voltage divider on V_{cc} with a division ratio of two, a diode connected NPN device pulled up to V_{cc} by a 1 kΩ resistor, and a band gap reference. You may refer to Figure 1 for a schematic of the band gap reference. Use a 2N3904 for the diode reference and a BCM847DS matched NPN pair and an MCP601 op-amp for the band gap.

   You will need to select the gain M for the band gap reference and then use that value of M to select R_1, R_2 and R_3. Recall that M depends on the temperature sensitivity of v_{be} (-2 mV/K) and the temperature sensitivity of ϕ_T (+3300 ppm/K = +0.086mV/K). You can calculate the expected V_{OUT} of the band gap based on your value of M, make sure you produce that output.

2. Vary V_{cc} from 2.7 V to 6 V and observe v_{out} for each of the three references.

3. Use the cold spray and heat gun to vary the temperature of the three circuits and observe the maximum excursions of v_{out} while they are heated or cooled. Be sure to keep scope probes far away from the area being heated or cooled and try to avoid damaging breadboards.

   When applying heat/cold to the bandgap, focus on the NPNs rather than the rest of the circuit. Enusre that the two transistors are in close thermal contact and far from the rest of the circuit for best results.

4. Which circuits are temperature insensitive? Which are supply insensitive? Why?