SEMICONDUCTOR DIODES AND TRANSISTORS

PROGRAMED INSTRUCTION

MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

VOLUME 4
CIRCUITS 1

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SEMICONDUCTOR DIODES AND TRANSISTORS

VOLUME 4

CIRCUITS

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STOP!

In Volume 4 we will discuss characteristics of the transistor and its associated circuitry when the transistor is operated in the linear region of its characteristic curves (Class A operation). The transistors shown in schematic diagrams will be silicon unless marked G_e for germanium. The forward biased silicon junction will drop $\approx$.7v. The forward biased germanium junction will drop $\approx$.3v.

The prerequisites for taking this volume are Volumes 1, 2 and 3 of Semiconductor Diodes and Transistors, or the equivalent.

The objectives for each set on the following page can also be used as a table of contents. That is objective 1 will indicate the material in set 1, etc.

The level after each objective is used to indicate the knowledge level the material is to be taught to. An appendix in the back gives a detailed explanation of the meaning of each knowledge level.

Have fun!

OBJECTIVES

1. Recall that "h" parameters are the most useful parameters when analyzing transistors, and recall the four basic h parameters. (2 level)

2. Recall that the basic h equivalent circuit will remain the same as the transistor configuration is changed, but the value of the four components will change. (2 level)

3. Recall that the hi parameter is the input resistance of a transistor, and recall the relative hi value for the three transistor configurations. (3 level)

4. Recall that the hf parameter is the forward current transfer ratio or current gain of a transistor, and recall the relative hf value for the three transistor configurations. (3 level)

5. Recall that the ho parameter is the output conductance of a transistor, and recall the relative ho value for the three transistor configurations. (3 level)

6. Recall that the hr parameter is the reverse voltage transfer ratio of a transistor. Recall the hr value for the three transistor configurations. (3 level)

7. Review of Sets 3-6.

8. Recall that for a given set of "h" parameters, temperature, emitter current, and collector to emitter voltage must be specified. (2 level)

9. Recall that $\frac{26}{I_E}$ is a very close approximation of the emitter resistance in a given transistor circuit. (3 level).

10. Be able to calculate the approximate input resistance (r_i) and the approximate output resistance (r_o) in the common base configuration, recalling and using the approximate formulas. (3 level)

11. Be able to calculate the approximate r_i and r_o of a common collector configuration, recalling and using the approximate formulas. (3 level)

12. Be able to calculate the approximate r_i and r_o of a common emitter configuration, recalling and using the approximate formulas. (3 level)

13. Be able to calculate the transimpedance of the common base configuration. (3 level)

14. Be able to calculate the approximate A_v, r_i, and r_o of the common collector configuration, recalling and using the approximate formulas. (3 level)

15. Be able to calculate the approximate A_v and r_i of the common emitter configuration, recalling and using the approximate formulas. (3 level)

16. Be able to apply the approximating formulas (A_v + r_i) to push-pull amplifiers. (5 level)

17. Be able to apply the approximating formulas (A_v + r_i) to paraphase amplifiers. (5 level)

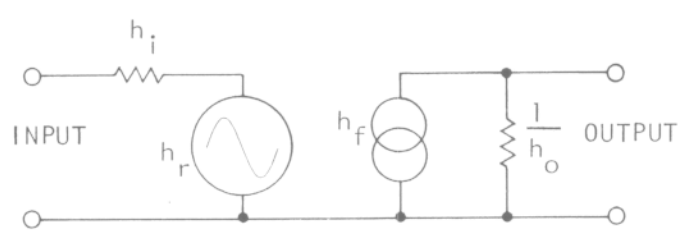
1.0 To analyze a transistor, we represent the transistor AC characteristics or parameters with four linear components. These four components represent the "h" parameters of the transistor. The four "h" parameters are ________________, ________________, ________________, and ________________.

---

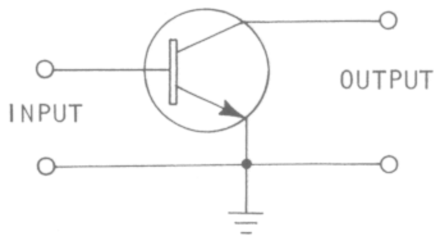
input resistance (h_i)
forward current transfer or current gain (h_f)
output conductance (h_o)
reverse voltage feedback or transfer (h_r)

The most common method of analyzing a transistor is with "h" parameters. There are four AC characteristics or parameters of the transistor represented by four linear components in an "h" equivalent circuit. These four parameters of the transistor are:

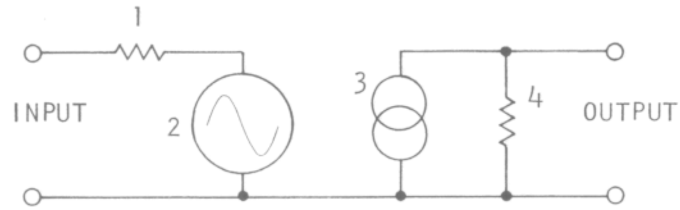
1. Input resistance (h_i)
2. Forward current transfer or current gain (h_f)
3. Output conductance (h_o)
4. Reverse voltage feedback (h_r)



1.1 The transistor AC characteristics or parameters are represented in the equivalent circuit by #________ linear components.



TRANSISTOR



TRANSISTOR "h" EQUIVALENT

---

four

1.2 These four linear components will represent the transistor AC characteristics or ________________________.

---

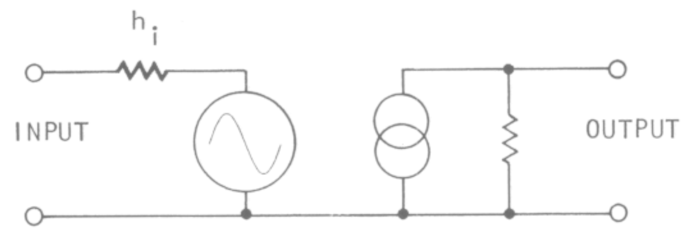
parameters

1.3 The four transistor parameters represented by the four components are labeled the ________ parameters.

---

h

1.4 The input resistance to the transistor is represented by the "h" parameter ____________.



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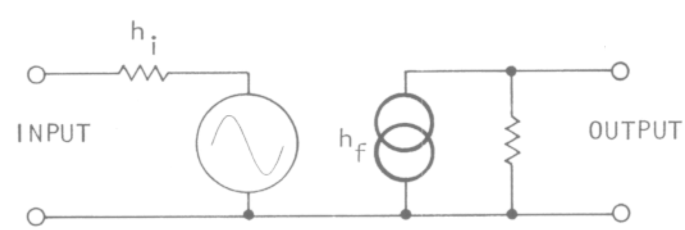
h_i

1.5 The "h" parameter with the first subscript being i, then, represents ________________ ____________________ to the transistor.

---

input resistance

1.6 The forward current transfer, or current gain, of the transistor is represented by the "h" parameter ____________.



---

h_f

1.7 The h parameter with the first subscript being f, then, represents the forward current transfer, or ________________ ______________, of the transistor.

---

current gain

1.8 The h_i parameter represents the ____________ __________________ to the transistor.

---

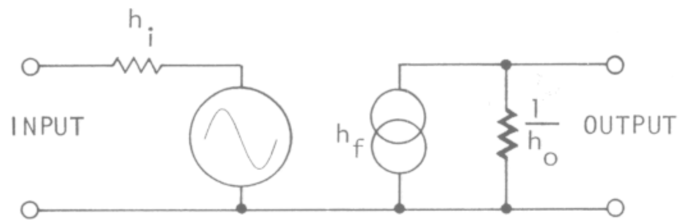
input resistance

1.9 Conductance is the reciprocal of __________________.

---

resistance

1.10 We can represent the output resistance of the transistor by its reciprocal which is the output ______________________, or the "h" parameter __________. (In the diagram, it is drawn as a resistance so we label it $\frac{1}{h_o}$.)



---

conductance
h_o

1.11 The "h" parameter with the first subscript being o, then, represents ______________ ________________ of the transistor.

---

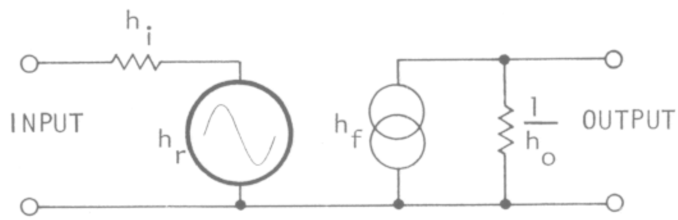
output conductance

1.12 The h_f parameter represents the __________________________ of the transistor.

---

current gain or forward current transfer

1.13 The reverse voltage feedback from the output of the transistor to the input is represented by the "h" parameter __________.



---

h_r

1.14 The "h" parameter with the first subscript being r, then represents the ________________________ voltage feedback in the transistor.

---

reverse

1.15 The h_o parameter represents the ________________ ______________________ of the transistor.

---

output conductance

1.16 The h_r parameter represents the ________________ ________________ feedback in the transistor.

---

reverse voltage

1.17** There are # ________ 'h' parameters that represent the characteristics of the ____________________. The "h" parameters are ____________________, ____________________, ____________________, and ____________________.

---

four
transistor
h_i - input resistance
h_f - forward current transfer or current gain
h_o - output conductance
h_r - reverse voltage feedback

Set 1 Summary

In Set 1, we have said that a transistor's AC characteristics may be represented by an equivalent circuit containing four linear components. The AC characteristics of the transistor that these four components represent are termed "h" parameters. The four "h" parameters are:

- h_i - input resistance to the transistor
- h_f - forward current transfer or current gain of the transistor
- h_o - output conductance of the transistor
- h_r - reverse voltage feedback in the transistor

The transistor equivalent circuit that we have discussed in Set 1 will remain the same regardless of the transistor configuration. That is, the equivalent circuit will be the same for a transistor whether it is in the common base, common emitter, or common collector configuration. The value of the "h" parameters contained in the equivalent circuit will change, however.

In the following sets, we will discuss each of the "h" parameters one by one.

2.0 The three transistor configurations are ______________________________,

______________________________, and ______________________________.

As the transistor configuration is changed, the h equivalent circuit will ______________________ (change/remain the same). As the transistor configuration is changed, the values of the components in the h equivalent circuit will ______________________ (change/remain the same). The second subscript in the h parameter will identify the transistor ______________________.

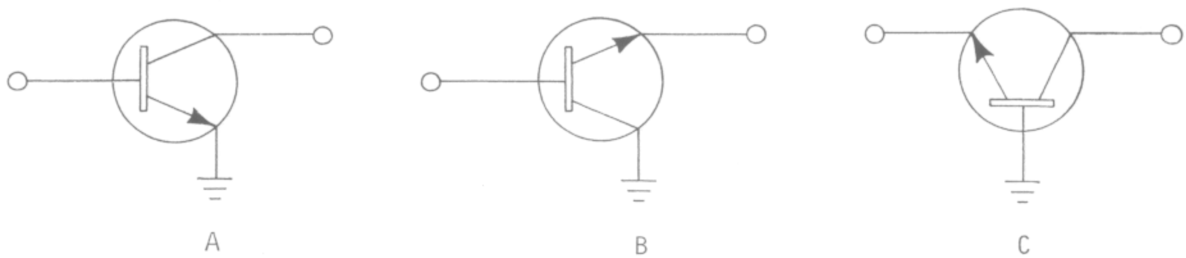
---

common base
common emitter
common collector
remain the same
change
configuration

There are three transistor configurations. The "h" equivalent circuit of the transistor remains the same as the configuration changes. However, the values of the components used to represent the transistor do change as the configuration changes. For example, the input resistance (h_i) is not the same for the common emitter and common base configurations.

Because the h parameters are different for each transistor configuration, a second subscript is added to identify the configuration. For example, the h_{ie} parameter would be the input resistance to a transistor in the common emitter configuration.

2.1 In the circuit below, circuit A is in the common ______________ configuration, circuit B is in the common ______________ configuration, and circuit C is in the common ______________ configuration.



---

emitter
collector
base

2.2 The "h" equivalent circuit is the same for each ______________. However, there may be a change in the value of the four linear ______________ in the "h" equivalent circuit.

---

configuration
components

2.3 The h_i parameter for all three transistor configurations will be a measure of ______________ ______________.

---

input resistance

2.4 When the transistor configuration is changed, the value of the h_i parameter will be ________________.

---

changed

2.5 The "h" parameter termed h_i then is incomplete because it does not indicate the transistor ____________________.

---

configuration

2.6 The second subscript in the h parameter will indicate the transistor configuration. That is, h_{ie} will be the input resistance for a transistor in the common ______________ configuration.

---

emitter

2.7 h_{fb} is the current gain of a transistor in the common ______________ configuration.

---

base

2.8 h_{fb} and h_{fe} both indicate the measurement of ______________ __________ in a transistor. They ____________ equal.
(are/are not)

---

current gain
are not

2.9 h_{fb} is the current gain of a transistor in the common __________________ configuration. h_{fe} is the current gain of a transistor in the common _______________________ configuration.

---

base
emitter

2.10 In a transistor amplifier circuit, regardless of the configuration, the emitter-base junction is always ____________________ biased and the collector-base junction is always _______________________ biased.

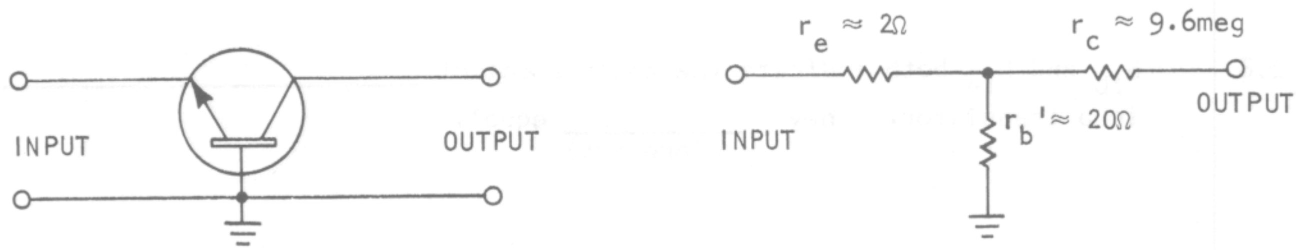
---

forward
reverse

2.11 Because of the biasing, there is a relatively low resistance across the ______________________ to base junction, and a relatively high resistance across the ______________________ to base junction.

---

emitter
collector



COMMON BASE

FIGURE 2-1

COMMON EMITTER

FIGURE 2-2

COMMON COLLECTOR

FIGURE 2-3

2.12 In figures 2-1, 2-2, and 2-3, the emitter-base junction AC resistance is represented by _________, and the collector-base junction AC resistance is represented by _________.

---

r_e
r_c

2.13 The value of r_b' in the three figures is the sum of the base material resistance and the base contact resistance. The reason for the different value of r_c in figures 2-2 and 2-3 from 2-1 will be explained in Set 5.

No answer needed

2.14** The output conductance of a transistor in the common base configuration would be labeled by the "h" parameter _________. It would have a different value than the output conductance for the transistor in the common __________________ configuration or the common ________________ configuration.

---

h_{ob}
emitter
collector

Set 2 Summary

In Set 2, we have reviewed the three transistor configurations and said that the "h" equivalent circuit will be the same for all three configurations. However, the value of the four components, h_i, h_f, h_o, and h_r, may change as the configuration is changed.

Because the h parameters may be different for a different configuration, a second subscript is added to the h parameter to identify the configuration. Example: h_{fe} and h_{fb} are both current gain parameters, but h_{fe} applies to a transistor in the common emitter configuration, and h_{fb} applies to a transistor in the common base configuration.

The resistive equivalent circuit for a transistor was introduced here to be used as an aid in understanding the four "h" parameters. The four "h" parameters will be introduced in the following four sets.

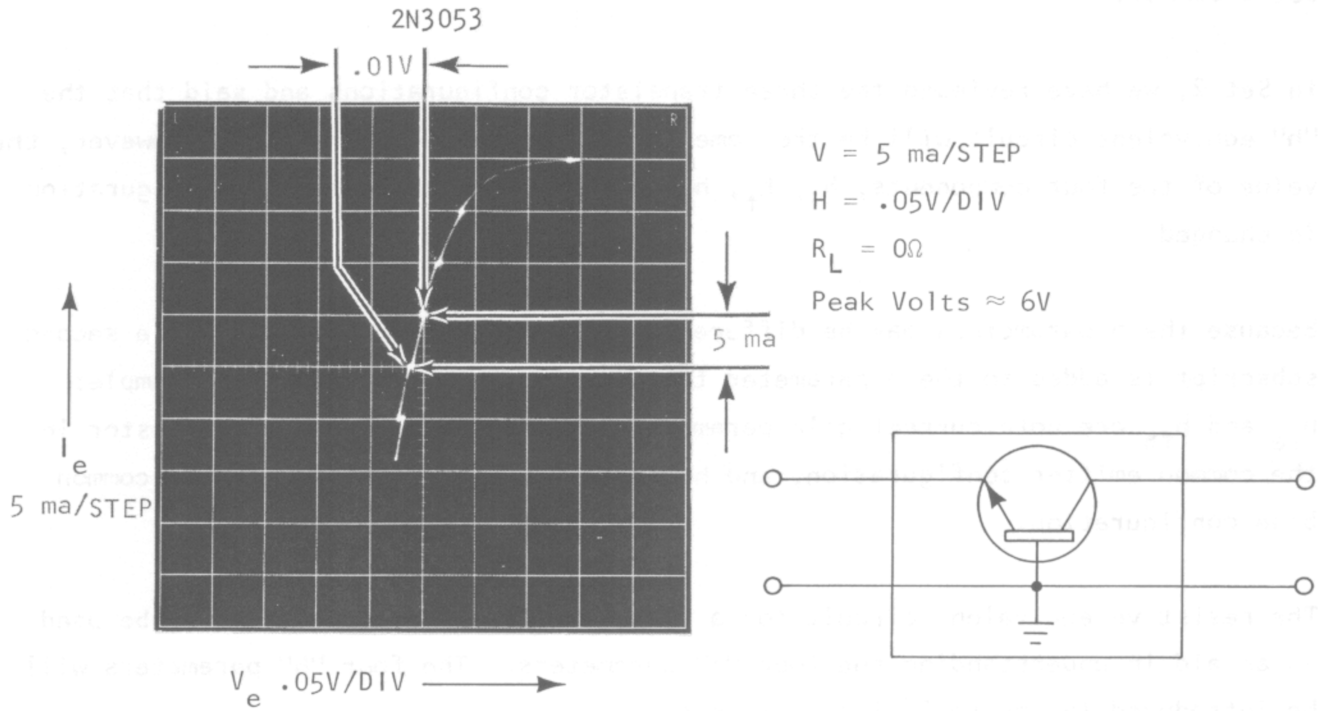


FIGURE 3-1

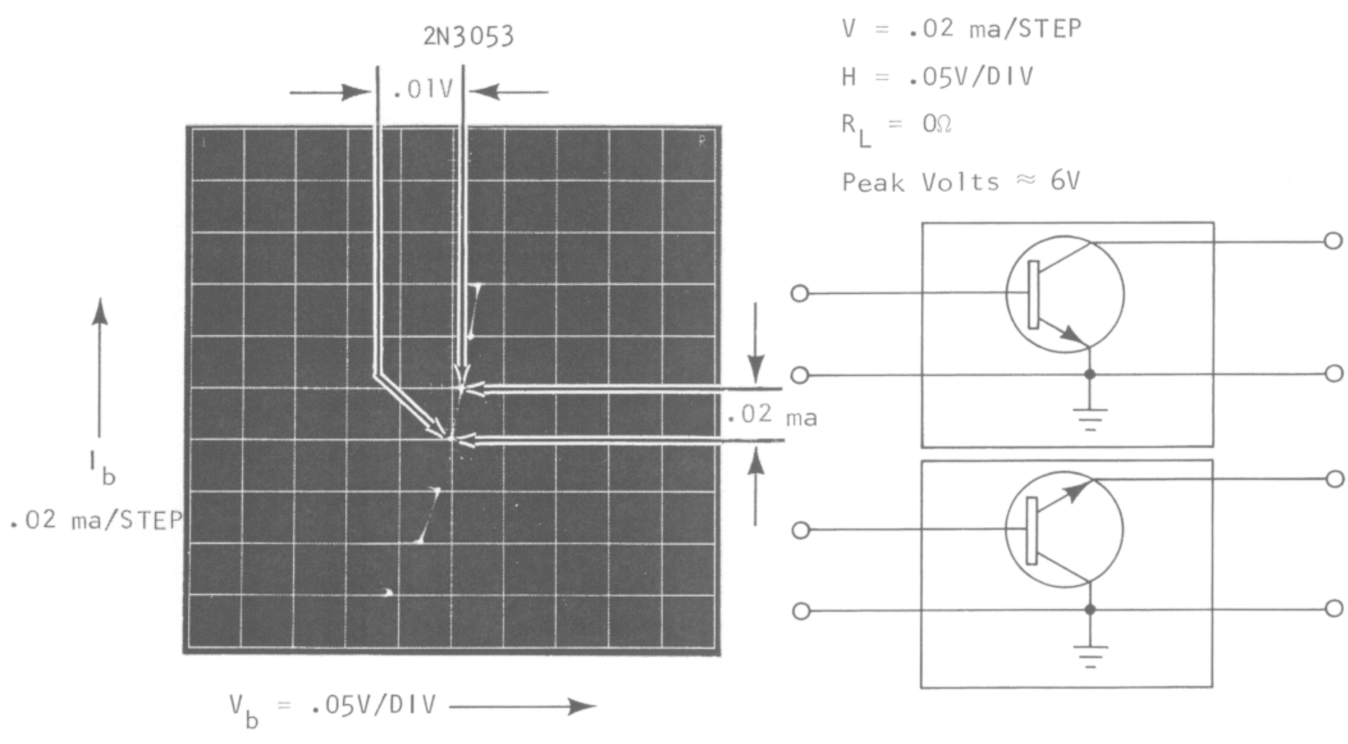


FIGURE 3-2

3.0 The h_i parameter is a measure of the transistor ________________ ____________________. From the curves on the facing page, for a 2N3053 determine h_{ib}, h_{ie}, and h_{ic}.

h_{ib} = __________

h_{ie} = __________

h_{ic} = __________

---

input resistance
≈2Ω
≈500Ω
≈500Ω

The input resistance (h_i) is determined by changing input voltage and observing the corresponding change in input current. The output voltage must be held constant (AC short circuit).

