

**PHYSICS 3500/8800**  
**Electronics**  
**Homework Set #4**

1. Consider the following electrical equivalent circuit of an amplifier:

$V_{it}$  = voltage at the input terminals

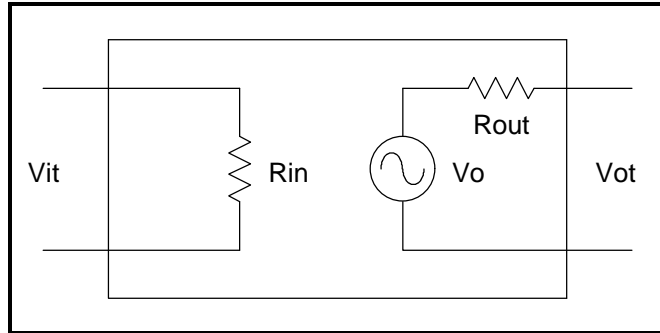
$A$  = Amplification factor

$R_{in}$  = input resistance

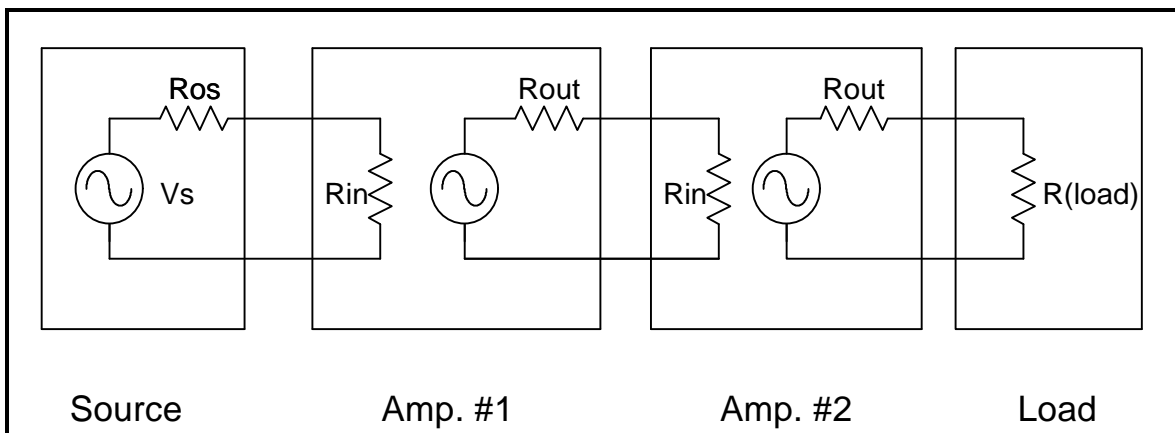
$V_o$  = output open-circuit voltage  
 ( $V_o = A \cdot V_{it}$ )

$R_{out}$  = output resistance

$V_{ot}$  = voltage at output terminals



Calculate the **Effective Amplification** factor (*defined as*  $EA = V_L/V_{os}$ ) of a system of *two* such units as sketched below:



<b>a.</b>	$R_{os} = 20\Omega$	$R_{in} = 10k$	$R_{in} = 50k$
		$R_{out} = 100\Omega$	$R_{out} = 10\Omega$
		$A = 20$	$A = 10$
			$R_L = 100\Omega$

<b>b.</b>	$R_{os} = 10k$	$R_{in} = 1k$	$R_{in} = 100\Omega$
		$R_{out} = 100\Omega$	$R_{out} = 10\Omega$
		$A = 20$	$A = 10$
			$R_L = 10\Omega$

2. "**Design**" a transistor amplifier using our "**standard**" circuit (a "common-emitter" type) to meet the following specifications:

$$A \geq 15; R_{out} \leq 3k; R_{in} \geq 12k$$

For this circuit, assume that a 15V power supply and a "typical" NPN silicon transistor will be used. Also, estimate the base current and take it into account in calculating the base resistors.

