Design Project #3

ELECENG 2EI4

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L03

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Circuit Schematic:

The chosen transistor for this project is an NPN Bipolar Junction Transistor (BJT). I chose to work with a BJT over a MOSFET because of the need of high transconductance and because of my understanding of BJTs in comparison to MOSFETs. At the time of writing this report I have just finished midterm 2, which mainly focussed on BJTs, leading to increase familiarity.

The amplifier topology chosen was the common collector BJT. As shown in the project 3 design guide, our input resistance must be significantly greater than Rs. When comparing common emitter, common base, and common collector amplifiers, it is seen that Rin for CB amplifiers are small, which eliminates that from our choice. When comparing the gains of the CE and CC amplifiers it shown that the gain of CC amplifiers produces a gain of around 1 or less, which fits our requirements for gain ideally. As a final check, it would be ideal if Rout for our topology was small, which also makes the CC amplifier the best choice for the topology used in this project.

Calculations:

gm calculations:

$$|V_{in}| = (0.2)(x)(1 + g_m * R_L)$$

$$0.5 = 0.2(0.025)(1 + g_m(100))$$

$$100 = 1 + 100 g_m$$

$$g_m = 0.99\ S \Rightarrow 990\ mS$$

$$\therefore g_m \geq 990\ mS$$

$|V_{in}| \geq 0.5\ V$

$\underbrace{x = 25\ mV}_{\text{represnts } V_T}$

$R_L = 100\Omega$

Rin Calculations:

$$\frac{g_m R_L}{1 + g_m R_L} \cdot \frac{R_{in}}{0.1 + R_{in}} \geq 0.9$$

$$\frac{(0.99)(100)}{1 + (0.99)(100)} \cdot \frac{R_{in}}{0.1 + R_{in}} = 0.9$$

$$0.99 \cdot \frac{R_{in}}{0.1 + R_{in}} = 0.9$$

$$0.99 R_{in} - 0.9 R_{in} = 0.09$$

$$\therefore R_{in} \geq 1K$$

$$\Rightarrow R_{in} = R_1 // R_2$$

$\underbrace{5K//5K = 2.5\ k\Omega}_{\text{Choice of } R_1\ \&\ R_2}$

Figure 1 Calculations used for component values

Shown in Figure 1 are the calculations used to determine the required component values in the circuit. The actual value of the resistors, R1 and R2, used in my circuit are 4.99 kOhm. These produce an equivalent resistance close 2.5 kOhm, which satisfies the need of having an Rin above 1 kOhm. Along with these values calculated, the two capacitors used in the circuit were chosen to be 100 µF an 10 µF, however the values are arbitrary.

Simulation:

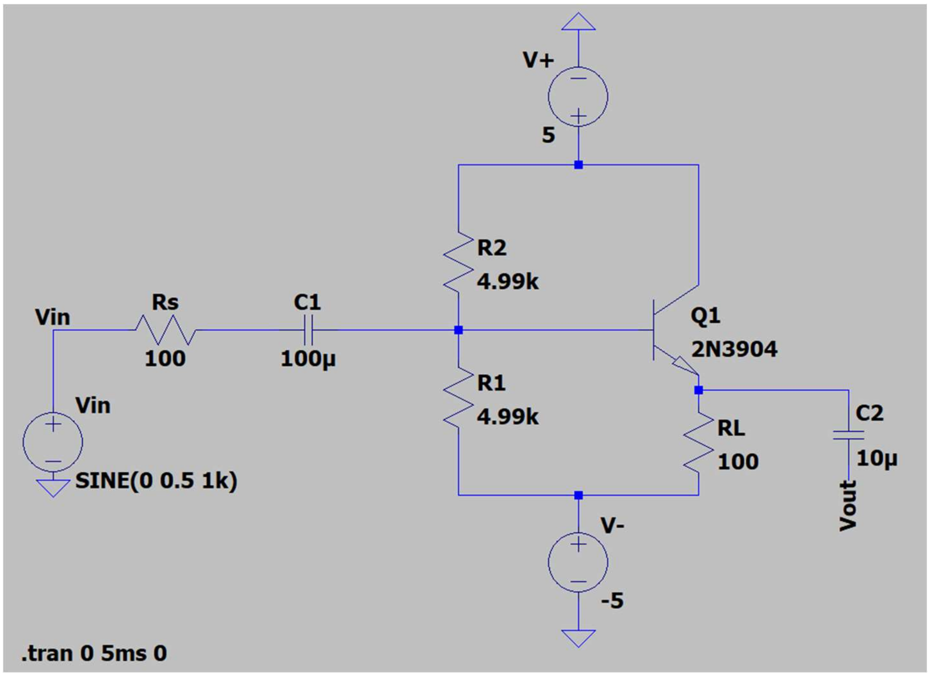

Figure 2 Schematic of circuit used in LTSpice

To model the common collector (BJT) amplifier, an NPN BJT of the same specifications as the one used in our components package was chosen. To make it common collector, the collector of the BJT was connected directly to the +5 V DC source. When analysed with small signal, this DC source will act as ground making the collector connected directly to ground. For each simulation, a transient analysis was performed. The stop time was set to 5 ms to show the waveform with an appropriate amount of detail. The input source of the circuit is an AC sinewave source, with 0.5 V amplitude and a frequency of 1 kHz.

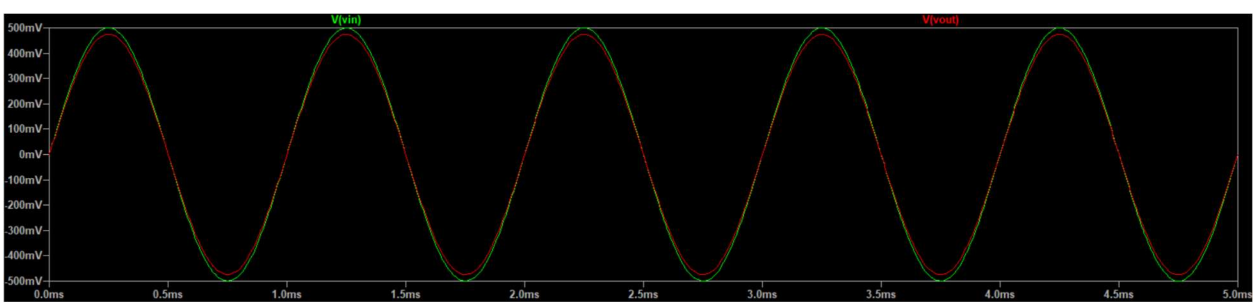

Figure 3 Simulated Vin (green) and Vout (red)

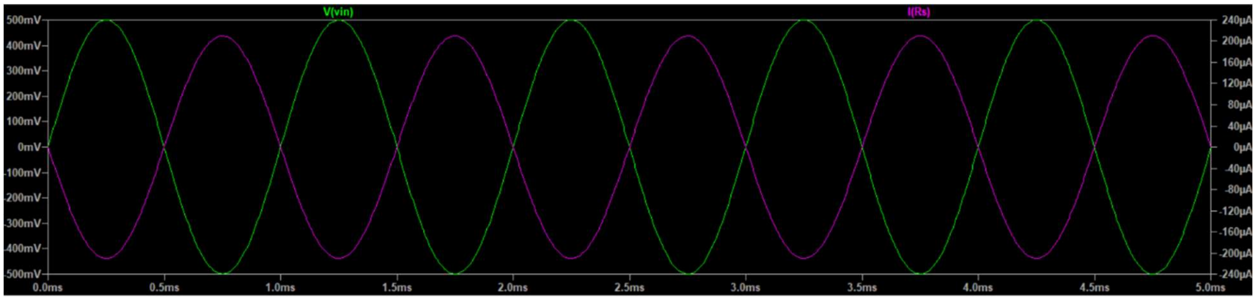

Figure 4 Simulated Vin and Iin

Simulation:

$$\text{gain} = \frac{V_{outmax}}{V_{inmax}} = \frac{474\,mV}{500\,mV} = 0.948 \geq 0.9 \quad \underline{OK}$$