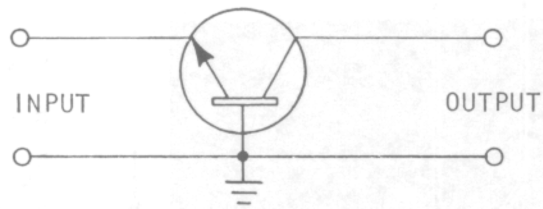
$$h_i = \left.\frac{\Delta v_i}{\Delta i_i}\right|_{\Delta v_o = 0}$$

3.1 To determine the input resistance (h_i), we must divide the input ____________________ by the input ________________ (Ohm's law).

---

voltage
current

3.2 When the transistor is in the common base configuration, the input is applied between the ________________ and base.



---

emitter

3.3 Input voltage to a transistor in the common base configuration would be the ________________ to base voltage.

---

emitter

3.4 The emitter current of a transistor in the common base configuration would also be the ______________ current.

---

input

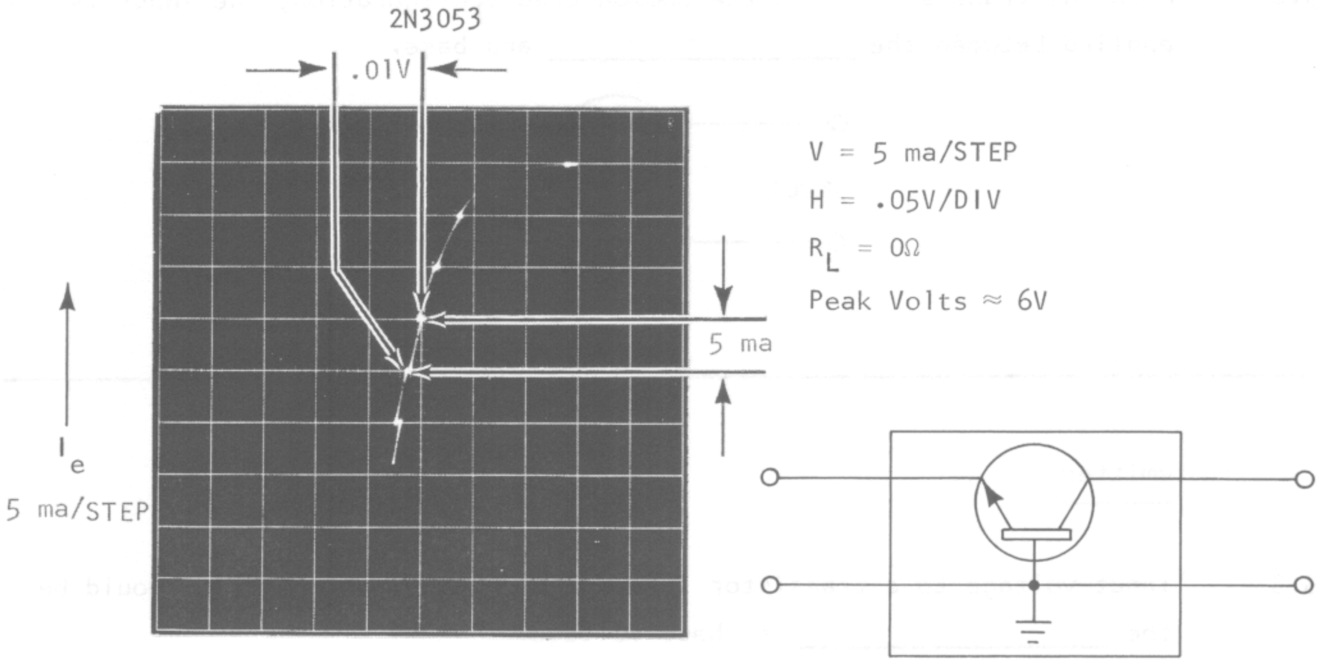


FIGURE 3-1

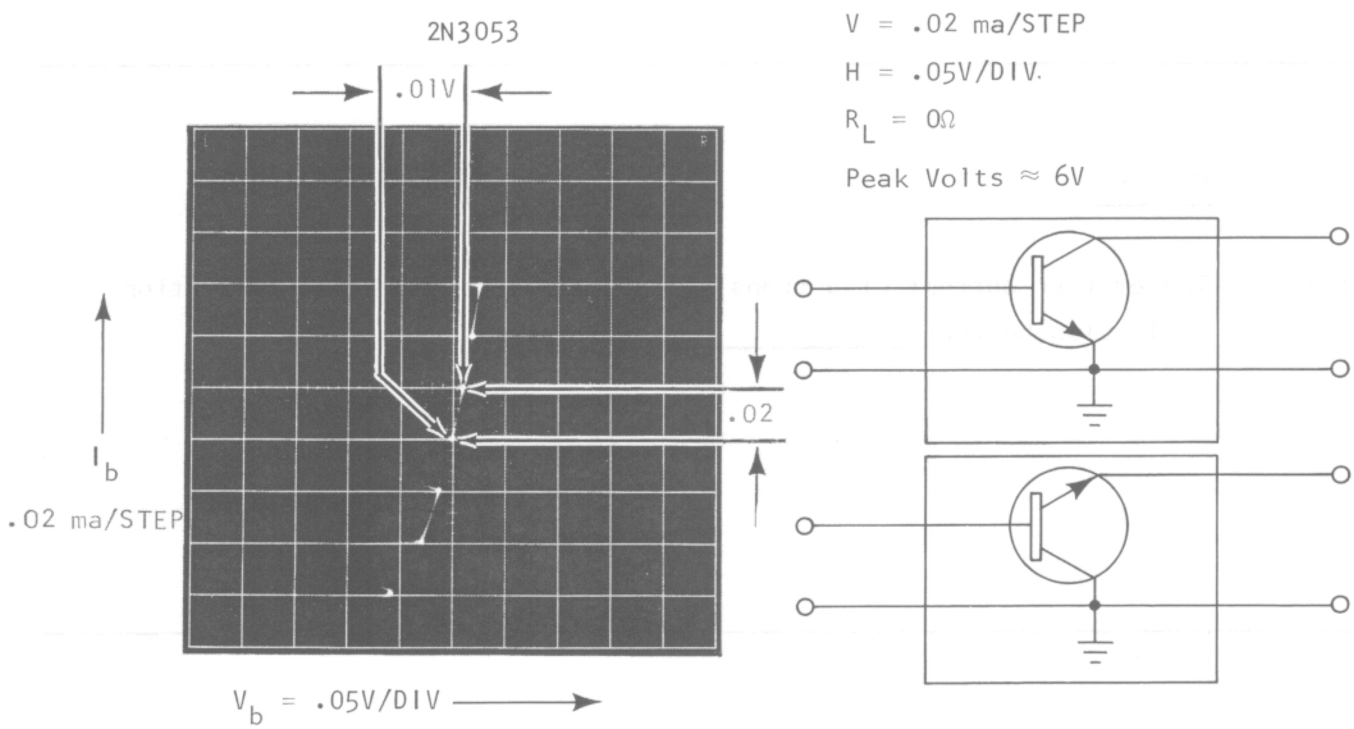


FIGURE 3-2

3.5 To determine the value of h_i, since it is an AC parameter, we will divide a change in ____________________ to base voltage by a change in emitter ______________________.

---

emitter
<u>current</u>

3.6 In figure 3-1, the horizontal axis measures a change in ______________ to base voltage and the vertical axis measures a change in ____________________ current.

---

emitter
<u>emitter</u>

3.7 In figure 3-1, a change of .01V from emitter to base results in a change in emitter current of __________ mA.

<u>5</u>

3.8 The h_{ib} of the 2N3053 transistor used for the curves in figure 3-1 is ________________Ω.

$$h_{ib} = \frac{.01V}{5\ mA} = 2\Omega$$

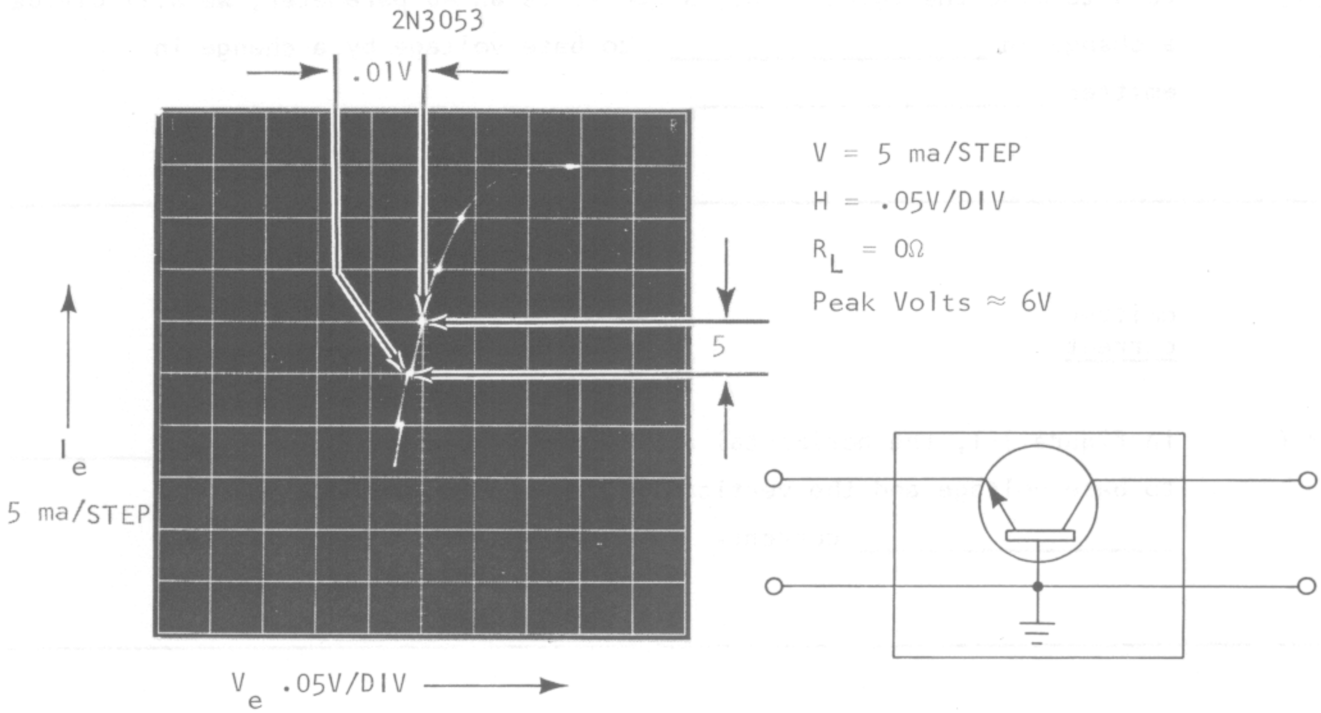


FIGURE 3-1

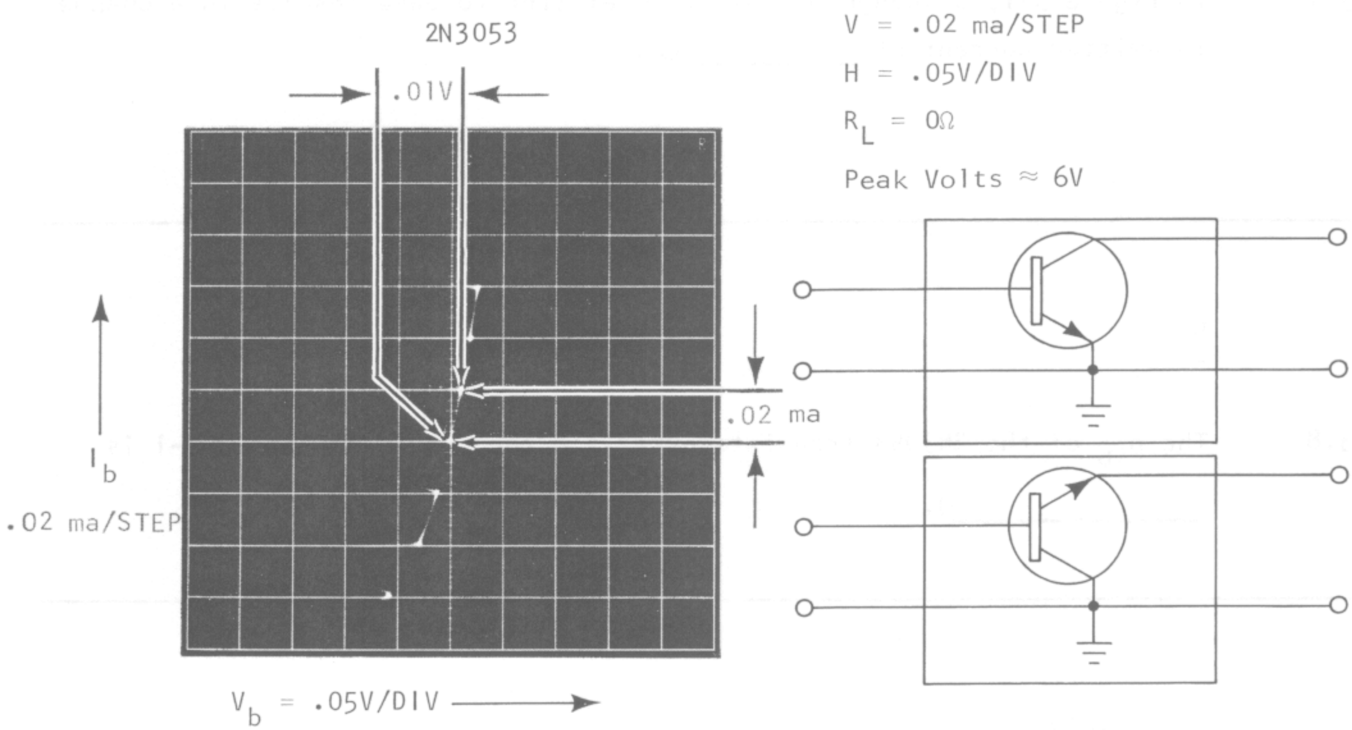
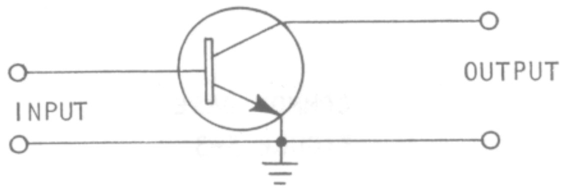


FIGURE 3-2

3.9 The input voltage to a transistor in the common emitter configuration is the ______________ to emitter voltage. The input current to a transistor in the common emitter configuration is the base ____________.



---

base
current

3.10 In figure 3-2, the horizontal axis measures a change in ______________ to emitter voltage, and the vertical axis measures a change in base ________________.

---

base
current

3.11 In figure 3-2, a change of .01V from base to emitter results in a change in base current of ________ mA.

.02 mA

COMMON BASE
FIGURE 3-3

COMMON EMITTER
FIGURE 3-4

COMMON COLLECTOR
FIGURE 3-5

3.12 The h_{ie} of the 2N3053 transistor used for the curves in figure 3-2 is ________Ω.

$$h_{ie} = \frac{.01V}{.02\ mA} = 500\Omega$$

3.13 From the figures on the facing page (3-3 through 3-5), we can see that a relatively high resistance separates the input from the output in the common ________ and common ________ configurations.

---

base
emitter

3.14 Due to the high impedance between input and output of the common base and common emitter configurations, a change in the output voltage will have a very ________ effect on the input.

---

small, little, etc.

3.15 From figure 3-5, we can see that in the common collector configuration the input is separated from the output by a relatively ________ resistance.

---

low, etc.

3.16 To determine the h_i parameter for any of the configurations, the output voltage should be held constant. However, due to the high resistance between input and output, the output voltage has very little effect on the h_i parameter for either the common ______________ or common ________________ configuration.

---

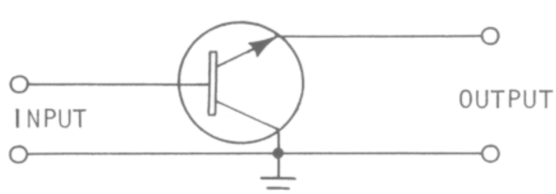
base
emitter

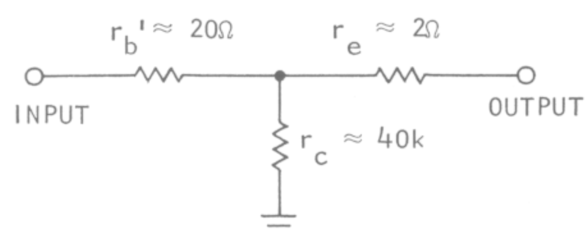
3.17 A change in the output voltage will have the greatest effect on the h_i parameter when the transistor is in the common ____________________ configuration.

---

collector

3.18 To hold the output voltage constant, the output resistance must be an AC short. The input resistance is then the emitter to base junction in shunt with the collector to base junction, or essentially the ________________ to base junction.





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emitter

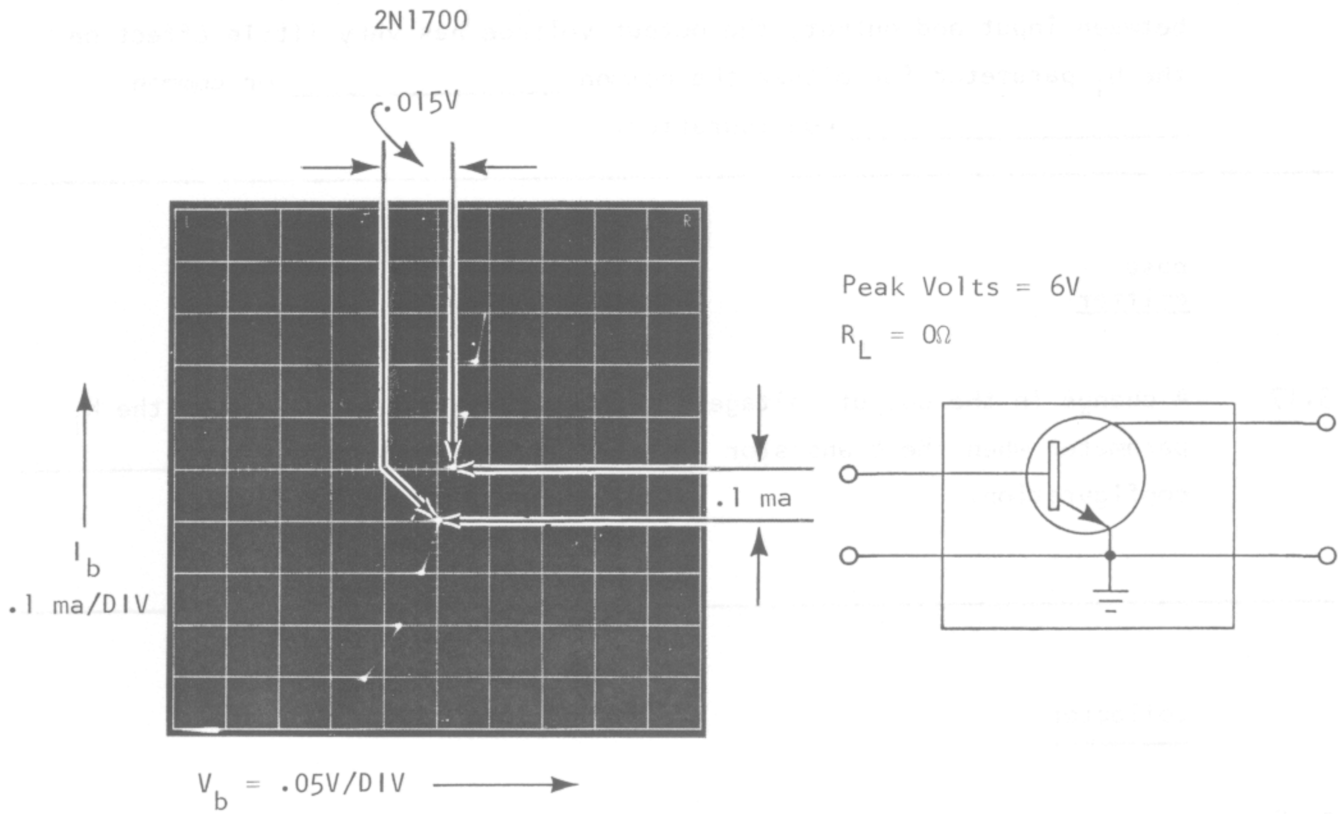


FIGURE 3-3

3.19 If the input resistance to a transistor in the common collector configuration (h_{ic} parameter) is essentially taken across the base to emitter junction, it must be equal to the ____________ parameter.

