# Lab 6 Cascaded C.E. Amplifiers

**Name** ______________________________ **Section** ______

## *Purpose*:

To demonstrate the ac operation of a two-stage (CE) amplifier.

## *Equipment:*

- 1 dc Power Supply
- 1 Digital Multimeter (DMM)
- 1 Variable ac Signal Generator
- 1 Dual Trace Oscilloscope
- 2 2N3904 npn Transistors

Resistors

| | |
|---|---|
| 2 - 150 Ω | 2 - 2.2 k Ω |
| 2 - 1 k Ω | 2 - 3.6 k Ω |
| 1 - 1.5 k Ω | 3 - 10 k Ω |

Capacitors

| | |
|---|---|
| 1 - 1 $\mu$F | 2 - 470 $\mu$F |
| 2 - 10 $\mu$F | |

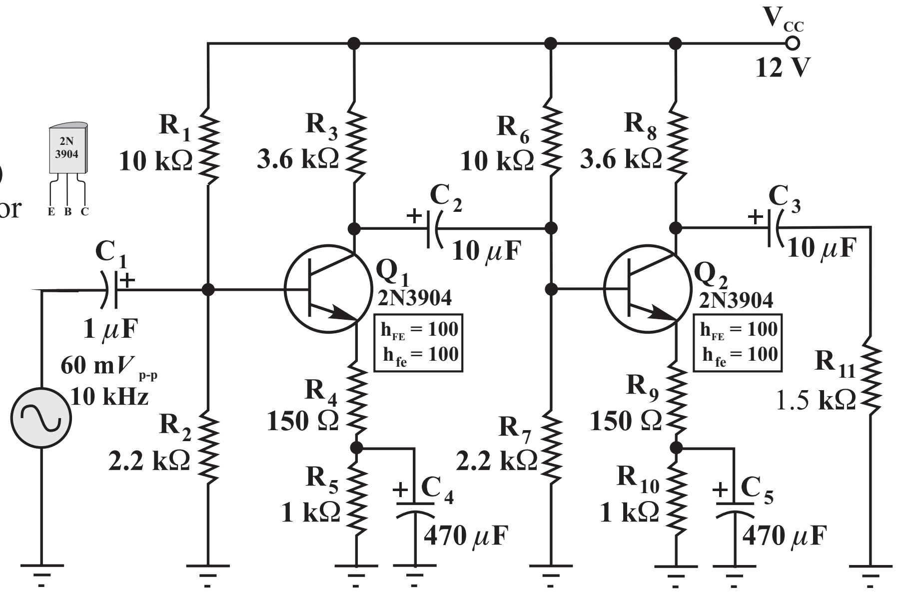


**Figure 1**

## *Prelab:*

- Construct the circuit shown in Figure 1 on your breadboard.
- Perform the dc analysis for both stages and record your answers in the Table 1.
  ***Show all calculations***.

- Perform the ac analysis for both stages and record your answers in Table 2. The worksheet on ac analysis will take you step-by-step through the process.
  ***Show all your calculations.***

## *Discussion:*

The amplified signal out of a CE stage can be used as the input to another CE stage. We know that the ordinary gains of each stage multiply. By building a multi-stage amplifier, we can achieve a very large voltage gain.

We know that a CE amplifier has an input impedance. Because this input impedance is the load for the preceding stage, it has a loading effect on the preceding stage. In other words, the loaded voltage gain is less than the unloaded voltage gain.

In this lab, you will build a two-stage amplifier that uses swamped stages to stabilize the overall voltage gain.

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Complete the dc analysis here:
Be sure to include $R_{in}$ in your calculations.