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{0.5\,V}{0.210\,mA} = 2.38\,K\Omega \geq 1K \quad \underline{OK}$$

Figure 5 Calculations of simulated performance

Shown in Figures 3 – 5, we can see the performance of our circuit. In Figure 3 the overall gain of the simulation can be calculated and was determined to be 0.948. Along with the gain, Rin was calculated from the data gathered in Figure 4. Rin was calculated to be 2.38 kOhm. Both measurements, gain and Rin, fit within the performance parameters of having gain greater/equal to 0.9 and Rin being greater/equal to 1 kOhm.

Physical Circuit:

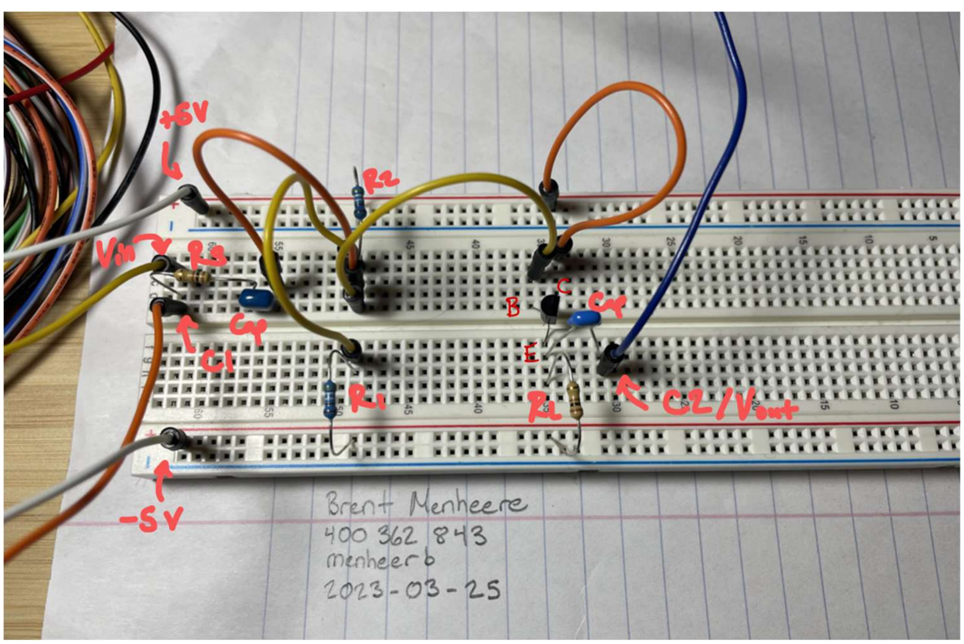

Figure 6 Annotated photo of physical circuit

Shown in Figure 6, it is apparent how this circuit corresponds to the schematic used in the simulation. All components involved with the circuit are labeled, along with the terminals of the BJT and testing nodes.

Waveform Measurements:

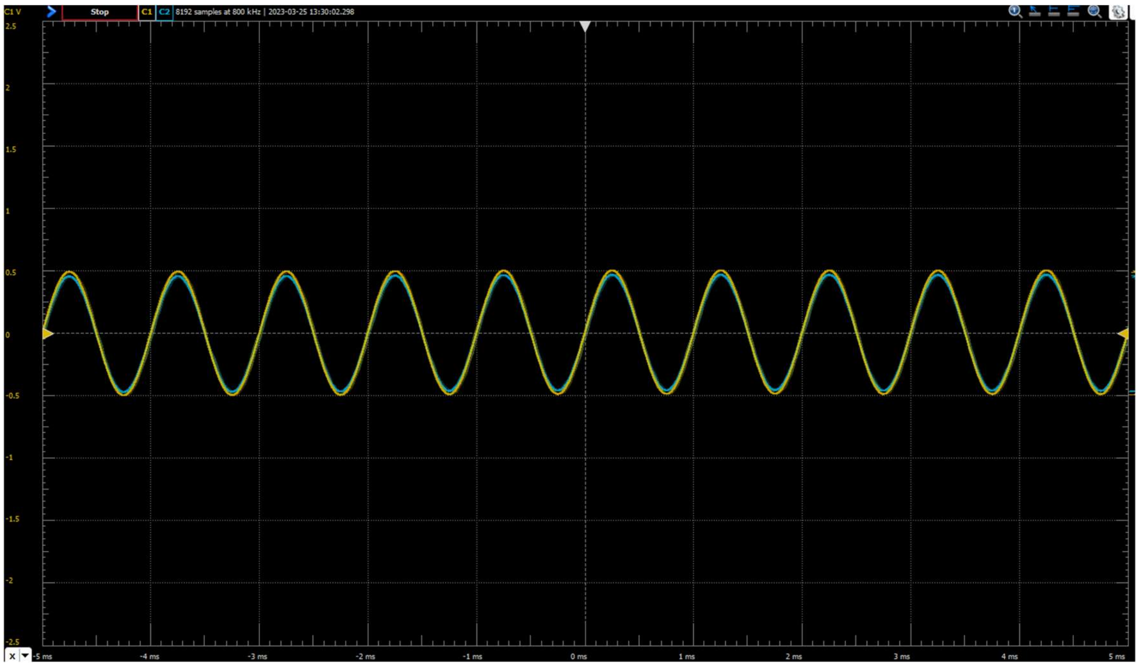

Figure 7 Vin (yellow) vs. Vout (blue)

	Name	Value
C1	Maximum	0.50206 V
C2	Maximum	466.79 mV
C1	Peak2Peak	1.0016 V
C2	Peak2Peak	0.94100 V

Figure 8 Exact measurements of waveform

Figure 7 shows the input voltage and the output voltage in respect to time. This precise screen shot was taken roughly a minute after first running the Waveforms functions, as it took time for the capacitors to react and give an output voltage that matched the input voltage as shown. From this plot, in Figure 8 the exact measurements of these waveforms are displayed. I chose to display both the maximums and the peak-to-peaks of the two waves. The maximum values were used to calculate the gain of the circuit. I chose to display the peak-to-peak values because they show a an easy representation of the gain. Without doing any calculations you can see that the gain of the circuit is about 0.94.

Physical Circuit: $gain = \frac{V_{outmax}}{V_{inmax}} = \frac{466.8\,mV}{502.1\,mV} = 0.93 \geq 0.9$ ok

Figure 9 Calculation of gain

The value of the gain was calculated to be 0.93. This value is exactly within what we expect from our calculations and the simulation.