---

h_{ie}

3.20 The h_{ic} for the 2N3053 transistor used in figure 3-2 is __________Ω.

500Ω

3.21** Determine the h_{ie} and h_{ic} for the 2N1700 transistor used for the curves in figure 3-3.

h_{ie} = ____________

h_{ic} = ____________

---

h_{ie} = 150Ω

h_{ic} = 150Ω

Set 3 Summary

In Set 3, we have established the method for determining the h_i parameter for a transistor in any of the three transistor configurations. h_{ie} and h_{ic} are equal in value, and h_{ib} is always a much smaller value.

2N3053

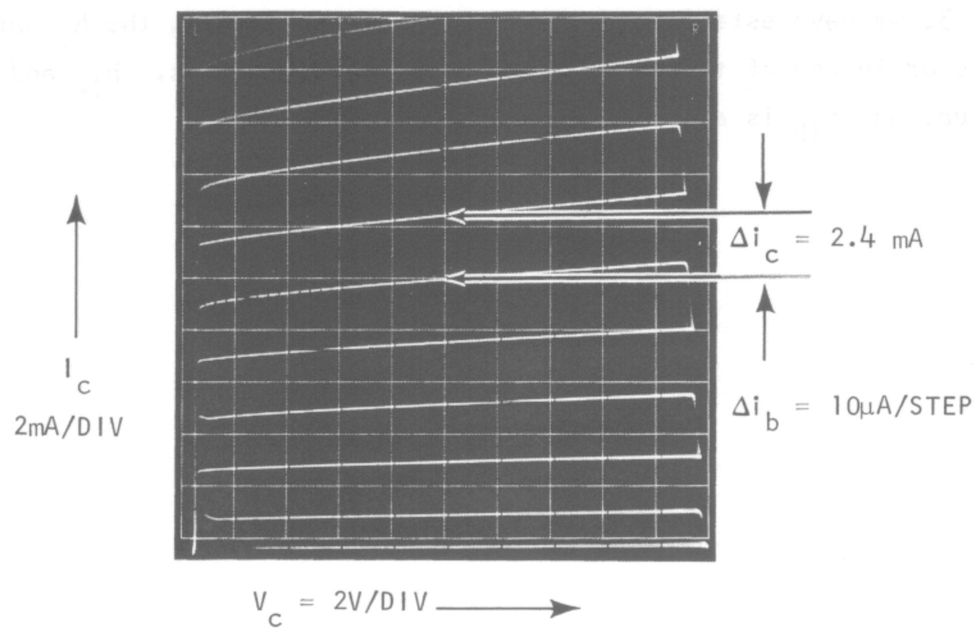


FIGURE 4-1

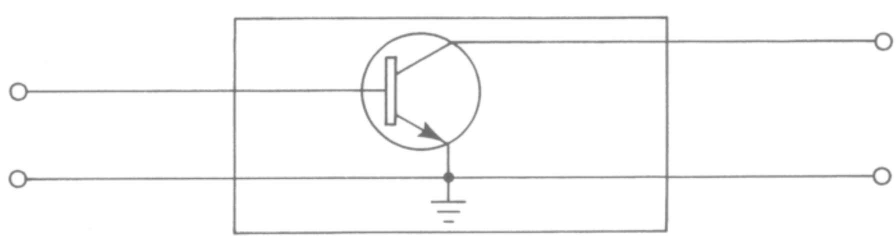


FIGURE 4-2

4.0 The h_f parameter is a measure of the __________ __________ or __________ __________ transfer ratio. From the curves in figure 4-1, for a 2N3053 transistor, determine the h_{fe}, h_{fb}, and h_{fc}.

h_{fe} = ________

h_{fb} = ________

h_{fc} = ________

---

current gain
forward current

$h_{fe} = 240$

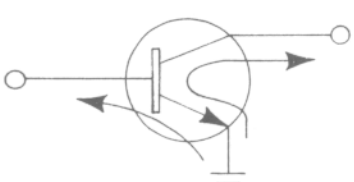
$h_{fb} = .995$

$h_{fc} = 241$

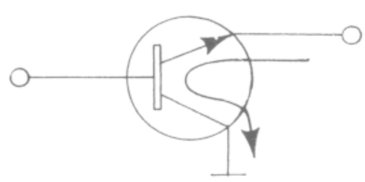
The current gain (h_f) of a transistor is determined by the ratio of output current to the input current, with the output voltage held constant (AC short circuited).

$$h_f = \left.\frac{\Delta i_b}{\Delta i_i}\right|_{\Delta v_o = 0}$$

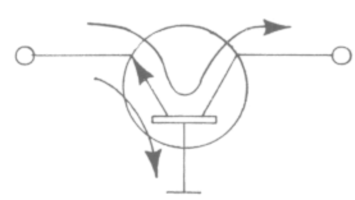
The current gain of a transistor in the common emitter or common collector will be greater than one. Current gain for a transistor in the common base configuration will always be less than one, because the output current is part of the input current.



COMMON EMITTER



COMMON COLLECTOR



COMMON BASE

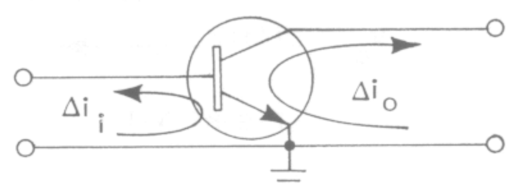
4.1 Current gain (h_f) in a transistor is the ratio of output current to input ____________ with the output voltage held constant

$$h_f = \left. \frac{\Delta i_o}{\Delta i_i} \right|_{\Delta v_o = 0}$$

---

current

4.2 The input current to a transistor in the common emitter configuration is the ____________ current, and the output current is the ________________ current.



---

base
collector

4.3 The current gain of a transistor in the common emitter configuration (h_{fe}) is the ratio of base current to ________________ current with ________________ voltage held constant.

---

collector
collector

2N3053

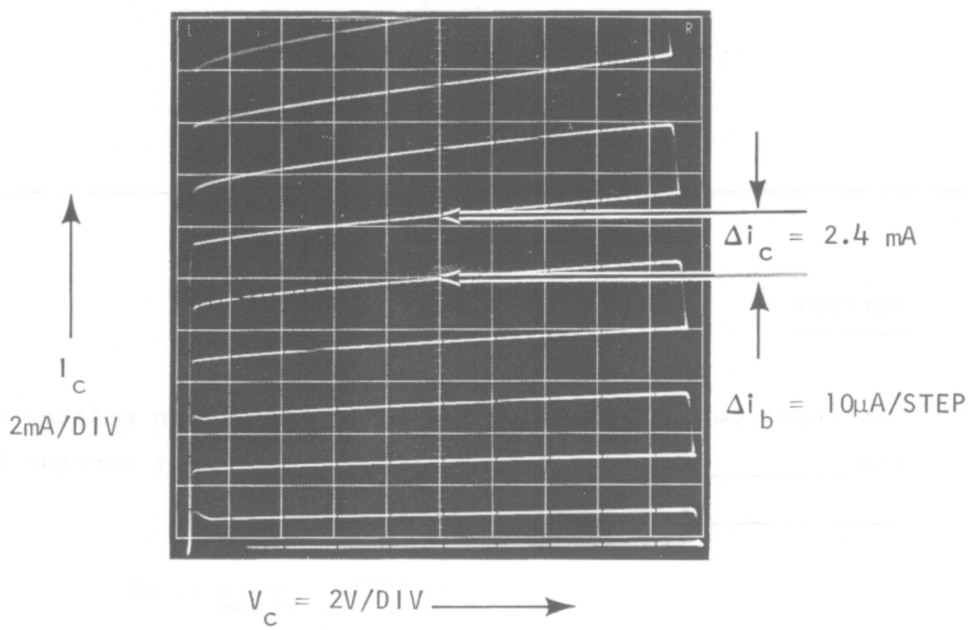


FIGURE 4-1

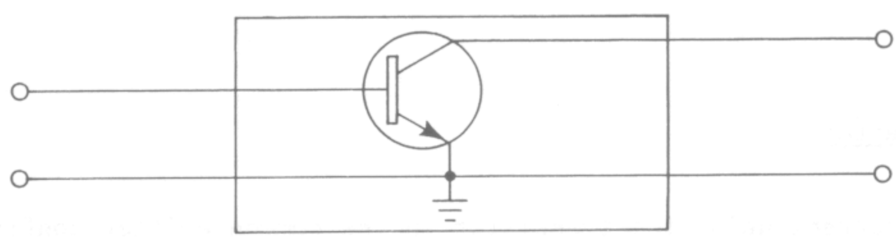


FIGURE 4-2

4.4 In figure 4-1, the characteristic curves for a 2N3053 transistor, a change in base current of 10μA results in a change in collector current of ________A.

2.4 mA

4.5 The h_{fe} of the 2N3053 transistor used for the curves in figure 4-1 is ____________.

$h_{fe} = 240$

4.6 The parameter h_{fe} is often represented by the Greek letter ________.

β

2N3053

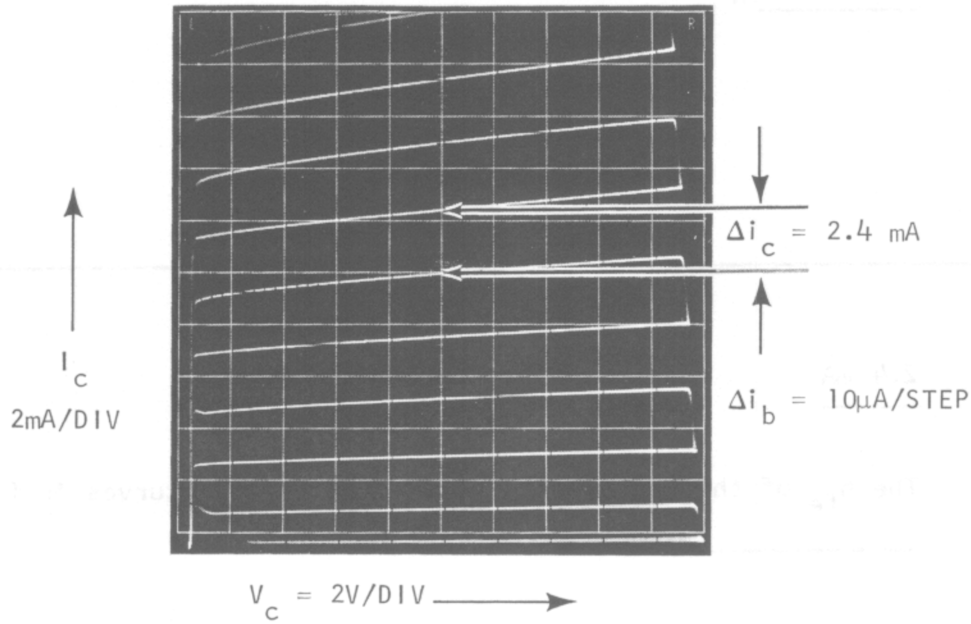


FIGURE 4-1

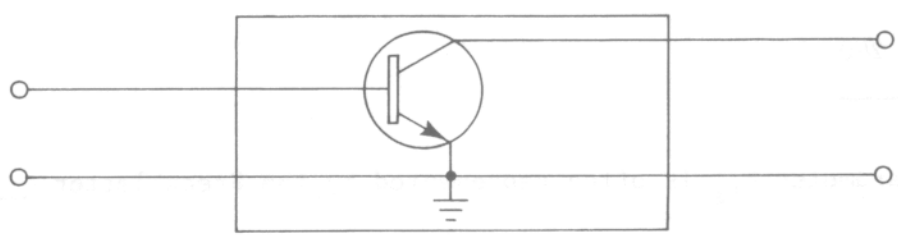
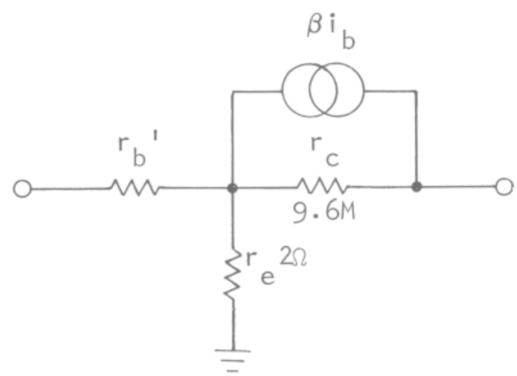


FIGURE 4-2

4.7 In our equivalent circuit, a current generator with a current amplitude of βi_b is used to represent the effects of the parameter __________.



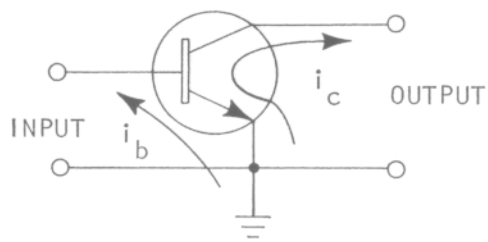
---

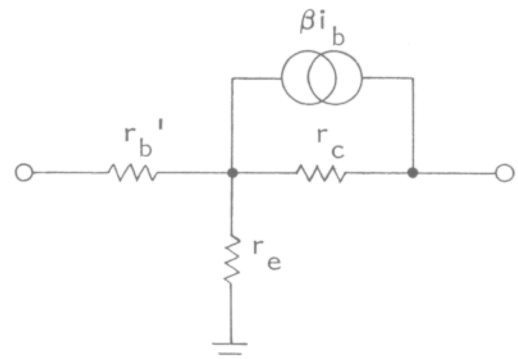
h_{fe}

4.8 The β of the 2N3053 transistor used for the curves in figure 4-1 is __________.

240

4.9 Any current that flows through r_e but does not flow through the current generator (βi_b) will cause an increase in the current through the current generator (βi_b) of β times. That is, if current flow to R_b (the transistor base) from r_e (the transistor emitter) is increased by 1µA, the current from r_e to the current generator (βi_b)(the transistor collector) is increased by _________µa.





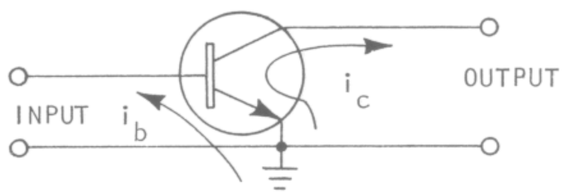
240µA

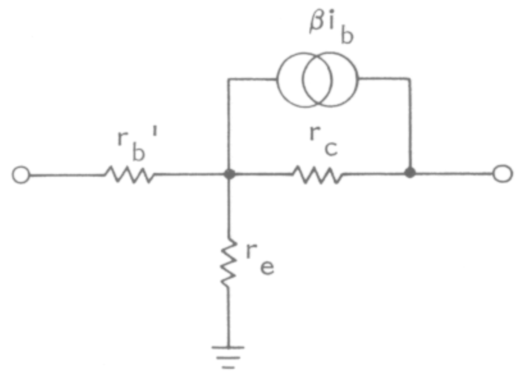
4.10 The majority of the collector current is through the current generator (βi_b) in the equivalent circuit. Only leakage current due to minority carriers flow through _________.

---

r_c

4.11 The emitter current equals the sum of the _______________ current and the _______________ current.





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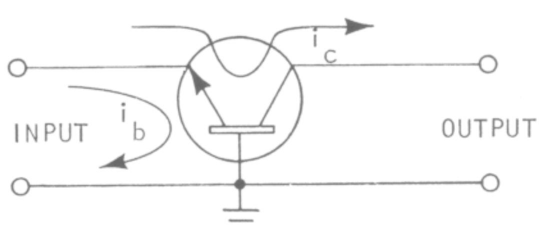
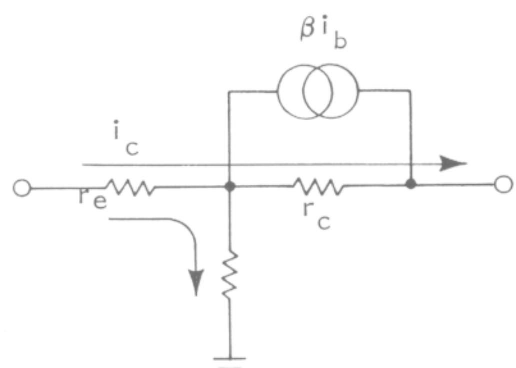
base
<u>collector</u>

4.12 In the common base configuration, the input current is the _______________ current and the output current is the _______________ current.





---

emitter
<u>collector</u>

4.13 In a linear amplifier, collector current is always smaller than __________ current.

---

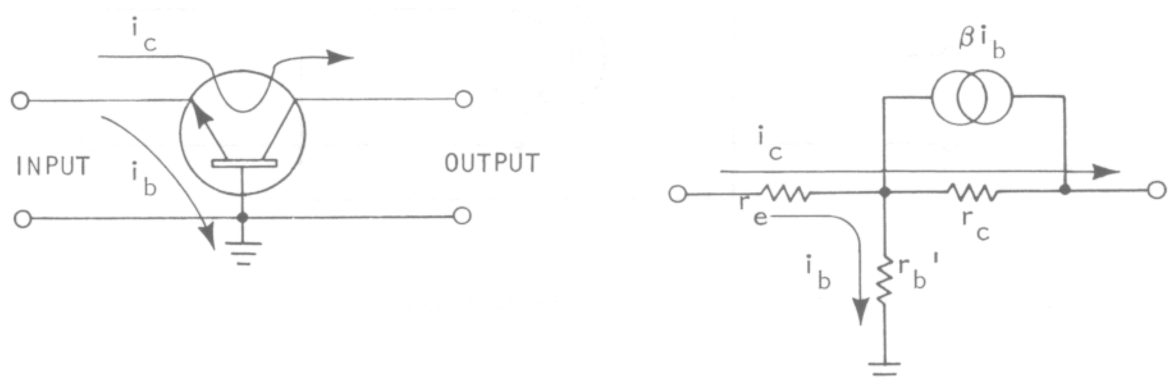
emitter

4.14 In the common base configuration then, output current is smaller than __________ current.

---

input

4.15 From the figures below, we see that βi_b is the __________ current and $\beta i_b + i_b$ is the __________ current.



---

collector, output
emitter, input

2N3053

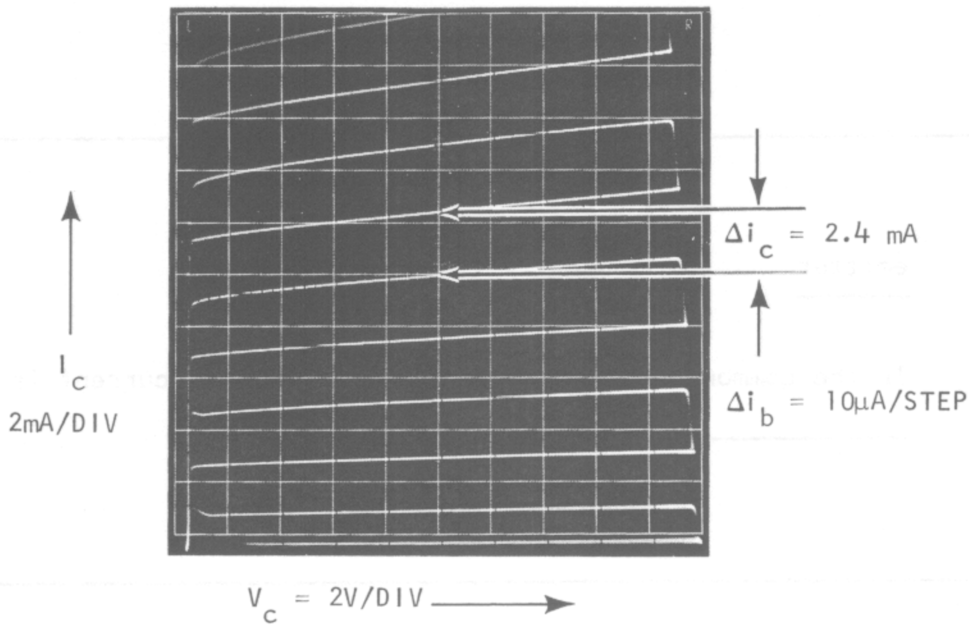


FIGURE 4-1

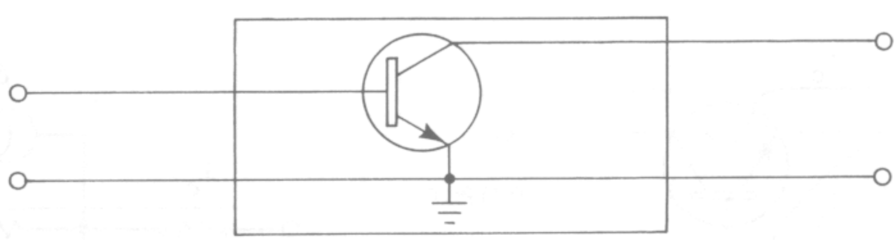


FIGURE 4-2

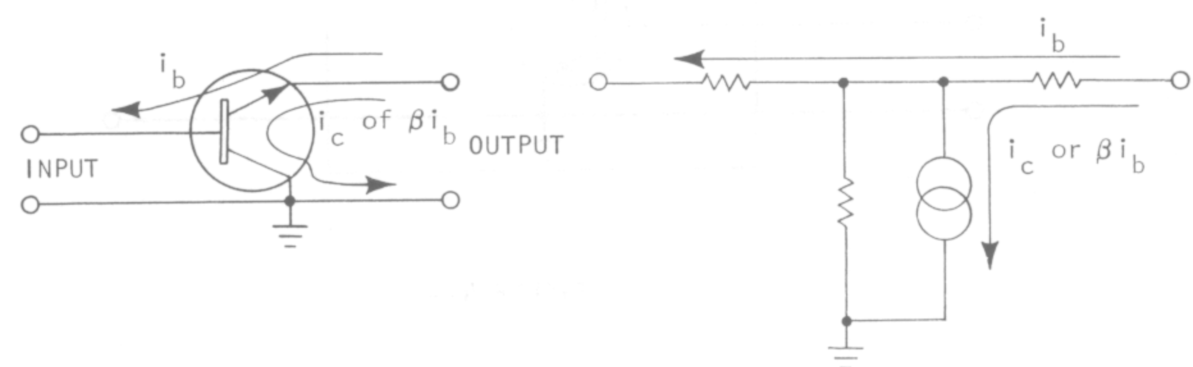
4.16 The formula for current gain for a transistor in the common base configuration is ______________________.