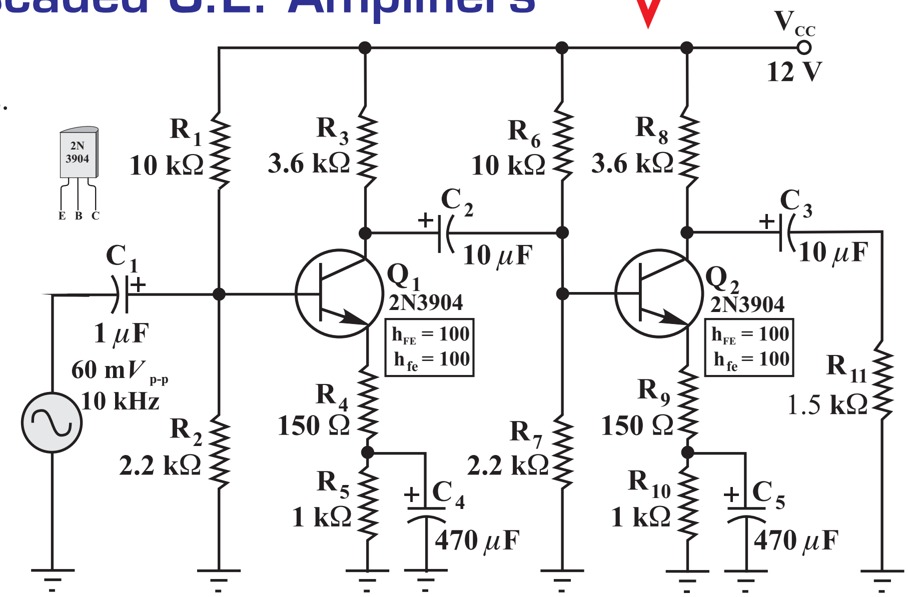


**Figure 1**

| **Table 1 dc Values** | $V_{B\ (Q1)}$ | $V_{C\ (Q1)}$ | $V_{E\ (Q1)}$ | $V_{B\ (Q2)}$ | $V_{C\ (Q2)}$ | $V_{E\ (Q2)}$ | $r'_{e\ (Q1)}$ | $r'_{e\ (Q2)}$ |
|---|---|---|---|---|---|---|---|---|
| **Calculated** | | | | | | | | |
| **Measured** | | | | | | | | |

**AC Analysis Worksheet** ( Refer to example 9.11 and 9.12 in the text for this part of the analysis)
Find $A_{V1}$, $A_{V2}$ and $A_{VT}$ for the amplifier shown.

Find $A_{V1}$ We know that this is a swamped amplifier and that the formula for voltage gain is
We need to find $r_C$ and $r_C = R_C \parallel R_L$. $R_L$ for the first stage is $Z_{in}$ for the second stage.
This is where we start.

- ☐ Find $Z_{base}$ for $Q_2$. $Z_{base} = h_{fe}(r'_e + r_E)$ Use $h_{fe} = 100$ for this calculation

$Z_{base}$ = ____________________

- ☐ Find $Z_{in}$ for $Q_2$ $Z_{in} = R_6 \parallel R_7 \parallel Z_{base}$ $Z_{in}$ is $R_L$ for stage 1

$Z_{in}$ = ____________________

- ☐ Find $r_C$ for stage 1. This is usually $R_C \parallel R_L$ but here it is $R_C \parallel Z_{in}$

$r_C$ = ____________________

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- [ ] You found $r'_e$ for stage 1 when you did the dc analysis. Use it now to find $A_V$.
In this case $r_E$ is the emitter resistor that is not bypassed , – the 150 Ω -- $R_4$

