BJT Amplifier: Temperature Dependence Study

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Objective

To investigate how temperature affects the linearity and gain of a BJT amplifier by analyzing the output waveform shape across a temperature sweep in LTspice.

1. Circuit Description

The amplifier consists of a voltage divider bias using $R_1 = 1\,\mathrm{M}\Omega$ and $R_2 = 100\,\mathrm{k}\Omega$, with a BC547C transistor in common-emitter configuration. The collector is loaded with $5\,\mathrm{k}\Omega$ and powered by a $10\,\mathrm{V}$ DC supply. AC input is applied via capacitor C_1 with no DC offset, and output is observed through coupling capacitor C_2 into a $100\,\mathrm{k}\Omega$ load.

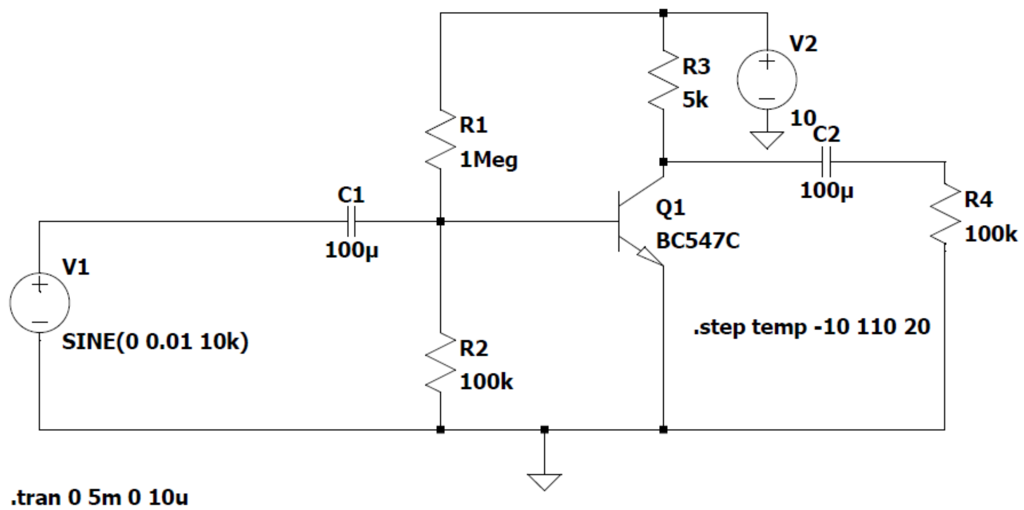

Figure 1: LTspice schematic of the BJT amplifier with fixed bias

2. Simulation Configuration

LTspice simulation was configured as follows:

- Transient analysis: `.tran 0 5m 0 10u`
- Temperature sweep: `.step temp -10 110 20`
- Input source: `SINE(0 0.01 10k)` (zero offset, 10 mV peak amplitude)

3. Simulation Results

The output waveform was recorded for each temperature from $-10\,^{\circ}\mathrm{C}$ to $110\,^{\circ}\mathrm{C}$ in 20 °C steps. The plot below overlays all waveform results.

At lower temperatures (e.g., $-10\,^{\circ}\mathrm{C}$), the output remains highly sinusoidal, indicating that the transistor operates in its linear active region. These traces typically appear as darker or colder-colored lines in the plot.

At higher temperatures (e.g., $90\,^{\circ}\mathrm{C}$ and above), the output waveform shows visible distortion — peaks become flattened or compressed. These curves generally appear in warmer colors, such as red or magenta, depending on LTspice's trace coloring.

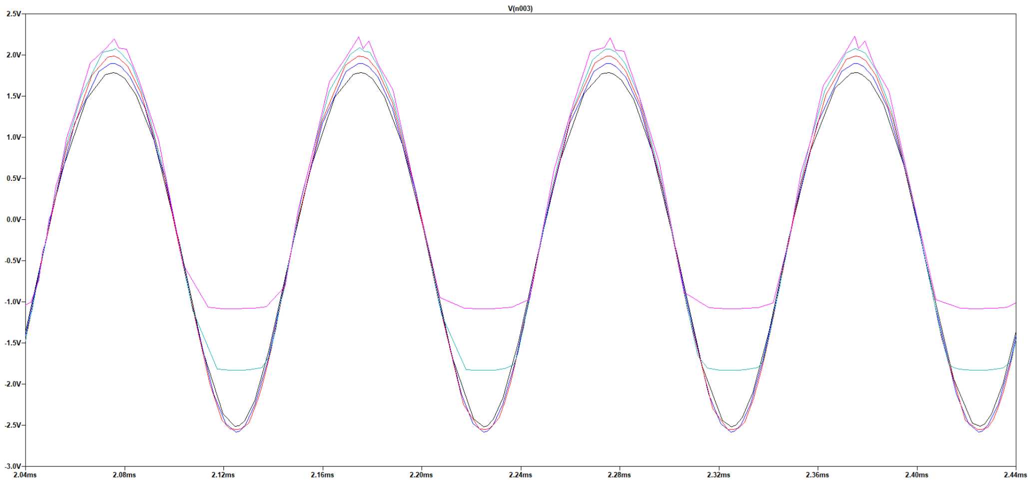

Figure 2: Output voltage waveforms for temperatures from –10 °C to 110 °C in 20 °C steps

4. Gain Estimation

To estimate the voltage gain from a representative low-distortion waveform (e.g., at $-10\,^{\circ}\mathrm{C}$):

- Input signal: `SINE(0 0.01 10k)` → peak amplitude = 10 mV, so **peak-to-peak** is 20 mV or 0.02 V
- Output waveform (from simulation) shows approximately 2.0 V peak-to-peak

Therefore, the AC voltage gain is calculated as:

$$A_v = \frac{V_{\text{out, pp}}}{V_{\text{in, pp}}} = \frac{2.0\,\text{V}}{0.02\,\text{V}} = 100$$

This gain value is meaningful only in the temperature range where the output remains linear. At higher temperatures, signal distortion makes such estimation unreliable.

5. Conclusion

This experiment demonstrates that the output of a BJT amplifier is temperature-sensitive. Even with a fixed bias, variations in V_{BE} and current gain with temperature cause the output waveform to shift from linear to non-linear behavior. The temperature sweep shows a clear progression from sinusoidal to distorted output, confirming the importance of temperature-stable biasing in analog amplifier design.