$\dfrac{\beta i_b}{\beta i_b + i_b}$ or $\dfrac{\beta}{\beta + 1}$

4.17 The h_{fb} for the 2N3053 transistor used for the curves in figure 4-1 is ________________.

$\frac{240}{241} \approx .995$

4.18 From the figures below, we can see that in the common collector configuration, i_b is the ________________ current and $\beta i_b + i_b$ is the ______________________ current.



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base, input
emitter, output

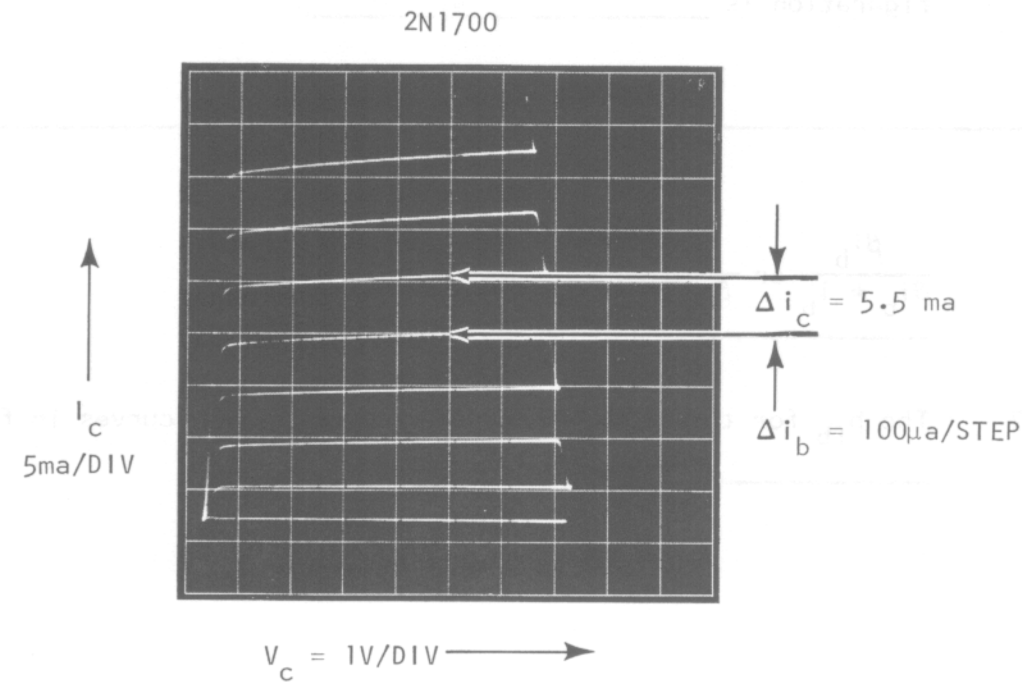


FIGURE 4-3

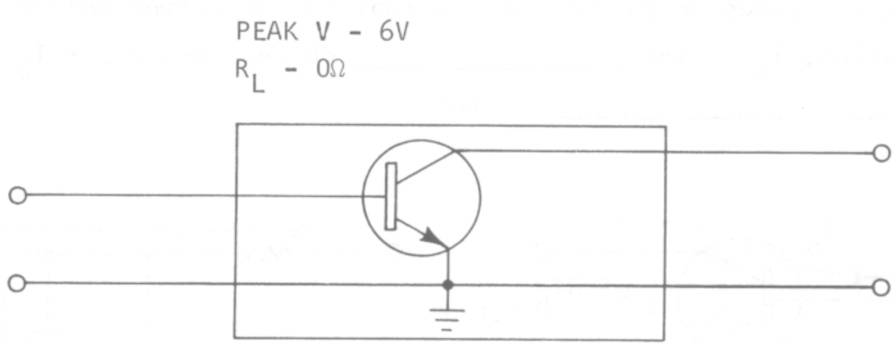


FIGURE 4-4

4.19 The formula for current gain for a transistor in the common collector configuration is ________________.

$$\frac{\beta i_b + i_b}{i_b} = \beta + 1$$

4.20 The h_{fc} for the 2N3053 transistor used for the curves in figure 4-1 is ____________________.

$240 + 1 = 241$

4.21** Determine the h_{fe} for the 2N1700 transistor used for the curves in figure 4-3, then calculate h_{fb} and h_{fc}.

h_{fe} = __________

h_{fb} = __________

h_{fc} = __________

$h_{fe} = 55$

$h_{fb} = .982$

$h_{fc} = 56$

Set 4 Summary

In Set 4, we have discussed the methods for determining the current gain (h_f parameter) of a transistor in any of the three configurations.

In the common emitter configuration, we divided input current (i_b) into output current (i_c) to determine h_{fe} or β. In the common base configuration (h_{fb}), the current gain is determined from β. $h_{fb} = \frac{\beta}{\beta + 1}$. In the common collector configuration (h_{fc}), the current gain is also determined from β. $h_{fc} = \beta + 1$.

The current gain of the transistor in the common emitter or common collector configuration is relatively large. The current gain of a transistor in the common base configuration is always less than one.

We also introduced a current generator into our equivalent circuit that will amplify the current from r_e to R_b by a factor of β.

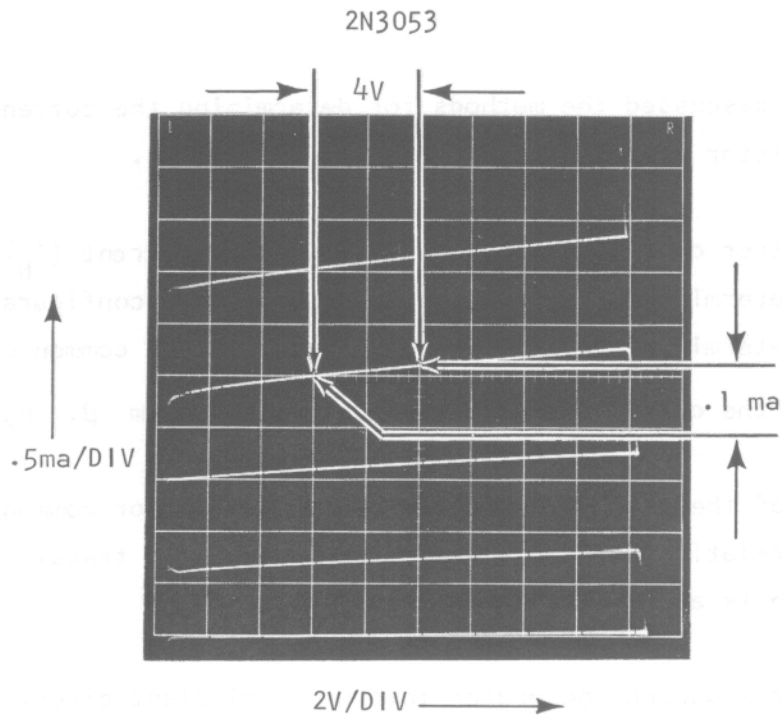


FIGURE 5-1

V = .5ma/DIV

H = 2V/DIV

I_b at point h_{oe} calculated = 20μa

R_L = 0

Peak Volts = 16V

5.0 The h_o parameter is a measure of the transistor ________________ ________________. Determine the h_{oe}, h_{ob}, and h_{oc} of the transistor used for the curves in figure 5-1.

h_{oe} = ________

h_{ob} = ________

h_{oc} = ________

---

output conductance

$h_{oe} = 25\mu℧$

$h_{ob} = .104\mu℧$

$h_{oc} = 25\mu℧$

To determine the output conductance (h_o), a change in the output current is divided by a change in output voltage, while holding the input current constant (AC open circuit).

$$h_o = \left.\frac{\Delta i_o}{\Delta e_o}\right|_{\Delta i_i = 0}$$

The h_o parameters show that the output conductance of the common base configuration (h_{ob}) is much lower than the output conductance of the common emitter (h_{oe}) or common collector (h_{oc}). If we convert conductance to resistance, this means the output resistance of the common base configuration is much higher than either of the other two configurations.

The h_o parameters also indicate that h_{oc} and h_{oe} are equal. But remember the h_{oc} measurement is made with the input (base) circuit an AC open circuit ($\Delta i_i = 0$).

2N3053

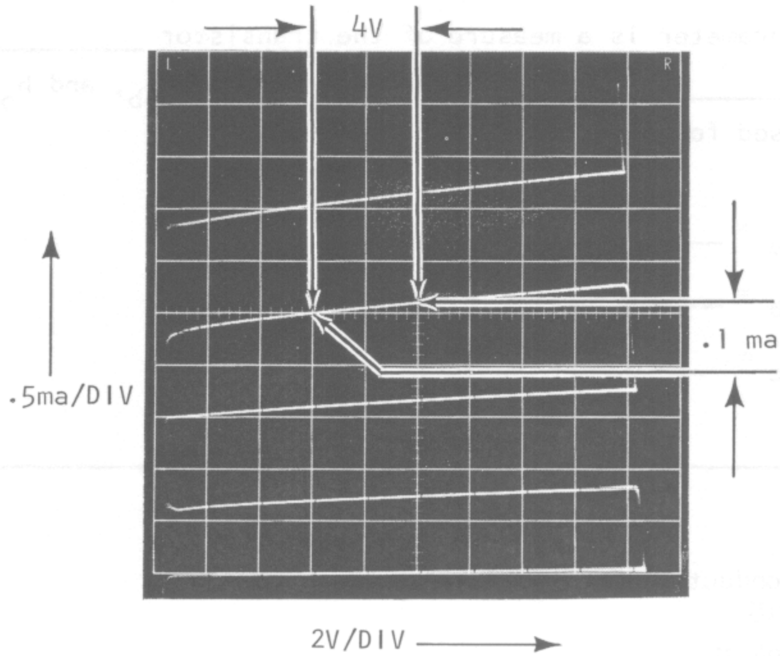


FIGURE 5-1

V = .5ma/DIV

H = 2V/DIV

I_b at point h_{oe} calculated = 20μa

R_L = 0

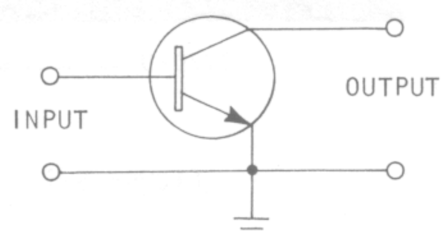
Peak Volts = 16V

5.1 Since the h_o parameter is an output conductance, we must divide the output current by the output ______________.

---

voltage

5.2 When the transistor is in the common emitter configuration, the output current is the ________________ current and the output voltage is the __________________ voltage.



---

collector
collector

5.3 From the curves in figure 5-1, we find that a change in collector voltage of 4V results in a change in collector current of ________A.

.1 mA

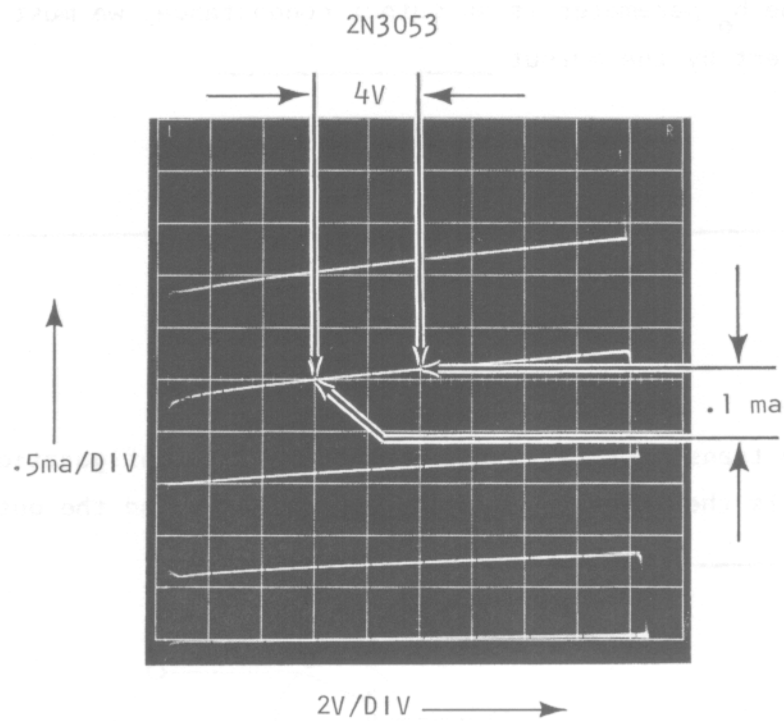


FIGURE 5-1

V = .5ma/DIV

H = 2V/DIV

I_b at point h_{oe} calculated = 20μa

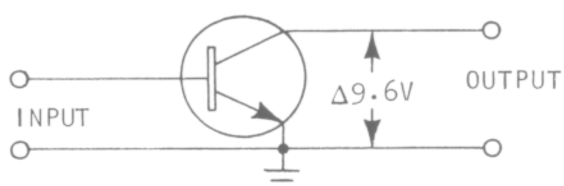
R_L = 0

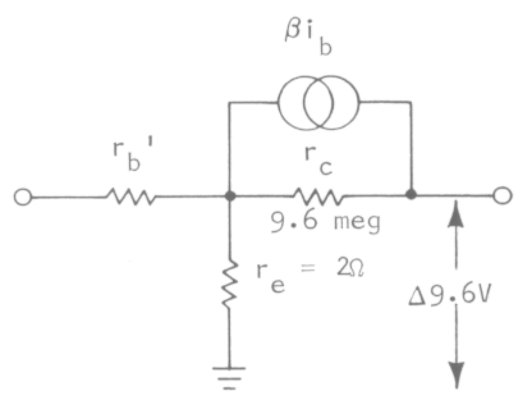
Peak Volts = 16V

5.4 The h_{oe} parameter for the 2N3053 transistor used for the curves in figure 5-1 is ______________.

$h_{oe} = \frac{.1\text{ mA}}{4V} = 25\mu\mho$

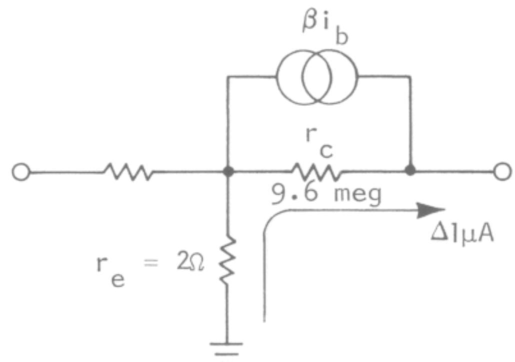
5.5 In our equivalent circuit, a change of 9.6V at the collector will cause the current through r_c to change by __________A.





1μA

5.6 This 1μA change in current through r_c will also occur through _________.



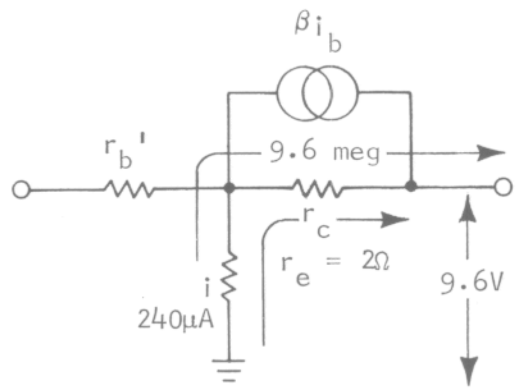
$\underline{r_e}$

5.7 If we gate 1μA of current from the emitter into the base because of r_c, the current through the current generator βi_b will increase by _________A.

NOTE: β for our 2N3053 was 240.

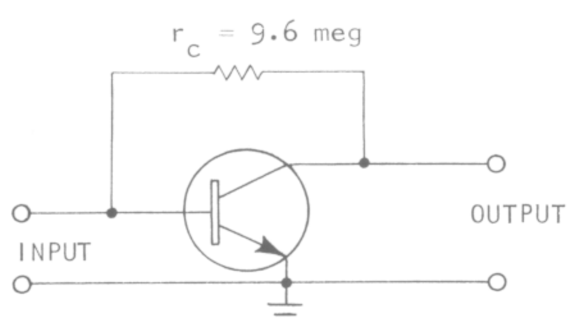
<u>240μA</u>

5.8 A change of 9.6V on the collector and a change of 240μA in collector current indicate an output conductance of __________ ℧.



25μ℧

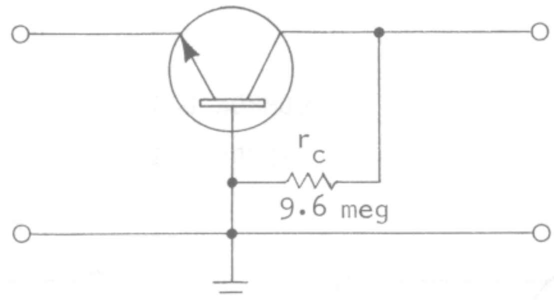
5.9 We can look at r_c as an external resistance connected from the collector to the __________________.



---

base

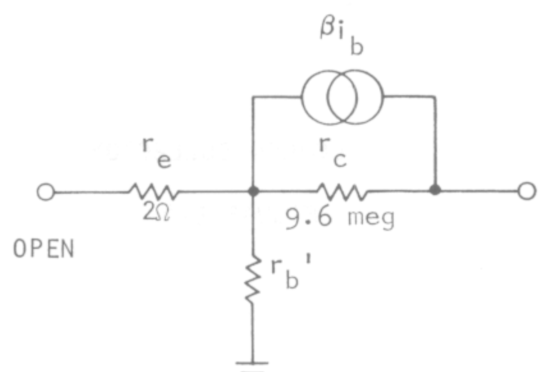
5.10 When the transistor configuration is changed to a common base, the change in current through r_c no longer flows through r_e, but now flows to ________________.



---

ground

5.11 If the change in current does not occur through r_e, the current through the current generator βi_b ________________ change.
(will/will not)



---

will not

COMMON BASE

FIGURE 5-2

COMMON EMITTER

FIGURE 5-3

COMMON COLLECTOR

FIGURE 5-4

5.12 Since the output current changes only $1/\beta$ as much for a given voltage change in the common base as for the common emitter, the output resistance must be ________ times as large.

$\underline{\beta}$

5.13 If output resistance is β times larger in the common base configuration than in the common emitter configuration, the output conductance in the common base must be 1/_____ as large.

$\underline{\beta}$

5.14 The h_{oe} for the 2N3053 transistor used was $25\mu℧$. The h_{fe} was 240. The h_{ob} for this 2N3053 transistor must be ________________________℧.

$$h_{ob} = \frac{h_{oe}}{\beta} = \frac{25 \times 10^{-6}}{240} \approx .104\mu℧$$

5.15 By examining the equivalent circuits on the facing page, we can see that the h_{oc} parameter is determined by the same resistors as the __________ parameter.

$\underline{h_{oe}}$

2N1700

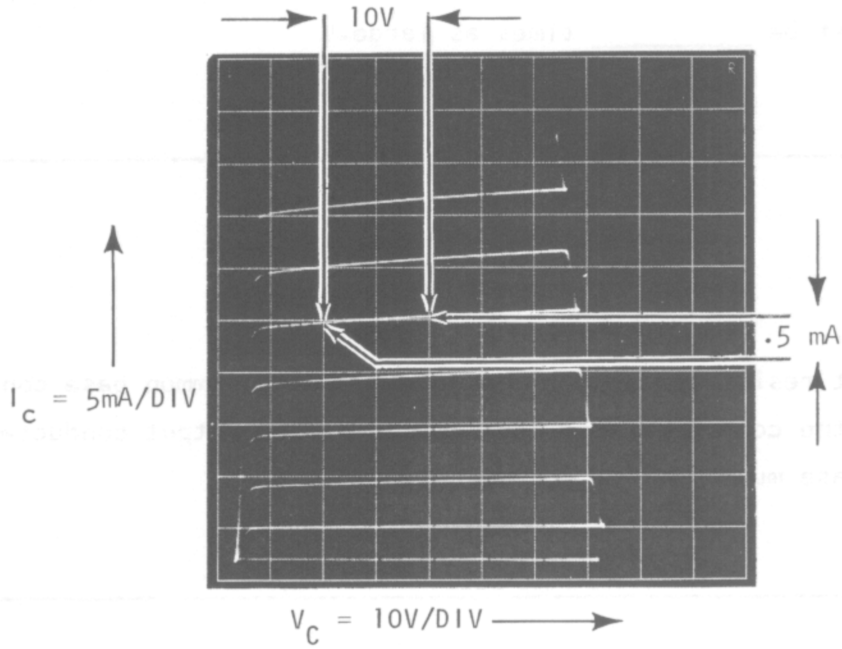
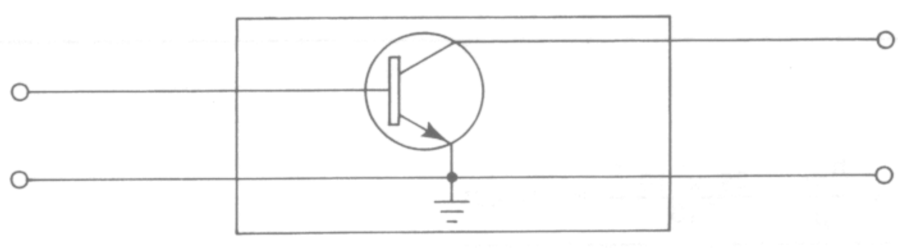


FIGURE 5-5

PEAK V - 30V

R_L - 0Ω



5.16 The h_{oc} for the 2N3053 transistor used is ____________ ℧.

$h_{oc} = 25\mu℧$

5.17** From the curves on the facing page, for a 2N1700 transistor determine h_{oe}, h_{ob}, and h_{oc}. ($\beta = 55$ for the 2N1700.)