$$A_V = \frac{r_c}{r_E + r'_e}$$

$A_{V1}$ = ________for stage 1

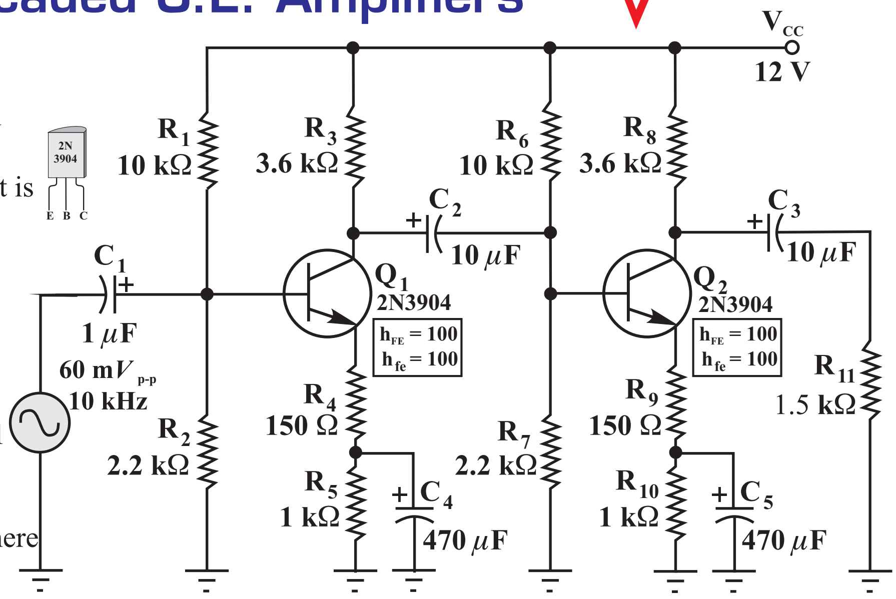


Figure 1

- [ ] ***Find $A_{V2}$***

Find $r_C$ for stage 2. This is $R_C \parallel R_L$, so here it is $R_8 \parallel R_{11}$

$r_C$ = ____________________

- [ ] Now find $A_V$ for stage 2.
In this case $r_E$ is the emitter resistor that is not bypassed , – the 150 Ω -- $R_9$

$$A_V = \frac{r_c}{r_E + r'_e}$$

$A_{V2}$ = ____________________ for stage 2

- [ ] Find $A_{VT}$ Ordinary gains multiply.
$A_{VT} = (A_{V1})(A_{V2})$

$A_{VT}$ = ____________________

- [ ] ***Finding the ac terminal voltages $V_B$ and $V_C$***

$V_{B\ (Q1)}$ is at 60 $mV_{p\text{-}p}$ since the generator is connected directly to it through capacitor $C_1$. All capacitors in this amplifier are operating well above $10f_C$ and appear as short circuits to the ac signal.

$V_{C\ (Q1)}$ is the amplified result of $Q_1$. The formula $V_{out} = A_V V_{in}$ becomes $V_{C(Q1)} = A_{V(Q1)} V_{B(Q1)}$ $V_{C\ (Q1)}$ = ________

$V_{B\ (Q2)}$ is at the same ac potential as $V_{C\ (Q1)}$ since there is a direct ac connection between them through capacitor $C_2$. This capacitor is operating well above $10f_C$ and appears as a short circuit to the ac signal.

$V_{C\ (Q2)}$ is the amplified result of $Q_2$. The formula $V_{out} = A_V V_{in}$ becomes $V_{C\ (Q2)} = A_{V(Q2)} V_{B(Q2)}$ $V_{C\ (Q2)}$ = _______

| Table 2 ac Values | $A_{V\ (Q1)}$ | $A_{V\ (Q2)}$ | $A_{V\ (T)}$ | $V_{B\ (Q1)}$ | $V_{C\ (Q1)}$ | $V_{B\ (Q2)}$ | $V_{C\ (Q2)}$ |
|---|---|---|---|---|---|---|---|
| Calculated | | | | | | | |
| Measured | | | | | | | |

# Lab 6 Cascaded C.E. Amplifiers

## *Procedure: Do this part in the Lab.*

1) Measure and record the dc values shown in Table 1. Do this with the signal generator ***disconnected*** from the circuit.

2) Connect the signal generator to the circuit and set the output to **60 mV** $_{p\text{-}p}$. using an oscilloscope.

3) Measure and record the ac values shown in Table 2 using the oscilloscope.