3. Choose input and output coupling capacitors for the circuit of Problem 2 using the following criteria:  $C_{in}$  such that  $X_c @ 10Hz = R_{in}$  and  $C_{out}$  such that  $X_c @ 10Hz = R_{out}$ . Use the "target" values of  $R_{in}$  and  $R_{out}$  from Problem 2 for your calculations.
4. Using the concept of Problem 1, calculate the **Effective Amplification @ 10Hz** of a system using your amplifier with the coupling capacitors, a source of output resistance  $R_{os} = R_{in}$ , and a load of resistance  $R_L = R_{out}$ . (The  $R_{in}$  and  $R_{out}$  values are the same ones used for Problems 2 and 3. Also, be sure to note that this is an a.c. problem since the coupling capacitors are included!)
5. Derive the amplification factor (for a.c. signals) for our "standard" transistor amplifier.
6. Derive the expressions for the **input** and **output resistances** for our "standard" amplifier circuit.
7. Calculate the voltages at the collector, base, and emitter of the transistor in a "standard" amplifier circuit for the set of values  $R_{B1} = 8k$ ,  $R_{B2} = 1k$ ,  $R_C = 3k$ ,  $R_E = 300\Omega$ , and  $V_s = 12V$ . (You may assume the base current to be negligible so that  $I_1 = I_2$  for the base resistors, but **explain** why this is reasonable for this specific set of values.)
8. Repeat Problem 7 with  $R_{B1} = 80k$  and  $R_{B2} = 10k$ , but with all other values the same, as follows:
- Ignore the base current, as in Problem 7;
  - Make an "exact" calculation by taking the base current into account.

Supplementary Transistor-Related problems  
Physics 3500/8800

- 1,2. a. Sketch the "standard" transistor amplifier circuit, including the input and output coupling capacitors.
- b. Calculate "suitable" resistor values for the following situation: "typical" NPN silicon transistor; Supply voltage = 15V. The design "targets" are: Amplification  $\geq 15$ ; Input resistance  $\geq 10k$ ; Output resistance  $\leq 3k$ . In your calculations of the biasing resistors, take the base current into account. Also, give the values for the voltages at the transistor's base, emitter and collector that you expect from your design.
- 3,4. a. Calculate "suitable" values for the coupling capacitors of the amplifier of the previous problem using the criteria that  $X_c$  of the input capacitor equals  $10k\Omega$ , and that  $X_c$  of the output capacitor equals  $3k\Omega$  (at 10Hz in both cases).
- b. Calculate the magnitude of the "effective" amplification ( $A = V_L / V_{os}$ ) of your amplifier in a system where the source has an output resistance of  $10k$ , and the load resistance is  $3k$ .
5. Sketch the "standard" transistor amplifier circuit including the input and output coupling capacitors. Calculate suitable values for the R's to meet the SPECIFICATIONS given, assuming the following: Supply Voltage = 12 V, and a typical NPN silicon transistor. In your calculations, take into account the base current.

SPECIFICATIONS:

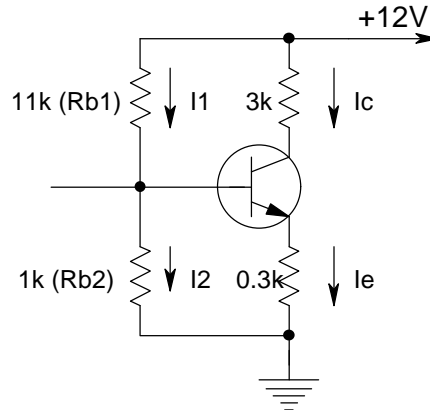
$$\text{Amplification} \geq 10$$

$$R_{in} \geq 15 \text{ k}\Omega$$

$$R_{out} \leq 3 \text{ k}\Omega$$

6. Sketched below is our "standard" transistor amplifier circuit.

a. Calculate the amplification factor of the circuit as shown.