$h_{oe} =$ ____________

$h_{ob} =$ ____________

$h_{oc} =$ ____________

$h_{oe} = 50\mu℧$

$h_{ob} = .91\mu℧$

$h_{oc} = 50\mu℧$

Set 5 Summary

In Set 5, we have examined the output conductance parameter (h_o) of a transistor in all of the three configurations. The h_{oe} and h_{oc} parameters are equal, and the h_{ob} is only $1/\beta$ as large. If we invert these figures, we can look at them in more familiar resistance terms. The output resistance of the common emitter configuration and the common collector configuration are equal. The output resistance of the common base configuration is β times as large as the other two.

Remember that the h_o parameters are measured with the input an AC open circuit ($\Delta i_i = 0$). When we discuss circuits, we will see that the output resistance of the common collector configuration is actually very low ($\approx 10\Omega$). This is because a change in input has such a drastic affect on the output of the common collector.

6.0 The h_r parameter is a measure of the ____________ ____________ feedback in a transistor. The h_{rc} for any transistor is ≈ ________. The h_{rb} and h_{re} for any transistor is very ____________.

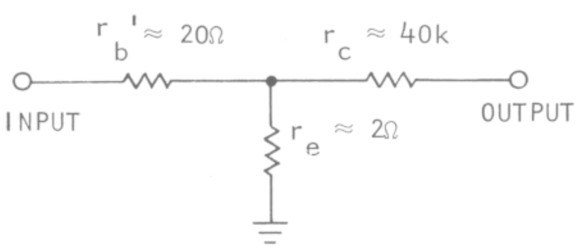
---

reverse voltage
one
small

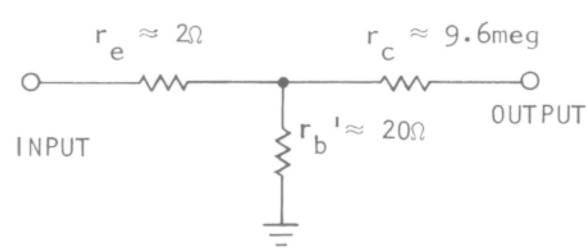
The h_r parameter is the voltage feedback from output to input. To determine the h_r parameter, a change in input voltage is divided by a change in output voltage, while holding the input current constant (AC open circuit).

$$h_r = \left.\frac{\Delta e_i}{\Delta e_o}\right|_{\Delta i_i = 0}$$

The effect of a change in output voltage on the input voltage is very small in the common emitter or the common base configuration. This is because the high value of r_c is between input and output.

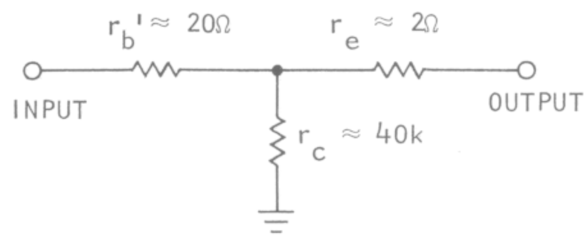


COMMON EMITTER



COMMON BASE

In the common collector configuration, however, there is a low impedance between input and output. For this reason, nearly all the output voltage change is felt at the input, or an $h_{re} \approx 1$.



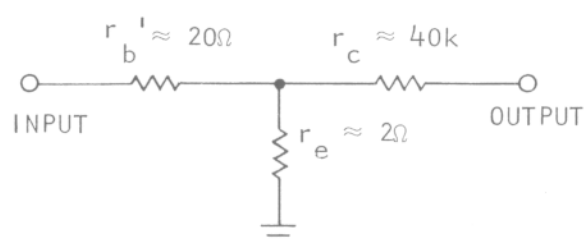
COMMON COLLECTOR

6.1 To determine the h_r parameter, the output voltage is changed and a corresponding change in input voltage is observed. To determine the h_{re} of a transistor, the collector voltage is changed and a corresponding change in ________________ voltage is observed.

---

base

6.2 When we examine the transistor equivalent circuit, we can see that the voltage feedback effect in a transistor in the common emitter configuration (h_{re}) will be very __________________.



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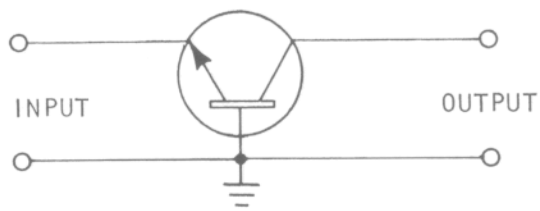
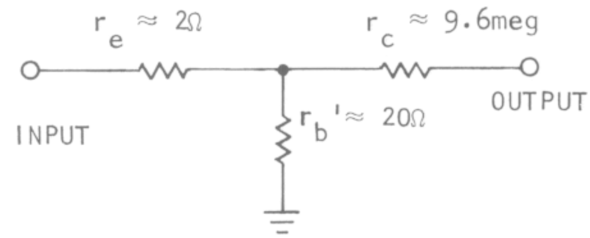
small

6.3 In the common base configuration, the voltage feedback from output to input (h_{rb}) is very ________________.





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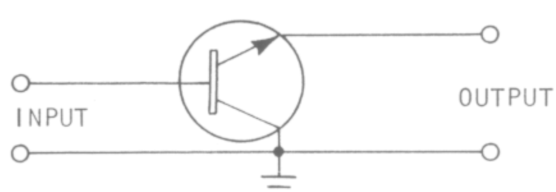
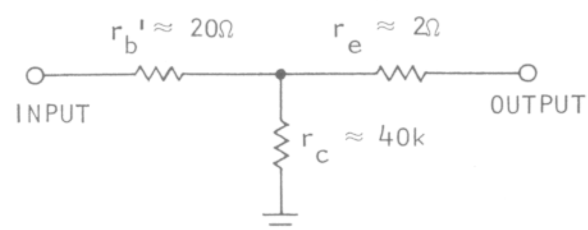
small

6.4 In the common collector configuration, the voltage feedback from output to input (h_{rc}) is very close to ____________.





---

one

6.5 Because of the large impedance between the input and the output, the reverse voltage feedback is very small for the common ________ and the common ________ configurations.

---

base
emitter

6.6** The h_{rc} for a 2N1700 transistor is ≈ ________. The h_{re} and h_{rb} parameters for a 2N1700 are very ________ in value.

---

one (it is ≈ one for any transistor)
small

Set 6 Summary

In Set 6, we have discussed the reverse voltage feedback characteristic (h_r) of a transistor in any of the three configurations. Because of the high impedance between output and input, the reverse voltage feedback is insignificant for a transistor in the common base or common emitter configuration. In the common collector configuration, the reverse voltage feedback is nearly 100%, or an h_{rc} of one.

Set 7 is a review set for the "h" parameters. The h parameters have been presented primarily to give us insight into the performance of the transistor in any of the three configurations.

The input resistance to a transistor in either the common emitter or common collector configuration (h_{ie} or h_{ic}) is usually on the order of a few hundred ohms. However, the input resistance to a transistor in the common base configuration (h_{ib}) is very low, usually less than 10Ω in Tektronix circuits.

The current gain of a transistor in either the common emitter or common collector configuration (h_{fe} or h_{fc}) is dependent on the transistor, usually greater than 20. The current gain of a transistor in the common base configuration (h_{fb}) is always less than one, because the collector current (i_o) is always less than emitter current (i_i). The "h" parameter h_{fe} is also known as beta (β). The h parameter h_{fb} is also known as alpha (α).

The output conductance of a transistor is the same in either the common emitter or common collector configuration. That is $h_{oe} = h_{oc}$. If we invert these parameters from conductance to resistance, we see that the h parameters indicate that the output resistance is the same for a common emitter and a common collector configuration. The output conductance for a transistor in the common base configuration (h_{ob}) is only $1/\beta$ as large as the output conductance for the common emitter or common collector. Converting this to resistance, the h parameters indicate that a transistor in the common base configuration has an output resistance of β times as large as the output resistance of the transistor when in the common emitter or common collector configuration.

The reverse voltage feedback is insignificant for a transistor in the common emitter or common base configuration (h_{re} and h_{rb}). However, in the common collector configuration, the reverse voltage feedback is nearly 100%, or approximately 1.

	h_i	h_f	h_r	h_o
Common Emitter	>100Ω	β	≈0	h_{oe}
Common Base	<10Ω	<1	≈0	h_{oe}/β
Common Collector	>100Ω	$\beta + 1$	≈1	h_{oe}

7.1 The h_{ie} parameter of a transistor is equal to the ________ parameter.

---

h_{ic}

7.2 Compared to the h_{ie} parameter of a transistor, the h_{ib} parameter is very ____________________.

---

small, low, etc.

7.3 The current gain of a transistor in the common base configuration (h_{fb} or α) is always less than __________.

---

one, unity

7.4 The output conductance is smallest for a transistor when it is in the common ____________ configuration.

---

base

7.5 The reverse voltage feedback is greatest when in the common ____________________ configuration.

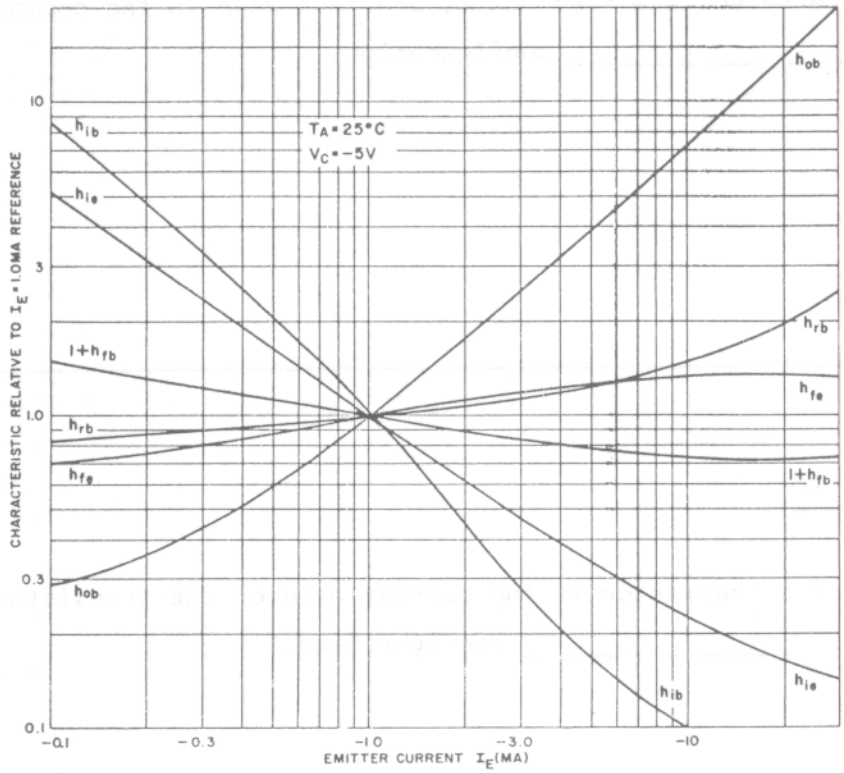
---

collector

7.6** The β of a transistor is the current gain of the transistor in the common ________________ configuration.

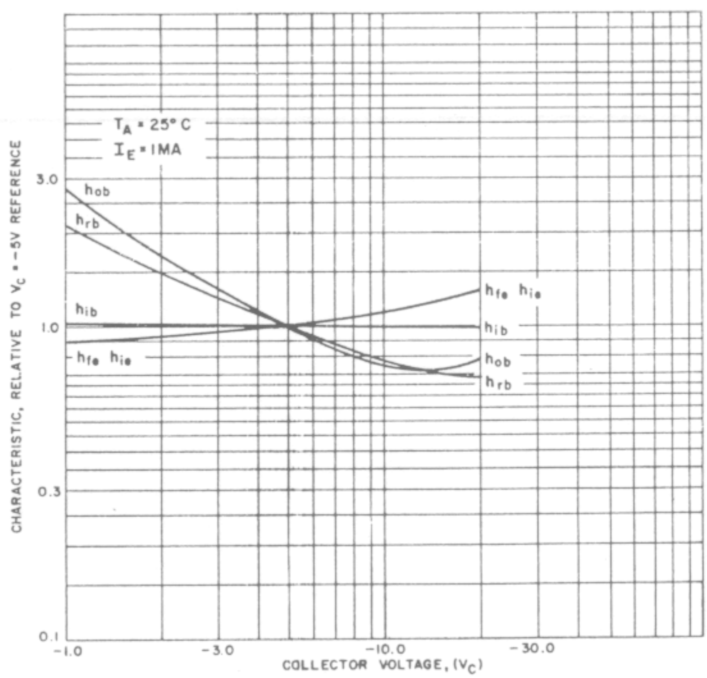
---

emitter



CHARACTERISTICS VS EMITTER CURRENT

FIGURE 8-1



CHARACTERISTICS VS COLLECTOR VOLTAGE

VARIATION OF h-PARAMETERS WITH BIAS CONDITIONS

FIGURE 8-2

Courtesy of General Electric Company, Semiconductor Products Department

8.0 There are three factors that must be specified for a given set of "h" parameters. These three factors are ______________________________, ____________________ current, and ________________________ voltage. A change in any one of these three factors requires a new set of h parameters.

---

temperature
emitter
collector

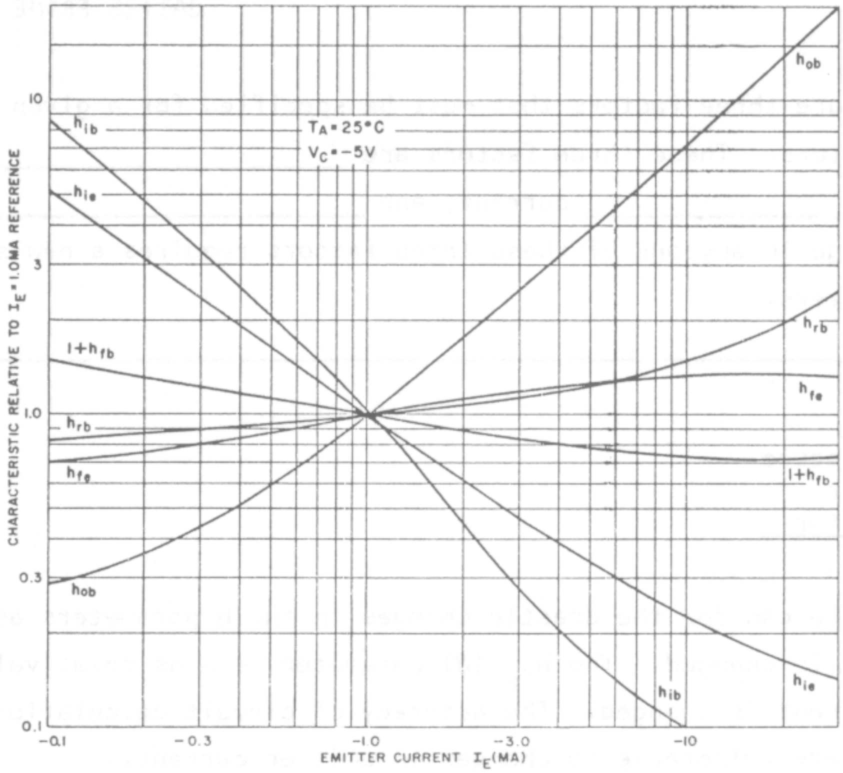
In figure 8-1, we can see the drastic changes in the h parameters as the transistor emitter current is changed. The h_{fe} (β) parameter remains relatively constant as the emitter current is changed. The accuracy of circuit calculations based on h parameters is very vulnerable to changes in emitter current.

In figure 8-2, the changes in h parameters are plotted against changes in collector voltage. The changes are not as drastic here as when emitter current is changed. Again the change in h_{fe} (β) is not too great.

As temperature is increased in a transistor, the minority carriers are greatly increased. This has its greatest effect on the reverse biased collector to base junction. As temperature is increased, more minority carriers are free to flow, making the collector base junction appear as a lower resistance.

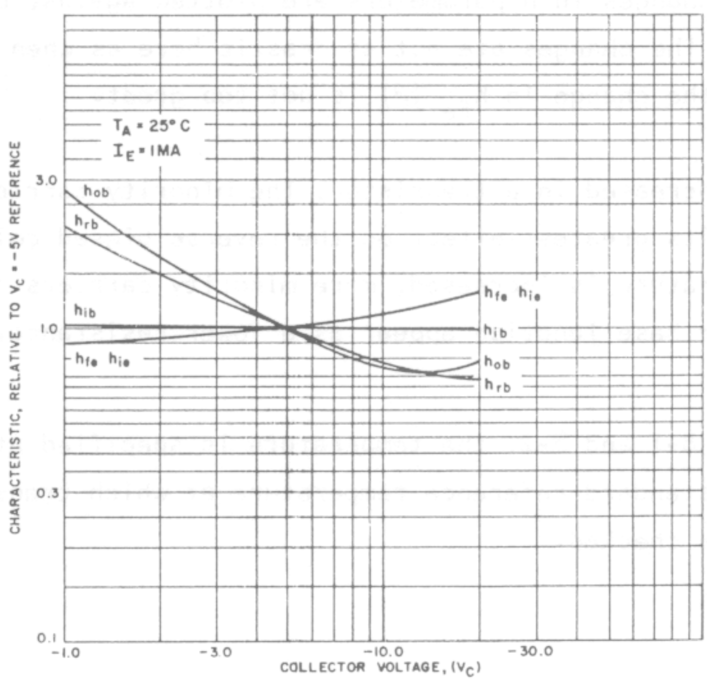
8.1 In figures 8-1 and 8-2, the temperature is specified at _________ °C. This is a standard reference temperature at which transistor parameters are usually checked.

25°C



CHARACTERISTICS VS EMITTER CURRENT

FIGURE 8-1



CHARACTERISTICS VS COLLECTOR VOLTAGE

VARIATION OF h-PARAMETERS WITH BIAS CONDITIONS

FIGURE 8-2

Courtesy of General Electric Company, Semiconductor Products Department

8.2 Figure 8-1 shows a drastic change in some of the h parameters as _______________ _______________ is changed.

---

emitter current

8.3 Compared to the other parameters, h_{fe} (β) _______________ (remains relatively constant, _______________ changes drastically) as emitter current is changed.

---

remains relatively constant

8.4 Figure 8-2 shows that a change in the "h" parameters also occurs as _______________ _______________ is changed.

---

collector voltage

8.5 As collector voltage is changed, _________ again remains relatively constant.

---

h_{fe}

8.6 As temperature changes, the predominant change in the transistor characteristics is the change in leakage current through the collector-base junction. As temperature increases, the collector resistance $(\frac{1}{h_{ob}})$ ____________________.
(increases/decreases)

---

decrease

8.7** The three factors that must be specified for a given set of "h" parameters are ___________________________, ______________________ current, and ___________________________ voltage.

---

temperature
emitter
collector

"h" parameters give us insight into the operation of transistors. They help us to relate the operation of the transistor to a particular circuit. However, as we have seen in Set 8, h parameters are very elusive as either temperature, emitter current, or collector voltage is changed. Due to this, calculations based on h parameters are <u>not</u> extremely accurate. It is possible to make calculations in transistor circuits that are much simpler than the calculations based on h parameters. The next nine sets will discuss methods of circuit analysis in which we are concerned only with the h_{fe} (β) parameter.