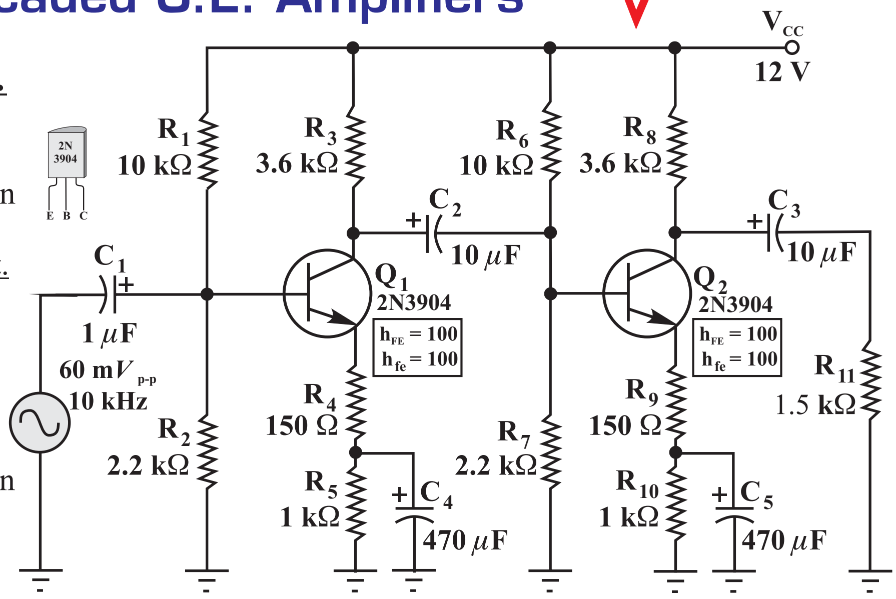


**Figure 1**

4) Using the measured values of $v_{B(Q1)}$ and $v_{C(Q1)}$, calculate $A_{V\,(Q1)}$. Insert this value in the measured section of Table 2.

5) Using the measured values of $v_{B(Q2)}$ and $v_{C(Q2)}$, calculate $A_{V\,(Q2)}$. Insert this value in the measured section of Table 2.

6) Using the measured values of $v_{B(Q1)}$ and $v_{C(Q2)}$, calculate $A_{VT}$. Insert this value in the measured section of Table 2.

7) Compare the values of $A_{V\,T}$ (measured) vs $A_{V\,T}$ (calculated). Calculate the percentage error.

$$\% \text{ Error} = \frac{|\text{measured - calculated}|}{\text{calculated}} \times 100$$

8) How would you account for this error? Give 3 reasons.

## *Loading Effects*

9) Open the coupling capacitor between the first and second stage ($C_2$). Measure the ac voltage on the collector of stage 1. Compare this with the measured value of $v_{C(Q1)}$ that you recorded in Table 2. Explain why the value in Table 2 is lower.

$v_{C(Q1)}$ ____________ ($C_2$ open)

$v_{C(Q1)}$ ____________ measured value from Table 2

10) Replace the coupling capacitor that you removed in Question 9. *Make sure that the amplifier is working normally.* Connect the scope to the collector of ***Stage 2***. Note the value of ac voltage and record it. It should be the same as the value you recorded in Table 2. Remove the load resistor ($R_{11}$). Note the value of $v_{CQ2}$ again.

$v_{C(Q2)}$ ____________ with the load resistor ($R_{11}$) ***in*** the circuit
$v_{C(Q2)}$ ____________ with the load resistor ($R_{11}$) ***out of*** the circuit

Why is the ac collector voltage higher with the load resistor removed?

______________________________________________________________
______________________________________________________________

11) Make sure that the amplifier is working normally. The load resistor is in the circuit. Connect the scope to the collector of ***Stage 1***. Note the value of ac voltage and record it. It should be the same as the value you recorded in Table 2. Remove the load resistor ($R_{11}$). Note the value of $v_{CQ1}$ again.

$v_{C(Q1)}$ ____________ with the load resistor ***in*** the circuit
$v_{C(Q1)}$ ____________ with the load resistor ***out of*** the circuit

Does the addition of the load resistance ($R_{11}$), have an impact on the output of the first stage? __________

12) Based on your answer to Question 11 above, what is your opinion of the use of a second amplifier stage as a means of isolating the first stage from the load?

______________________________________________________________
______________________________________________________________

13) Remove the load resistor and replace it with an 8Ω speaker. With the generator connected with ***60 m$V_{p\text{-}p}$*** applied to the input, measure the voltage that appears across the speaker. This is the same as $V_{CQ2}$

$v_{C(Q2)}$ ____________ the voltage across the speaker.

14) Explain why the output is so low.

______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________