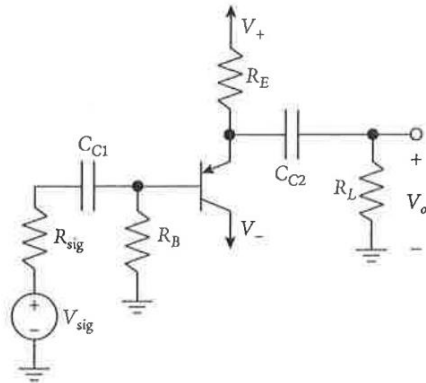


Lab 6.12 – A PNP Emitter Follower

In this lab we are going to use a bipolar PNP transistor (A 2N3906 small signal PNP Transistor) and build a “Common Collector” amplifier (AKA an Emitter Follower). It is called a Emitter follower since that describes its behavior, the Emitter (output) AC voltage is always approximately equal (there is a DC offset due to the Device threshold voltage) to the Base AC voltage.



Notes:

- R_{sig} is the output impedance of the AC signal generator which is 50 ohms for the function generator on our lab bench so do not put a physical source resistor in your actual circuit.
- The capacitors are there to block DC and at audio frequencies should have a negligible reactance.
- V_+ and V_- (15 volts) are ideally at AC ground (often bypass capacitors are used to insure this)

As with any design, you first select the resistors to put the transistor at a reasonable operating point. Then draw the AC (small signal) version of the circuit (capacitors are short circuits and the power rails are AC grounds and replace the 2N3906 transistor by a small signal model (I prefer the current controlled current source model here) to calculate the voltage gain (approximately 1), input impedance (A bit less than R_B), and output impedance (very low – ignore R_L).

The Emitter Follower is an effective “Buffer Amplifier” that isolates your signal source from the load.

- It will not “load” the signal source (high input impedance)
- The output “follows” the input (unity voltage gain)
- The output voltage is almost independent of the load resistance (low output impedance)

Most of these characteristics are due to a high degree of negative feedback in this circuit. Note that the input to the transistor is V_{BE} which is the input voltage minus the output voltage and the feedback gain is high due to the transistor gain (Beta).

LAB 6.12

PNP Emitter Follower

[See Section 6.8.5, p. 460 of Sedra/Smith]

OBJECTIVES:

To study a PNP-based emitter follower by:

- Completing the DC and small-signal analysis based on its theoretical behavior.
- Simulating it to compare the results with the paper analysis.
- Implementing it in an experimental setting, taking measurements, and comparing its performance with theoretical and simulated results.
- Qualitatively seeing the impact of transistor-to-transistor variations.

MATERIALS:

- Laboratory setup, including breadboard
- 1 PNP transistor (e.g., NTE2322)
- 3 large (e.g., $47\text{-}\mu\text{F}$) capacitors
- Several resistors of varying sizes
- Wires

PART 1: DESIGN AND SIMULATION

Consider the circuit shown in Figure L6.12:

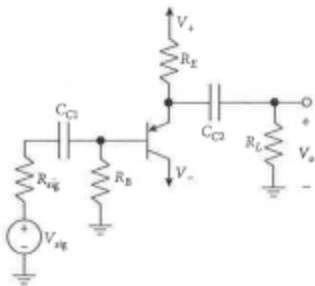


FIGURE L6.12: Emitter follower circuit, with coupling capacitors, and resistor R_B for DC-biasing purposes. Based on Fig. 6.68 p. 460 S&S.

Design the amplifier such that $I_C = 1 \text{ mA}$ and $A_v = 0.95 \text{ V/V}$. Use supplies of $V_+ = -V_- = 15 \text{ V}$, $R_{sig} = 50 \Omega$, and $R_B = 10 \text{ k}\Omega$. What is the minimum value of R_L that satisfies the design requirements? Obtain the datasheet for the PNP transistor that will be used. In your lab book, perform the following.

DC Operating Point Analysis

- Sketch a DC model of the circuit in your lab book, replacing the large-valued coupling capacitors C_{C1} and C_{C2} by open circuits (for simplicity you may also omit v_{sig} , R_{sig} , and R_L). What is I_B ? What are V_B and V_E ?
- Based on the required value of I_C , what is R_E ?

AC Analysis

- Sketch a small-signal model of the circuit in your lab book, replacing the transistor with its small-signal model (try a T model, ignoring r_o), replacing the capacitors with short circuits, and replacing V_+ and V_- with an AC ground. Label the base of the transistor as v_i , i.e., the small-signal voltage at the input.
- What is the ratio of v_o/v_{sig} ? How would you approximate it in further calculations?
- Derive an expression for $A_v = v_o/v_i$.
- What is the minimum value of R_L that satisfies the design requirements?
- What is the value of g_m ? What is r_e ? What is A_v ?
- Calculate the output resistance of your amplifier.

Simulation

- Simulate the performance of your circuit. Use capacitor values $C_{C1} = C_{C2} = 47 \mu\text{F}$ and the value of R_E based on your preceding calculations. Use a $10\text{-mV}_{\text{pk-pk}}$, 1-kHz sinusoid with no DC component applied at v_{sig} .
- From your simulation, report the DC values of V_{EB} , V_{EC} , and I_C . How closely do they match your calculations? (Remember: The simulator has its own, more complex model of the real transistor, so there should be some small variations.)
- From your simulation, report A_v . How closely does it match your calculations?

PART 2: PROTOTYPING

- Assemble the circuit onto your breadboard using the specified component values and those just calculated. Note that R_{sig} represents the output resistance of the function generator, and therefore you should *not* include it in your circuit.

PART 3: MEASUREMENTS

- *DC bias point measurement:* Using a digital multimeter, measure the DC voltages of your circuit at the base (V_B) and emitter (V_E) of your transistor.

- *AC measurement:* Using a function generator, apply a $10\text{-mV}_{\text{pk-pk}}$, 1-kHz sinusoid with no DC component to your circuit. (*Note:* Some function generators only allow inputs as small as $50\text{ mV}_{\text{pk-pk}}$. If this is the case, use that value instead.)
- Using an oscilloscope, generate plots of v_o and v_i vs. t .
- Using a digital multimeter, measure all resistors to three significant digits.

PART 4: POST-MEASUREMENT EXERCISE

- Calculate the values of V_{EB} and V_{EC} that you obtained in the lab. How do they compare to your pre-lab calculations? Explain any discrepancies.
- Based on the measured values of V_B and V_E and your measured resistor values, what is the real value of I_C based on your lab measurements?
- What is the measured value of A_v ? How does it compare to your pre-lab calculations? Explain any discrepancies.
- What would happen if you used the function generator with $50\text{-}\Omega$ output resistance to drive your load resistor directly? What gain would you get? What would happen if the output resistance of the function generation was changed from $50\ \Omega$ to $5\ \text{k}\Omega$? What do you conclude? Recall the value of output resistance you calculated earlier.
- *Hint:* The single biggest source of variations from your pre-lab simulation results will be due to variations in β .

PART 5 [OPTIONAL]: EXTRA EXPLORATION

- Add a $500\text{-}\Omega$ resistor between the function generator output and capacitor C_{C1} . How does the gain of your circuit change? Can you explain this?