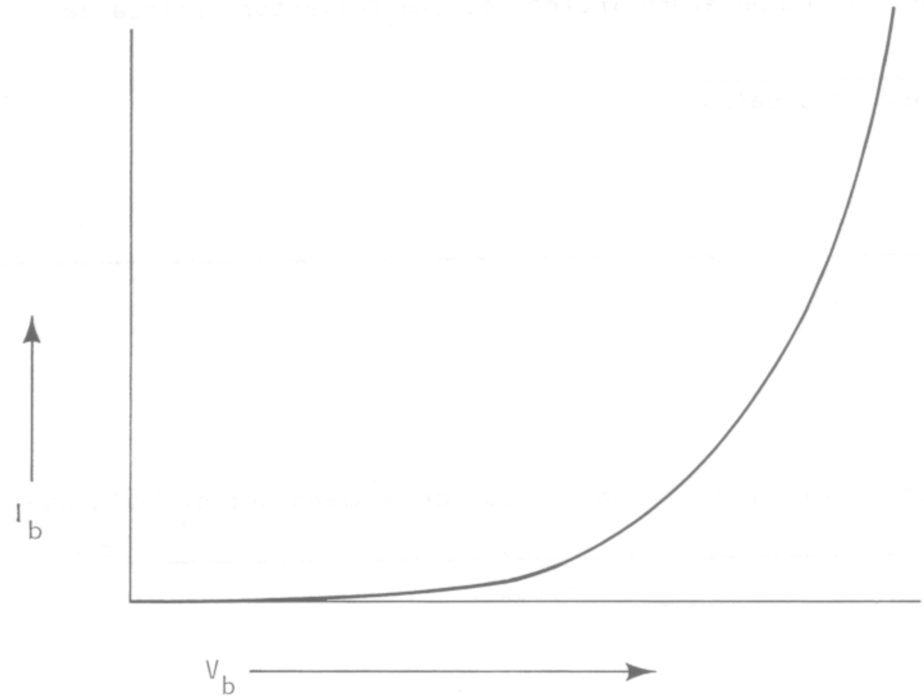


FIGURE 9-1

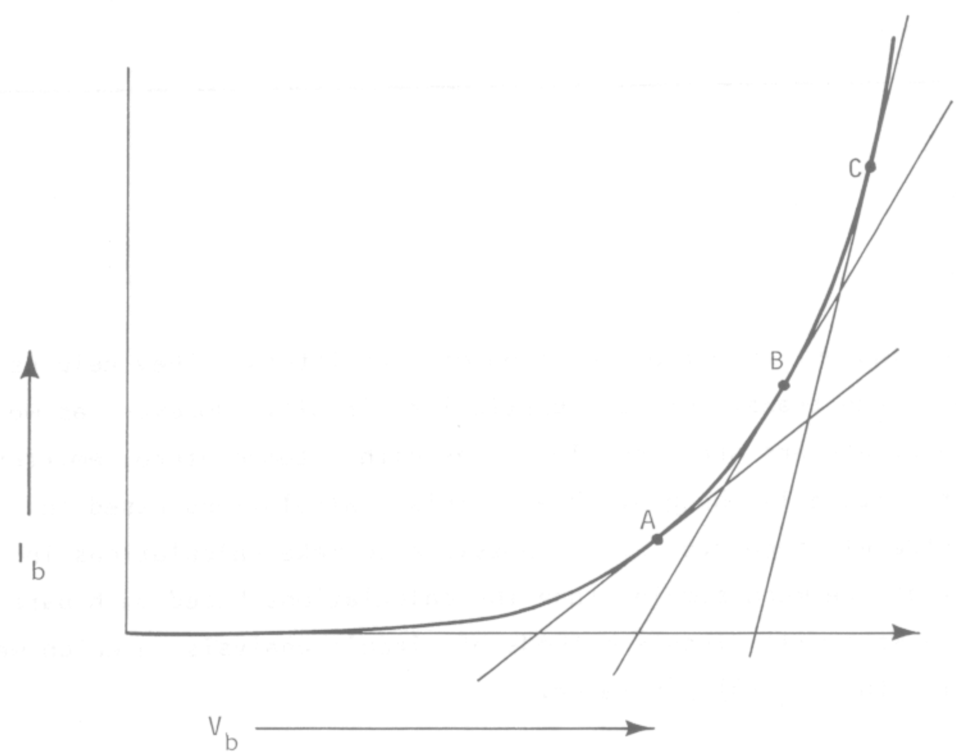
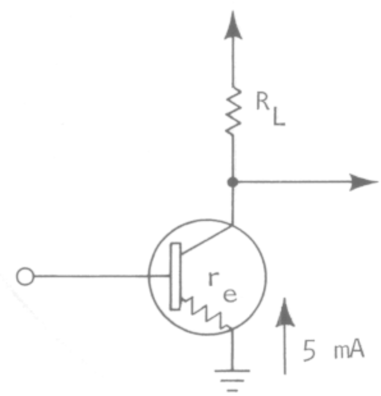


FIGURE 9-2

9.0 The approximate r_e of the transistor in the circuit below is ________Ω.

NOTE: r_e is the small signal AC emitter resistance.



$r_e = 5.2\Omega$

Figure 9-1 shows a typical forward biased junction curve. In a transistor, the forward biased junction is the emitter base junction. As the DC current through the junction increases, the slope of the curve increases. This is shown in figure 9-2 with the tangent lines at points A, B, and C. The slope of the curve at a given point indicates the AC resistance of the junction at that point. The AC emitter resistance decreases as the DC current through the junction increases. The AC emitter resistance of a transistor is approximated by the formula

$$r_e = \frac{26\ (mV)}{I_E(mA)}$$

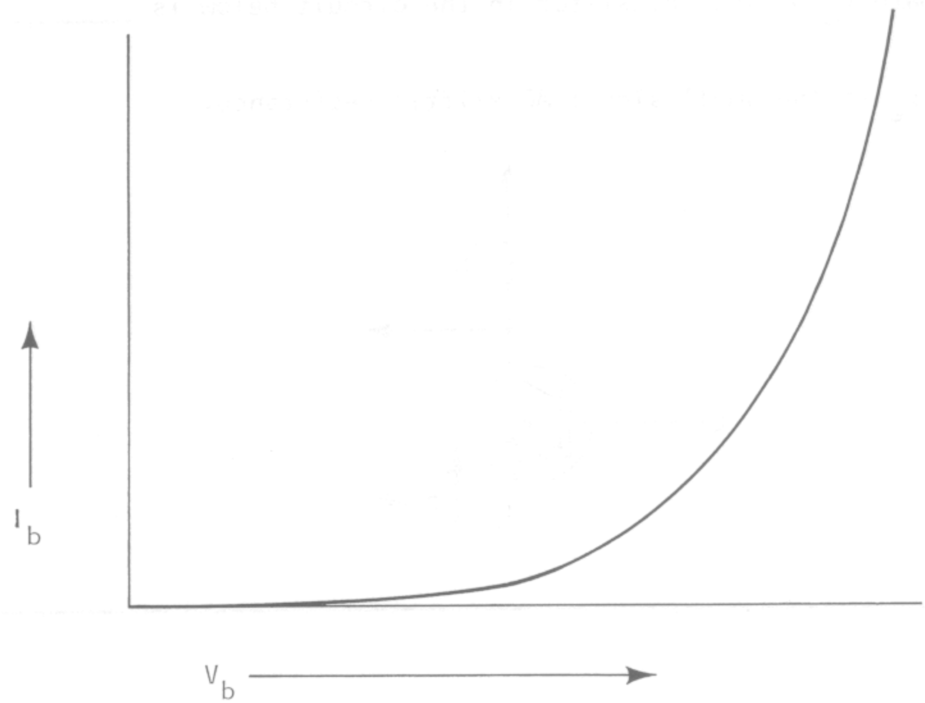


FIGURE 9-1

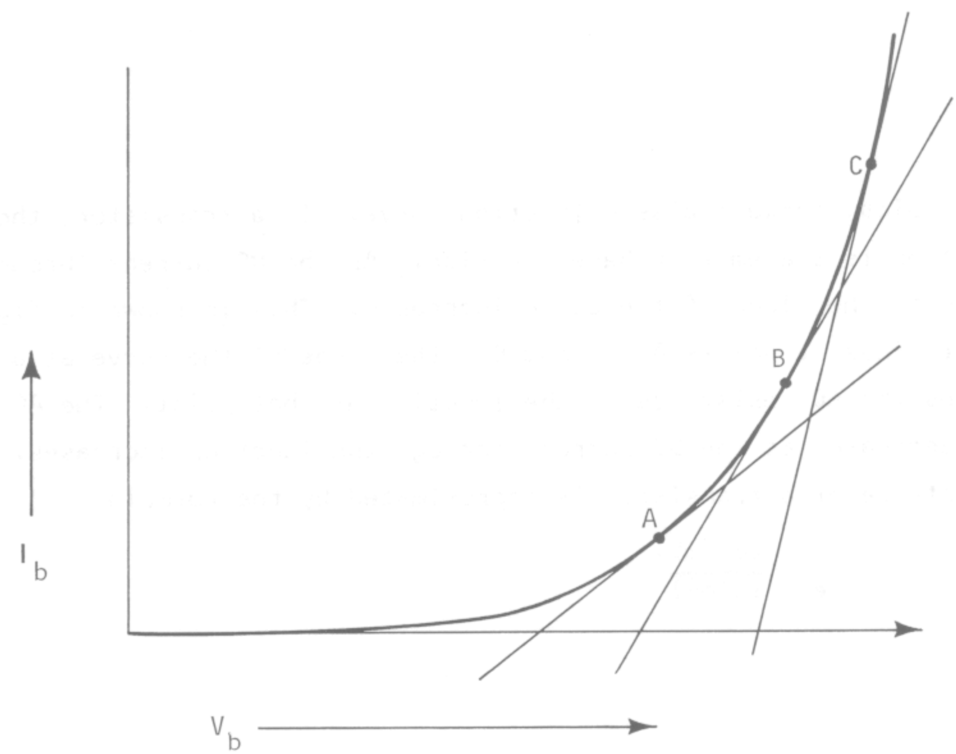


FIGURE 9-2

9.1 The curve in figure 9-1 shows the current, voltage relationship of a forward biased junction. The forward biased junction in a transistor is the ____________________ to ________________ junction.

---

emitter
base

9.2 The slope of the curve becomes steeper as the DC current through the junction ____________________.
(increases/decreases)

---

increases

9.3 The AC emitter resistance is indicated by the ________________ of the curve.

---

slope

9.4 Of the points A, B, and C in figure 9-2, the AC resistance is greatest at point __________.

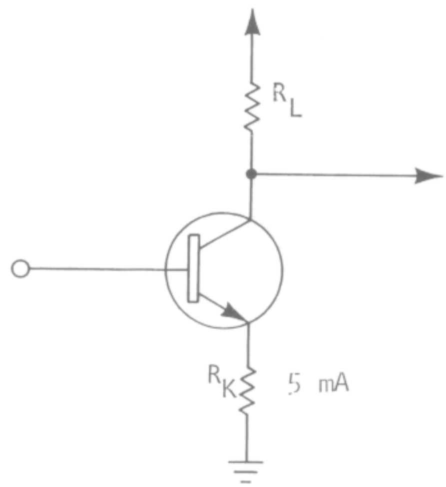
A

9.5 The relationship between DC current through the junction and the AC emitter resistance is approximated by the formula $r_e = \frac{26}{I_E}$.

r_e = emitter resistance

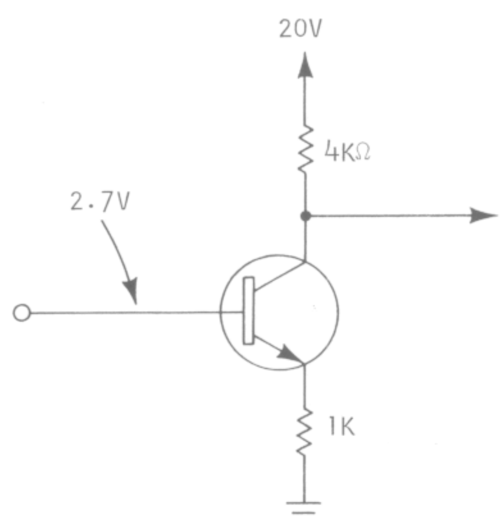
I_E = DC current through junction in mA

Determine r_e in the circuit below.



$r_e = \frac{26}{I_E} = \frac{26}{5} = 5.2\Omega$

9.6 The approximate r_e of the transistor in the circuit below is ________Ω.



$I_E = \frac{2V}{1k\Omega} = 2$ mA

$r_e = \frac{26}{2} = 13\Omega$

Set 9 Summary

In Set 9, we have said that the AC emitter resistance is dependent on the DC emitter current. The relationship between the AC emitter resistance and the DC emitter current is approximated by the formula

$$r_e = \frac{26}{I_E(mA)}$$

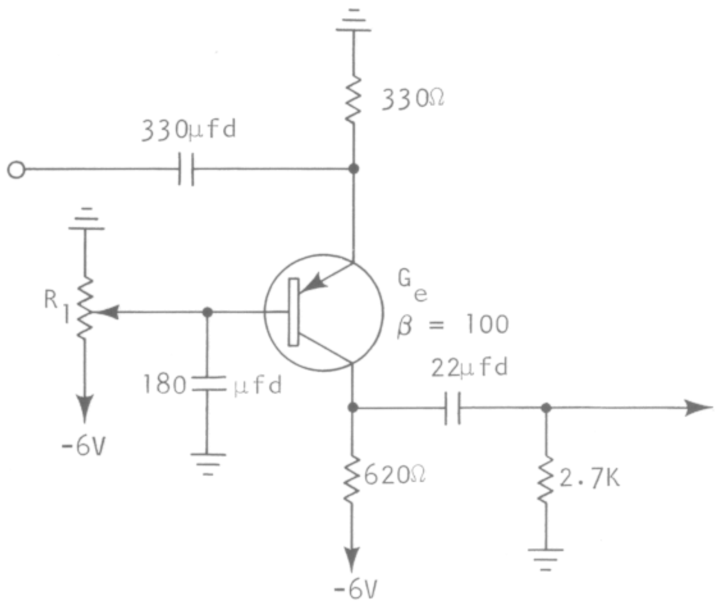


FIGURE 10-1

10.0 R_1 in figure 10-1 is adjusted for a 10Ω input resistance. The voltage at the base of the transistor is ________V. The r_o (output resistance) is ________Ω.

-1.16V
500Ω

The circuit in figure 10-1 is a practical application of using the emitter current to control the emitter resistance. The emitter resistance is the input resistance to the circuit. The transistor in figure 10-1 is in the common base configuration. In the h parameters, we said that a transistor in the common base configuration has a very high output resistance ($\frac{1}{h_{ob}}$). The transistor output resistance is large enough to ignore, and the r_o (output resistance) of the circuit in figure 10-1 is the parallel combination of the 2.7kΩ and the 620Ω resistors.

10.1 If the emitter resistance (r_e) in figure 10-1 is 10Ω, I_E in the transistor must be ________A.

$r_e = \frac{26}{I_E}$ or $I_E = \frac{26}{r_e} = 2.6$ mA

10.2 2.6 mA through a 330Ω resistor would develop ________V.

330Ω x 2.6 mA = .858V or .86V

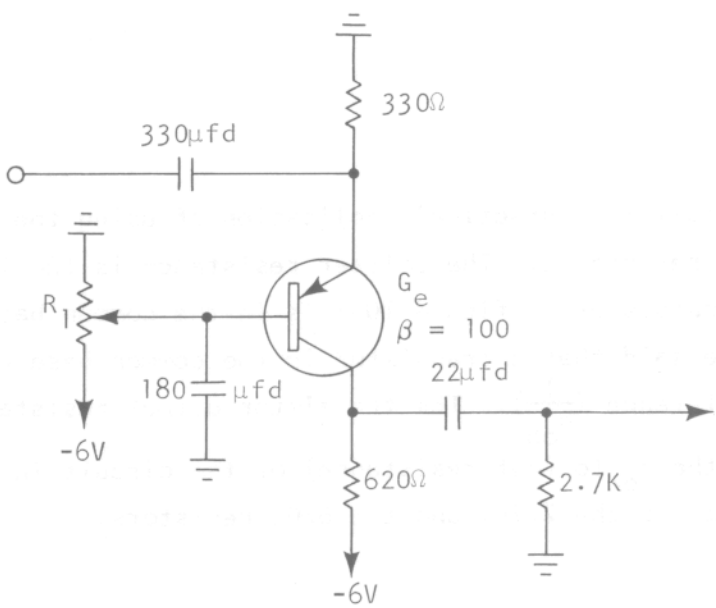


FIGURE 10-1

10.3 Because the transistor in figure 10-1 is germanium, the base is approximately _________V negative with respect to the emitter.

.3V

10.4 The quiescent voltage at the base would be the voltage across the 330Ω resistor plus the emitter to base voltage, or _________V.

-1.16V

10.5 The output resistance of a transistor in the common base configuration is very _________ (high/low).

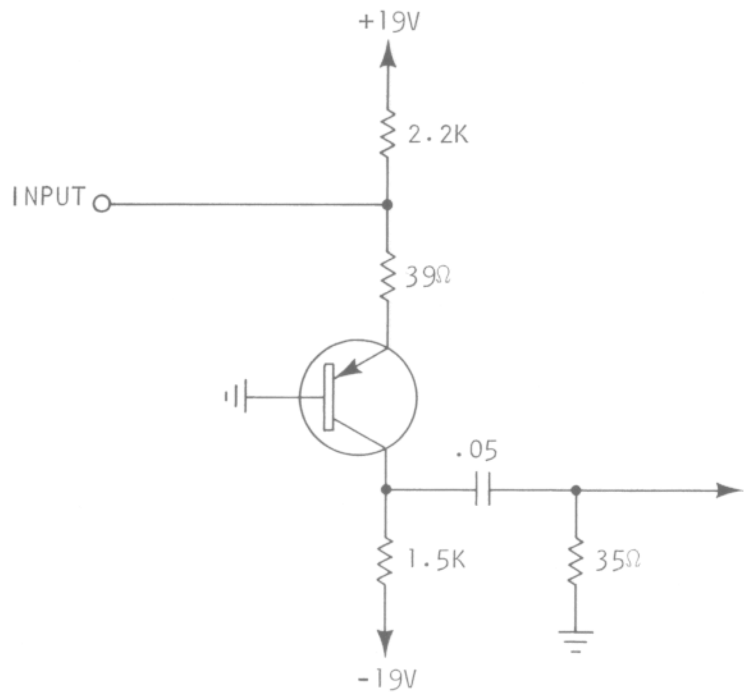
---

high (usually greater than 1 megΩ

10.6 The output resistance of the transistor can then be ignored. The r_o (output resistance) of the circuit is the parallel combination of the 620Ω and 2.7kΩ resistors. r_o = _________Ω.

500Ω

10.7** Determine the r_i (input resistance) and r_o (output resistance) of the circuit below:



$$r_i = r_e + 39\Omega = 3\Omega + 39\Omega = 42\Omega$$

$$r_e = \frac{26}{I_E(mA)} = \frac{26}{8.65} \approx 3\Omega$$

$$r_o \approx 35\Omega$$

Set 10 Summary

In Set 10, we have seen a practical application of controlling the AC resistance of the emitter by controlling the DC current through the junction. We have also established that, due to the high output resistance of a transistor in the common base configuration, the r_o of the circuit can usually be considered equal to the collector load resistance.

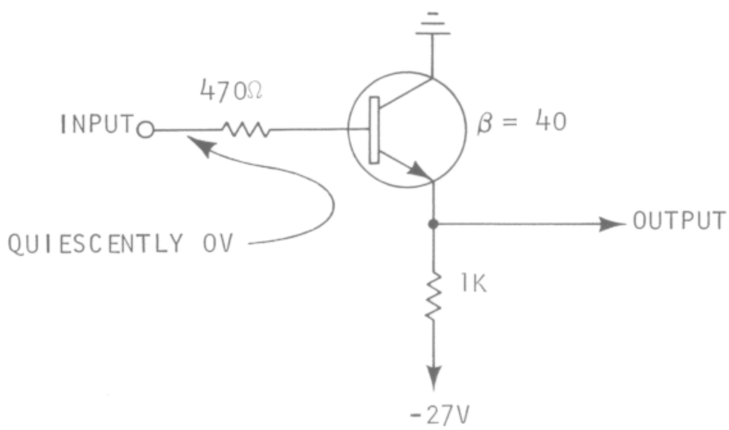


FIGURE 11-1

11.0 Determine the r_i (input resistance) and r_o (output resistance) for the circuit in figure 11-1.

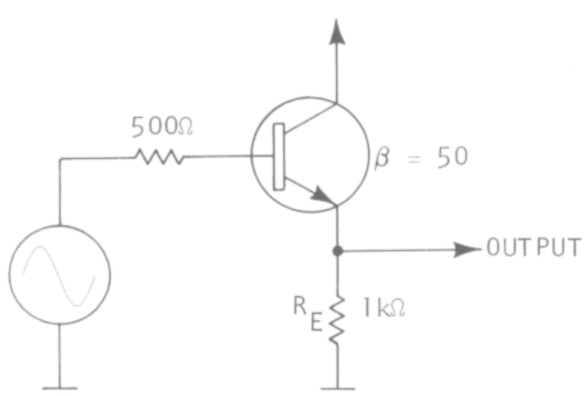
r_i = __________Ω

r_o = __________Ω

$r_i = 40.47k\Omega$

$r_o = 13\Omega$

To determine the input resistance to a transistor in the common collector configuration, we must remember that only $1/\beta$ of the emitter current will flow in the base. If we increase the voltage at the base in the circuit below by 1V, the emitter current will increase by 1 mA ($\frac{1V}{1k\Omega} = 1$ mA). The base current, however, will increase by only 1/50 of 1 mA, or 20µA. The r_i (input resistance), looking into the base, would then be 1V/20µA = 50kΩ, or $\beta \times R_E$. ($r_i = \beta \times r_e$ is true only if R_E is large compared to r_e. If not, the formula is expanded to $r_i = \beta(R_E + r_e)$. In the circuit below, input also has a 500Ω resistor in series for a total r_i of 50.5kΩ.