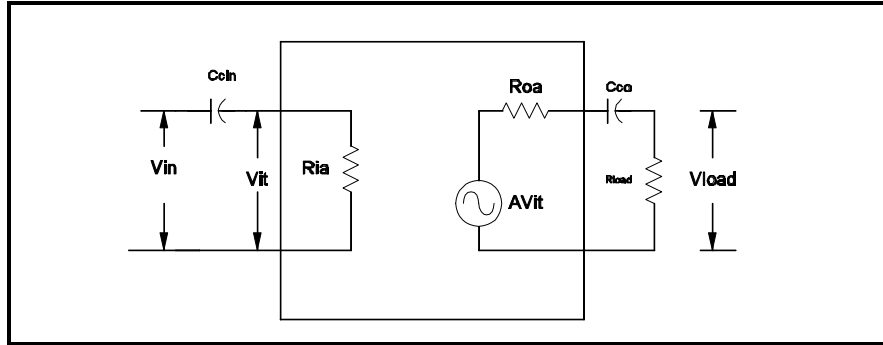


- b. What is the output resistance of the circuit shown?
- c. Calculate the input resistance of the circuit as shown.
- d. For the  $R_b$ 's chosen,  $I_b$  is much less than  $I_1$  or  $I_2$ . Use this fact to ignore  $I_b$ , and calculate the voltages at the base, the emitter, and the collector.
- e. For many applications, the input resistance of the circuit as shown is too low. Recalculate values for the  $R_b$ 's so that the input resistance is at least 11K. (In this calculation, you must take into account the estimated  $I_b$ . Do not change the values of  $R_c$  or  $R_e$ , however.)
7. Repeat part (d.) of the previous problem in the case  $R_{b1} = 220k\Omega$  and  $R_{b2} = 20k\Omega$ . This time do not neglect the base current; take it into account assuming that  $I_c = h_{fe}I_b$  and  $I_e = I_c + I_b$ . Use the "typical" value of  $h_{fe} = 100$  in your calculations.
8. Sketch the "standard" transistor amplifier circuit, and calculate values for the resistors to meet the following specifications: amplification = 10; input resistance  $\geq 8K$ ; output resistance  $\leq 2K$ .

Assume the following: 12V power supply; NPN silicon transistor with  $h_{fe} = 100$ .

Also, calculate values for the input and output coupling capacitors using the following criteria:  $C_{in}$  such that  $X_c =$  amplifier's input resistance at  $f = 10$  Hz.;  $C_{out}$  such that  $X_c =$  amplifier's output resistance at  $f = 10$  Hz.

9. Sketched below is the equivalent of a "capacitor-coupled" transistor amplifier, as used in your lab experiment. Shown also is specific load resistance. For the case  $A = 50$ ,  $R_{ia} = 10k$ ,  $R_{oa} = 3k$ ,  $R_{load} = 1.5k$ ,  $C_{cin} = 2\mu F$ , and  $C_{cout} = 6\mu F$ , calculate the **magnitude** of the load voltage at  $5/2$  Hz for a 0.1V input. (*Be sure to take into account the effect of the coupling capacitors.*)



10. Sketched below is a circuit including a typical NPN transistor.

- a. Assume the base current for the transistor to be negligible and calculate the voltages at the base, emitter, and collector of the transistor for the case  $V_s = 20V$ ;  $R_c = 3k$ ;  $R_e = 150\Omega$ ;  $R_{b1} = 9.3k$ ;  $R_{b2} = 0.7k$ .

- b. From your results of part (a) and the basic nature of transistors, **estimate** the base current of the transistor, and **justify** with a short explanation why it is reasonable to neglect the base current **for the circuit shown**. (In your explanation consider the following questions: What is the **maximum possible** collector current? How much base current is necessary for this collector current? How does this base current value compare with the currents through the base resistors?)