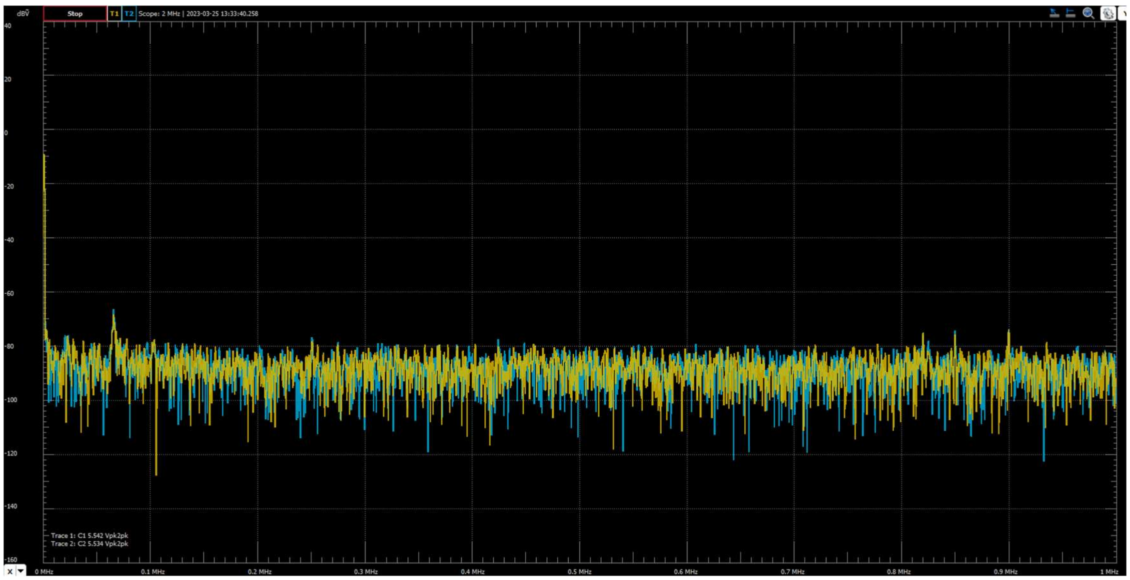

Figure 10 Spectrum of the waveforms

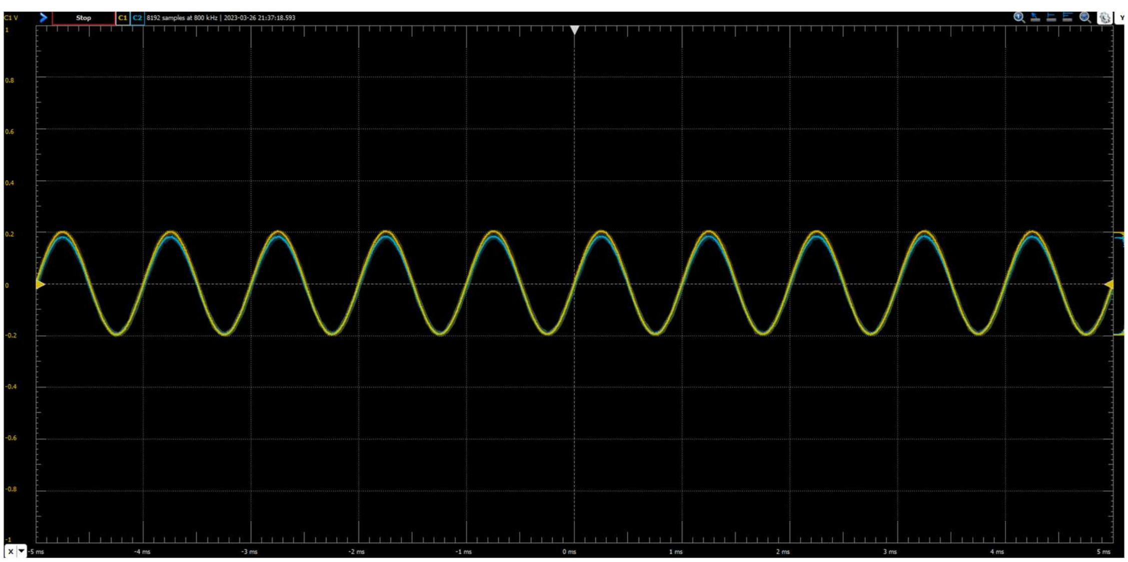

Figure 11 Functionality at 0.2 V

As a final check of the performance of this circuit, the spectrum was analyzed. The results in Figure 8 show linearity at an amplitude of 0.5 V. This is evident due to the spectrum of input and output “mirroring” each other. Along with this, the spike visible at the left edge of the spectrum is about -6 dBV which shows that this result can be achieved with 0.5 V. Figure 11 shows how this design also can function at a lower amplitude of 0.2 V.