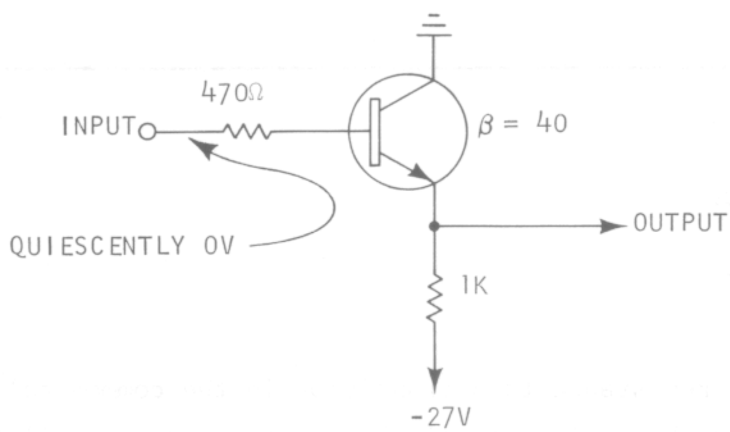
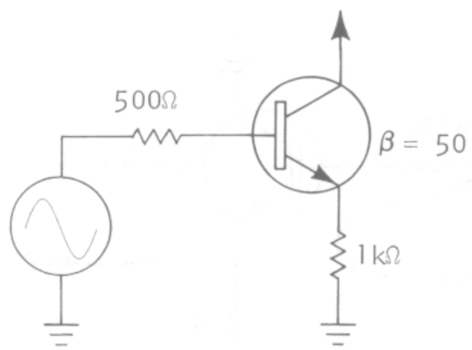


FIGURE 11-1

In a common collector transistor circuit, the base circuit is a low resistance when seen from the emitter of the transistor. The base circuit controls the emitter current, but only $1/\beta$ of the emitter current flows to the base circuit. The resistance of the base circuit, therefore, is only $1/\beta$ as large as its actual value when seen from the emitter. Example: The base circuit resistance seen from the emitter in the circuit below is 10Ω. $(\frac{500\Omega}{50\Omega} = 10\Omega)$



This 10Ω is in series with r_e. Looking into the emitter from the output of the circuit then, we would see 15Ω if r_e were equal to 5Ω. This 15Ω is in parallel with R_E (1kΩ). The circuit has an r_o of approximately 15Ω.

11.1 A 1V change in the base voltage of figure 11-1 will produce a ________ mA change in emitter current.

NOTE: The value of r_e is 1.3Ω. Because R_E is 1K, this 1.3Ω can be ignored.

≈ 1 mA

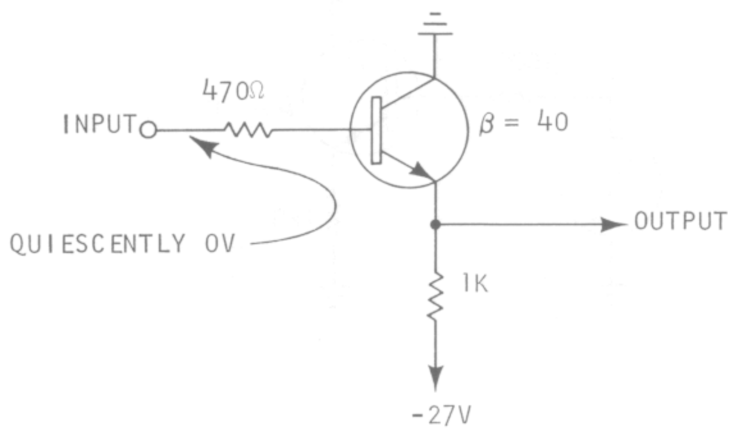


FIGURE 11-1

11.2 With a β (current gain) of 40, and a 1 mA change in emitter current, there will be a ________ μA change in base current.

$i_b = 25\mu A$

11.3 If the transistor is in the common collector configuration, the resistance seen from the base to ground will be approximately equal to the h parameter, ______, times the emitter resistance.

β

11.4 From Ohm's law, we can establish the input resistance, as seen from the base, to be ________Ω.

$\frac{1V}{25\mu A} = 40k\Omega$

11.5 The input resistance of the circuit in figure 11-1 will be R_B (470Ω) plus ________Ω for a total r_i of ________kΩ.

40kΩ
40.47kΩ

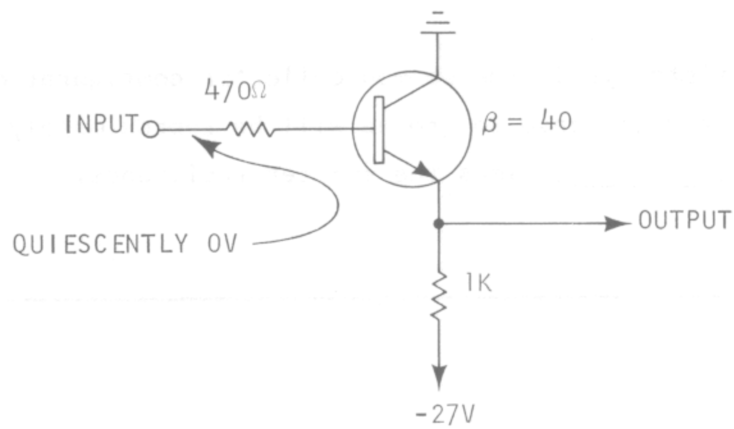


FIGURE 11-1

11.6 The output, looking back into the circuit in figure 11-1, will see R_E (1kΩ) in shunt with the resistance looking into the ____________ of the transistor.

---

emitter

11.7 The resistance looking into the emitter of the transistor is

$$r_e + \frac{R_B}{\beta}$$

No answer needed

11.8 Because only $1/\beta$ of the emitter current will flow through it, the resistance of the ____________ circuit will be divided by β.

---

base

11.9 The resistance looking into the emitter is ____________Ω.

$$r_e + \frac{R_B}{\beta} = 1.3 + \frac{470}{40} \approx 13\Omega$$

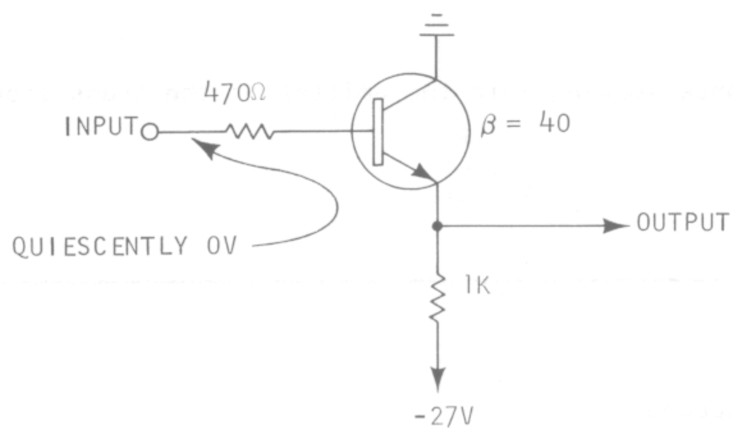


FIGURE 11-1

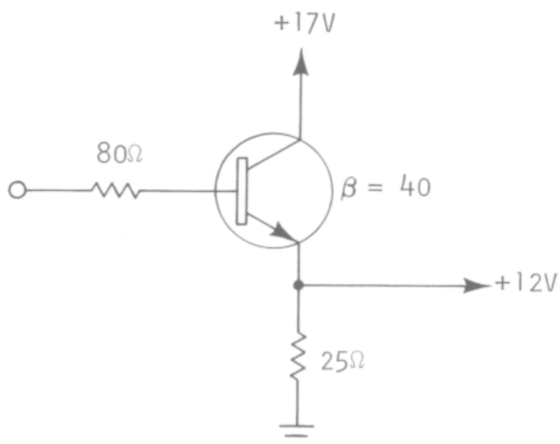
11.10 The resistance of the circuit in figure 11-1, looking in from the output, is ________Ω.

≈ 13Ω

11.11** Determine the r_i and r_o of the circuit below.

r_i = ________Ω

r_o = ________Ω



---

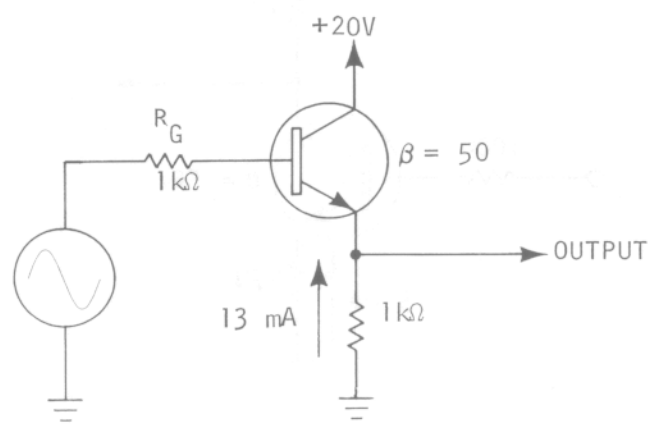
r_i = 1,080Ω

$r_o \approx 2\Omega$ $(\frac{80\Omega}{40} = 2\Omega)$

Set 11 Summary

In Set 11, we have established that the input resistance to a common collector circuit is approximately $\beta \times R_E$ plus any base resistance (R_B). The value of r_e is usually insignificant compared to R_E. The output resistance of a common collector circuit is usually very low. r_o is dependent, however, on the resistance of the circuit driving the base. The resistance in the base circuit is divided by β when seen from the emitter or output of the common collector.

Example:



$$r_o = r_e + \frac{R_G}{\beta} = 2 + \frac{1000}{50} = 22\Omega$$

If R_G is doubled, $r_o = 2 + \frac{2000}{50} = 42\Omega$

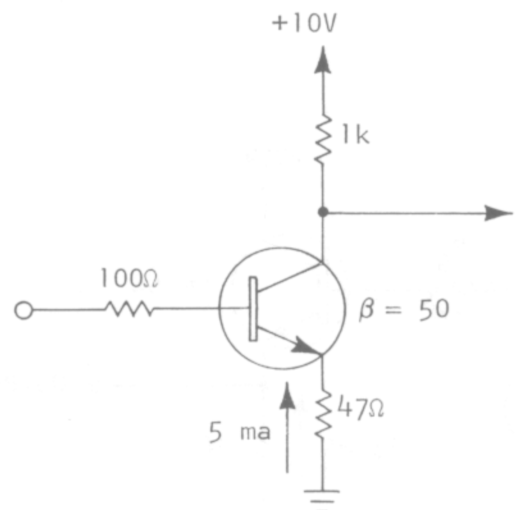


FIGURE 12-1

12.0 Determine the r_i and r_o for the circuit in figure 12-1.

r_i = ________Ω

r_o = ________Ω

$r_i = \beta(R_E + r_e) + 100\Omega = 50\ (47 + 5.2) + 100\Omega = 2.71k$

$r_o \approx 1k\Omega$

The r_i (input resistance) to a transistor in the common emitter configuration is determined in the same way as the r_i to a transistor in the common collector configuration. That is, $r_i = \beta(R_E + r_e)$.

The r_o (output resistance) to a transistor in the common emitter configuration is usually the value of R_L because the collector resistance $(\frac{1}{h_{oe}})$ is usually much larger. However, if R_L gets much larger than 1kΩ, the collector resistance may have to be considered. The exact value of collector resistance would have to be empirically derived because it is dependent on the impedance of the base circuit. As base circuit resistance decreases, the collector resistance in the common emitter configuration approaches $\frac{1}{h_{ob}}$. However, for our general rule of thumb, r_o will equal R_L.

12.1 The value of r_e for the transistor in figure 12-1 is ________Ω.

$r_e = \frac{26}{I_E(mA)} = \frac{26}{5} = 5.2\Omega$

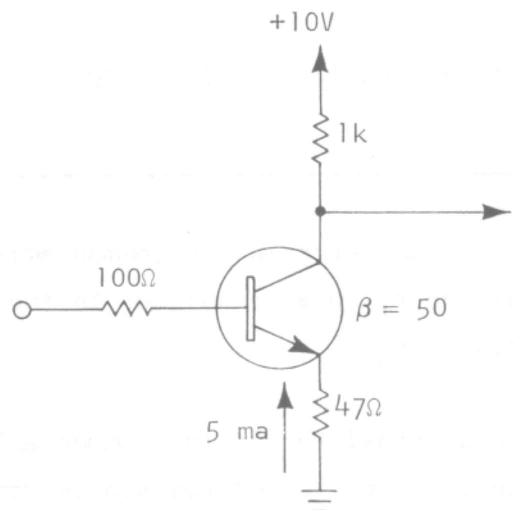


FIGURE 12-1

12.2 The total emitter resistance of the transistor in figure 12-1 is ________Ω.

$R_E + r_e = 47 + 5.2 = 52.2\Omega$

12.3 Because only $1/\beta$ of the emitter current flows into the base, the value of the total emitter resistance, looking in from the base, is ________ X emitter resistance, or ________Ω.

β, 50
2.61kΩ

12.4 The input resistance to the circuit in figure 12-1 is:

$$r_i = R_B + \beta(r_e + R_E) = \_\_\_\_\_\_\_\_\Omega$$

$r_i = 2.71\text{k}\Omega$

12.5 When compared to an R_L of 1kΩ, the output resistance of a transistor in the common emitter configuration is ________.
(high/low)

---

high

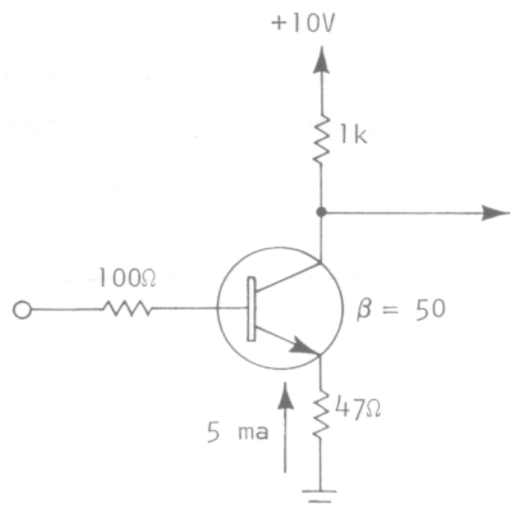


FIGURE 12-1

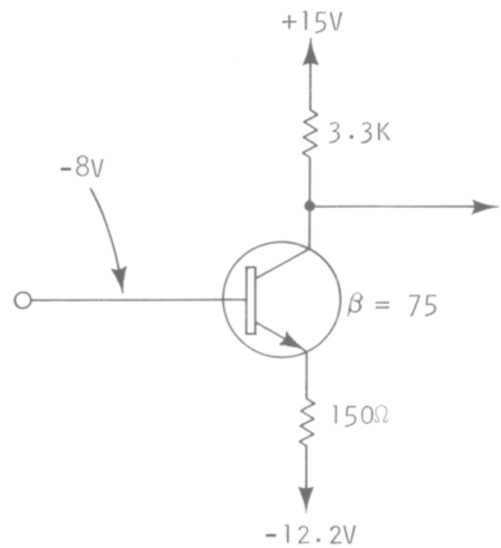
12.6 The output resistance (r_o) of the circuit in figure 12-1 is the collector load resistance of ≈ ________Ω.

$r_o \approx 1k\Omega$

12.7** Determine r_i and r_o in the circuit below.

r_i = ________Ω

r_o = ________Ω



$r_i \approx 11.25k\Omega$ (excluding r_e)

$\approx 11.3k\Omega$ (including r_e)

$r_o \approx 3.3k\Omega$

Set 12 Summary

In Set 12, we have determined that the input resistance (r_i) to a common emitter transistor circuit is approximately β X the emitter resistance, plus any base resistance (R_B). The same method of determining input resistance is used for the common emitter circuit and the common collector circuit.

The output resistance (r_o) of a common emitter transistor circuit is usually R_L. However, if R_L is much greater than 1kΩ, the output resistance of the transistor ($\frac{1}{h_{oe}}$) may have to be figured in parallel with R_L to determine r_o. Due to the large value of $\frac{1}{h_{oe}}$, we will use $r_o = R_L$.

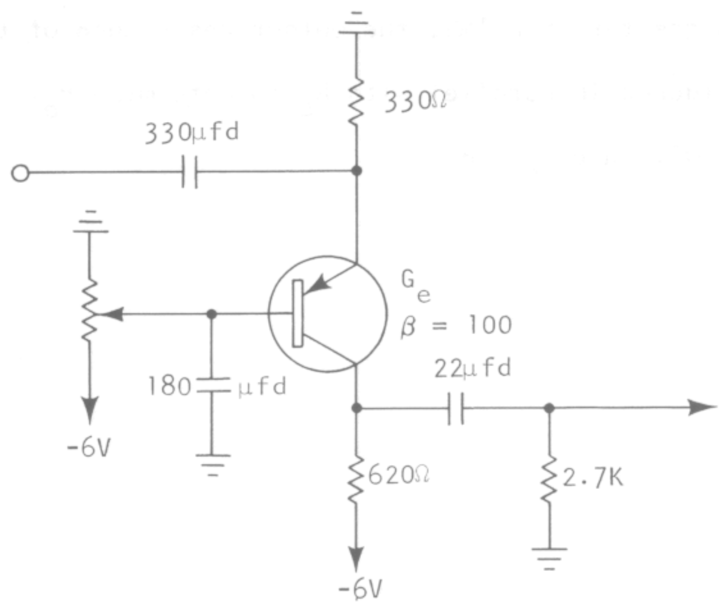


FIGURE 13-1

13.0 Determine the transimpedance of the common base circuit in figure 13-1.

T_z = __________Ω

$T_z = 500\Omega$

The input resistance to a common base transistor is very low ($\approx r_e$). Therefore, we are usually more concerned with a current amplitude input than a voltage amplitude. The output remains a voltage amplitude. To obtain a figure of merit for the circuit, we can use the transimpedance rather than compute a voltage gain. The transimpedance is merely output voltage divided by input current.

$$T_z = \frac{e_o}{i_i}$$ (T_z in a common base circuit will equal the AC collector load resistance.)

13.1 A characteristic of the common base configuration is the __________ (low/high) input resistance.

---

low

13.2 Because of the low input resistance, we are more concerned with the input ______________ than the input voltage.

---

current

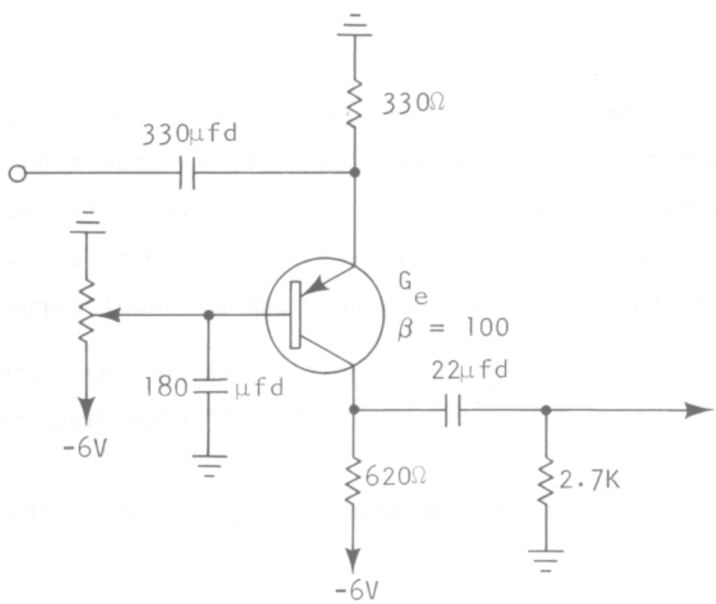


FIGURE 13-1

13.3 If the transistor in the common base configuration has a large β, the collector current is almost as large as the ________________ current.

---

emitter

13.4 In most situations, a common base circuit can be considered as having a current input and a ________________ output.

---

voltage

13.5 The transimpedance of a common base circuit is attained by dividing the output voltage by the input ________________.

---

current

13.6 If i_e and i_c are $\approx$ equal, $T_z = \frac{e_o}{i_o}$ which is the AC ________________ load resistance.

---

collector

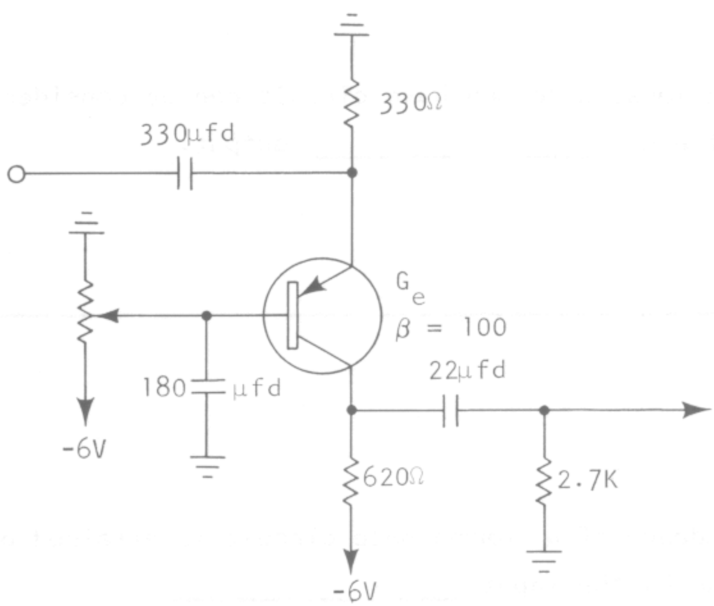


FIGURE 13-1

13.7 The figure of merit for a common base circuit is ______________ rather than gain.

---

transimpedance

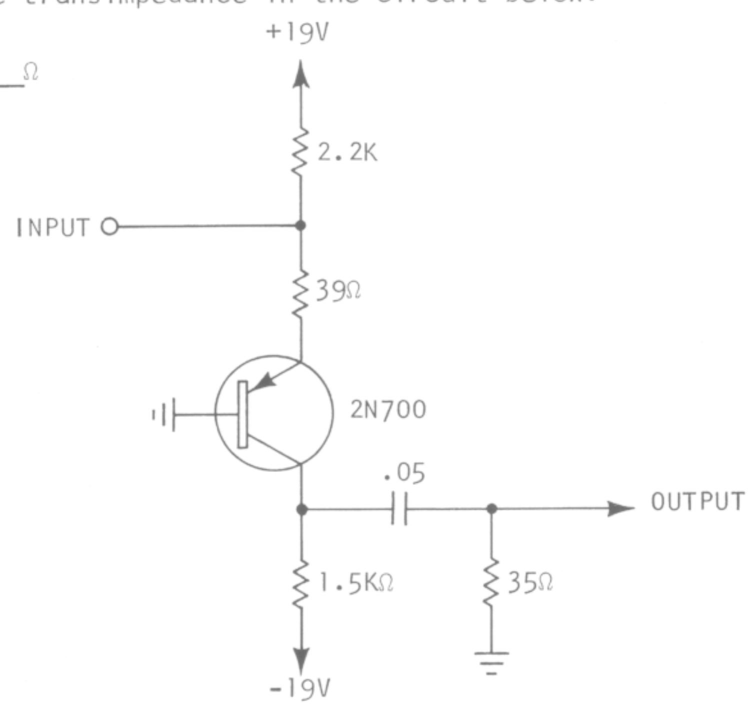
13.8 The gain (T_z) of the circuit in figure 13-1 is ________Ω.

NOTE: Assume a Δi_i of 1 mA.

T_z = 500Ω (Notice that T_z equals AC collector load resistance)

13.9** Determine the transimpedance in the circuit below.

T_z = ________Ω



T_z = 35Ω

Set 13 Summary

Due to the low input impedance of a common base circuit, the input signal is usually expressed in current amplitude. The output signal is expressed in voltage amplitude.

In Set 13, we have expressed the figure of merit for a common base circuit as transimpedance, the ratio of input current to output voltage.

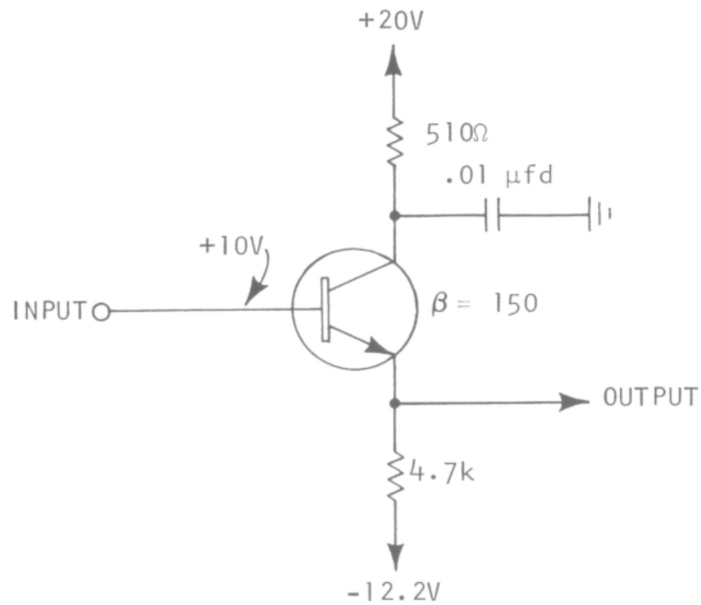


FIGURE 14-1

14.0 Determine the voltage gain (A_v), the input resistance (r_i), and output resistance (r_o) for the circuit in figure 14-1.

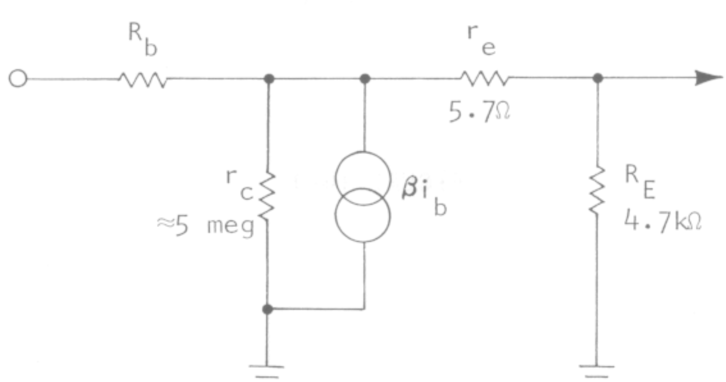
A_v = __________

r_i = __________Ω

r_o = __________Ω

$A_v \approx 1$
r_i = 705kΩ
$r_o \approx 5.7\Omega$

The voltage gain of a transistor in the common collector configuration is approximately one. If we draw the equivalent circuit of a transistor in the common collector configuration, we can see that nearly all the input voltage is felt at the output.



Only $1/\beta$ of the emitter current flows in R_b, so nearly all the input voltage will be applied to the voltage divider of r_e and R_E. Since r_e is about .1% of R_E, we can say that the output voltage is approximately equal to the input voltage or a voltage gain of one. The r_i and r_o are a review of Set 11. r_i = X R_E
$r_o = r_e$ since there is no series base resistance.

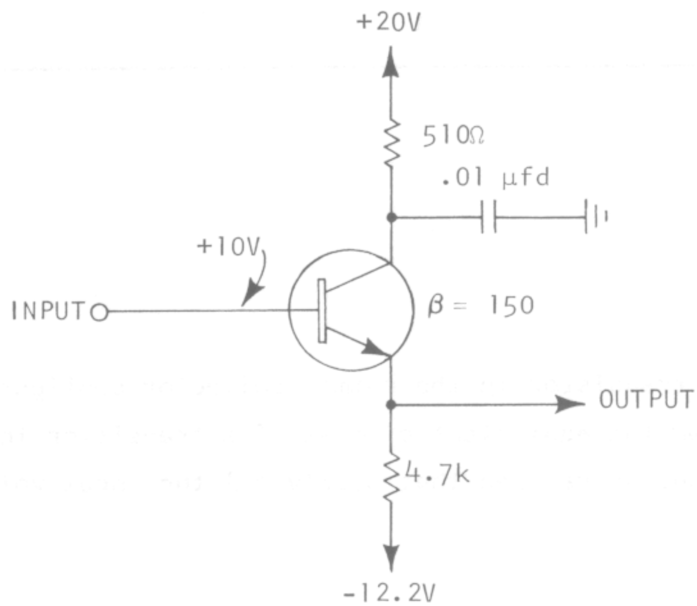


FIGURE 14-1

14.1 As with the h_{rc} parameter, we can consider the voltage gain of an emitter follower to be ≈ __________.

---

one

14.2 The input resistance to the circuit in figure 14-1 is β X __________.

R_E, 4.7kΩ

14.3 The input resistance to the circuit is __________Ω.

705kΩ

14.4 The emitter current of the transistor in figure 14-1 is __________ mA.

$I_E = 21.5V/4.7k\Omega \approx 4.58$ mA

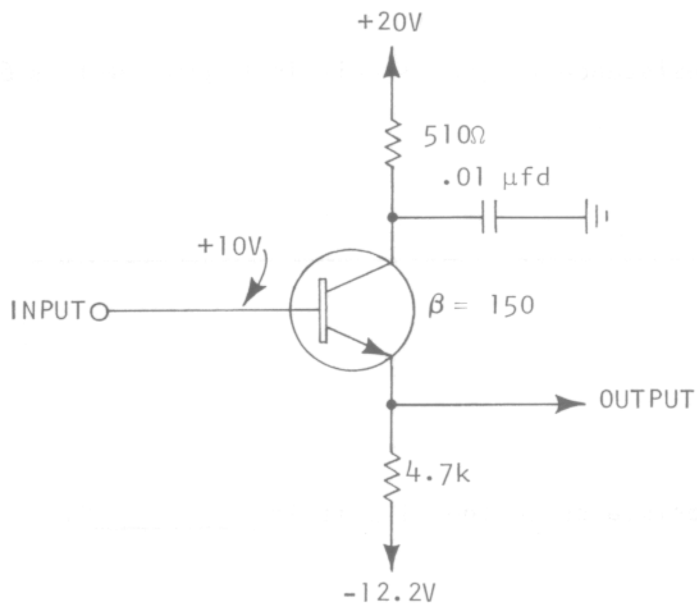


FIGURE 14-1

14.5 The value of r_e is ________Ω.

$$r_e = \frac{26}{I_E} = \frac{26}{4.58} \approx 5.7\Omega$$

14.6 Looking in from the output, we see the 4.7kΩ emitter resistance in parallel with __________.

---

r_e

14.7 The output resistance then is ≈ ________Ω.

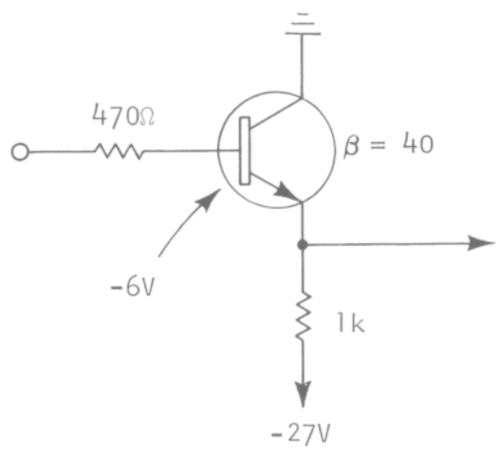
5.7Ω

14.8** Determine the A_v, r_i, and r_o for the circuit below.

A_v = ________

r_i = ________Ω

r_o = ________Ω



$A_v \approx 1$

$r_i = 40.47k\Omega$ $[(\beta \times R_E) + R_B]$

$r_o \approx 2.5\Omega$ $[r_e + R_b/\beta]$

Set 14 Summary

In Set 14, we have said that the voltage gain is $\approx$ one in an emitter follower because the resistance between the input and the output is very low. We have also reviewed r_i and r_o to an emitter follower. $r_i = \beta$. R_E and $r_o = r_e$ when there is no series base resistance.

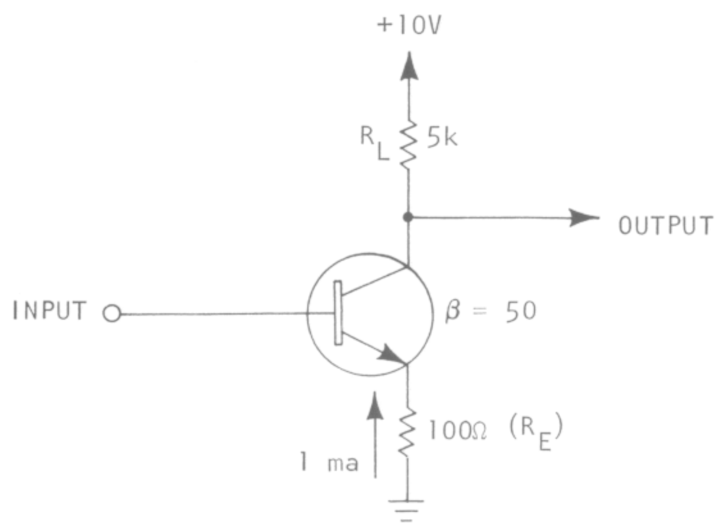


FIGURE 15-1

15.0 Determine the A_v and r_i for the circuit in figure 15-1. A_v = ________
r_i = ________ Ω

$A_v \approx 39.7$
$r_i = 6.3k\Omega$

Since the emitter current and collector current are very close to being the same, the voltage gain of a transistor in the common emitter configuration is approximately the ratio of emitter resistance to collector load resistance.

$$A_v \approx \frac{R_L}{R_E + r_e}$$

If r_e is very small compared to R_E, it can be ignored and A_v will be the ratio $\frac{R_L}{R_E}$.

The input resistance is a review of Set 12. $r_i = \beta(r_e + R_E)$

15.1 The r_e for the transistor in figure 15-1 is ________ Ω.

$r_e = \frac{26}{I_E} = 26\Omega$

15.2 The total emitter resistance is ________ Ω.

$R_E + r_e = 126\Omega$

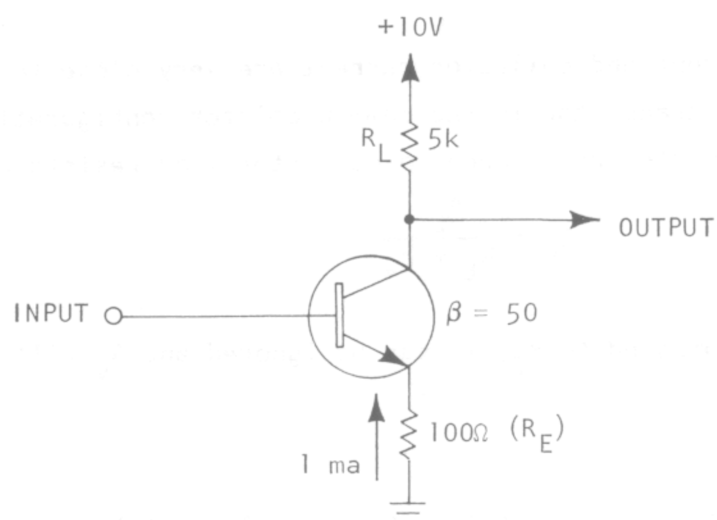


FIGURE 15-1

15.3 If we assume the emitter current and collector current are the same, signal current through $R_E + r_e$ and through R_L (5kΩ) will be

___________________.
(the same/different)

---

the same

15.4 The input voltage is applied across $R_E + r_e$ and the output is taken from acorss ___________________.

R_L, 5kΩ

15.5 The voltage gain will be determined by the ratio of R_L/________.

$R_E + r_e$, 126Ω

15.6 The voltage gain for the circuit in figure 15-1 is ≈ __________.

$$A_v \approx \frac{R_L}{R_E + r_e} = \frac{5k\Omega}{126\Omega} \approx 39.7$$

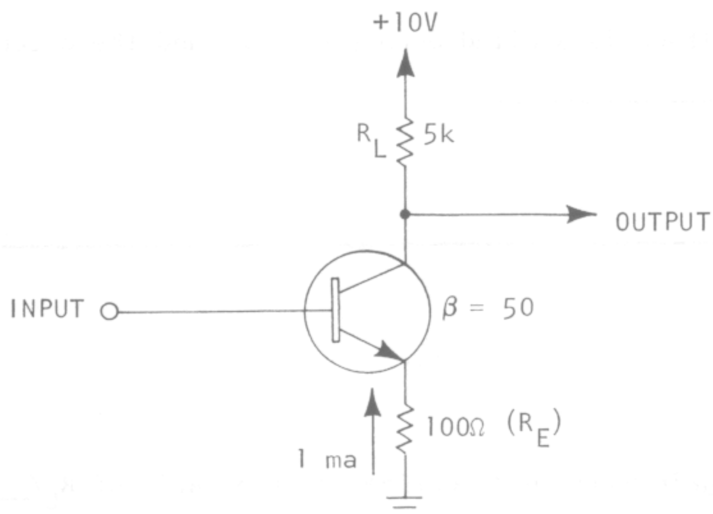


FIGURE 15-1

15.7 The input resistance to figure 15-1 is $(R_E + r_e)$ multiplied by ____________.

β, 50

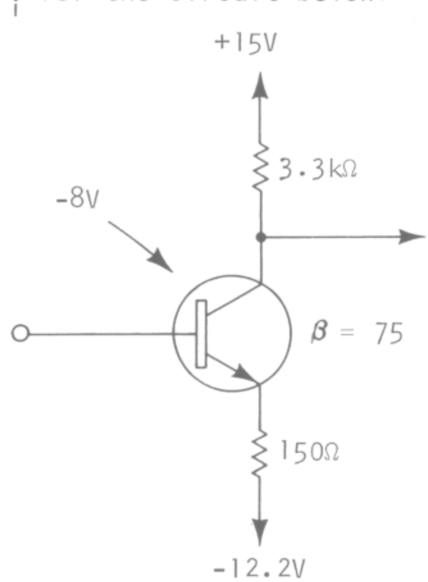
15.8 The r_i to figure 15-1 is __________Ω.

$r_i = 6.3k\Omega$

15.9** Determine the A_v and r_i for the circuit below.

A_v = __________

r_i = __________Ω



$A_v \approx 22$

$r_i \approx 11.25\Omega$

Set 15 Summary

In Set 15, we have said that the voltage gain of a common emitter is $\approx \frac{R_L}{R_E + r_e}$.

If r_e is small compared to R_E, then $A_v \approx \frac{R_L}{R_E}$.

We can always get an approximation of the voltage gain of a common emitter circuit by quickly comparing R_L to R_E.

The input resistance is again $\beta(R_E + r_e)$.

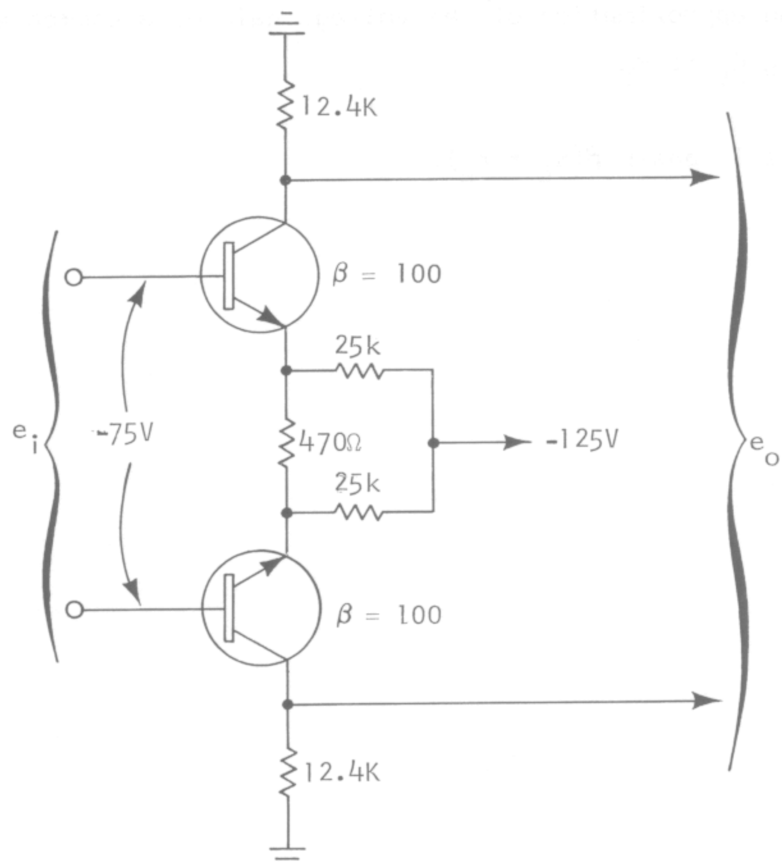


FIGURE 16-1

16.0 Determine the A_v and r_i for the circuit in figure 16-1.

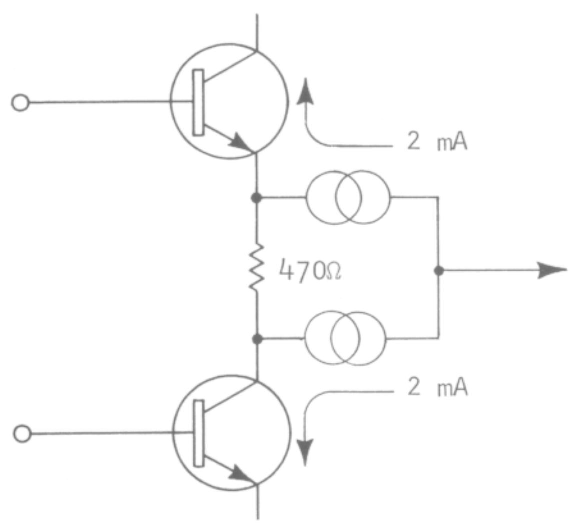
A_v = __________

r_i = __________Ω

$A_v \approx \frac{24.8k}{496} \approx 50$

$r_i \approx (496)(100) = 49.6k\Omega$

To determine the voltage gain of a push-pull amplifier, we will concern ourselves with the signal current path. The two 25kΩ resistors are large enough to be considered 2 mA current generators. The emitter circuit then looks as the circuit below.



If the base potentials are equal, there will be 2 mA of emitter current to each transistor. There is no current through the 470Ω resistor. This is a balanced condition.

The input resistance (r_i) is again β times as large as the total emitter resistance because only $1/\beta$ of the emitter current flows to the base.

$$r_i = \beta(r_{e_1} + R_E + r_{e_2}) = (100)(496) = 49.6\text{k}\Omega$$

16.1 If we assume a balanced condition (equal emitter current in each transistor), the value of r_e in each transistor in figure 16-1 is ________ Ω.

$r_e = \frac{26}{I_E} = \frac{26}{2 \text{ mA}} = 13\Omega$

16.2 The emitter resistance is the 470Ω plus the two r_e values in series for a total emitter resistance of ________ Ω.

NOTE: If the 25kΩ resistors were much smaller, they would have to be considered in parallel with the 470Ω.

496Ω

16.3 The input signal is applied to the bases of the transistors. Only $1/\beta$ of the emitter current change will occur in the bases. The input resistance is then the R_E (470Ω) + r_{e_1} (13Ω) + r_{e_2} (13Ω) times ________.

β, h_{fe}, 100 (all three are the same)

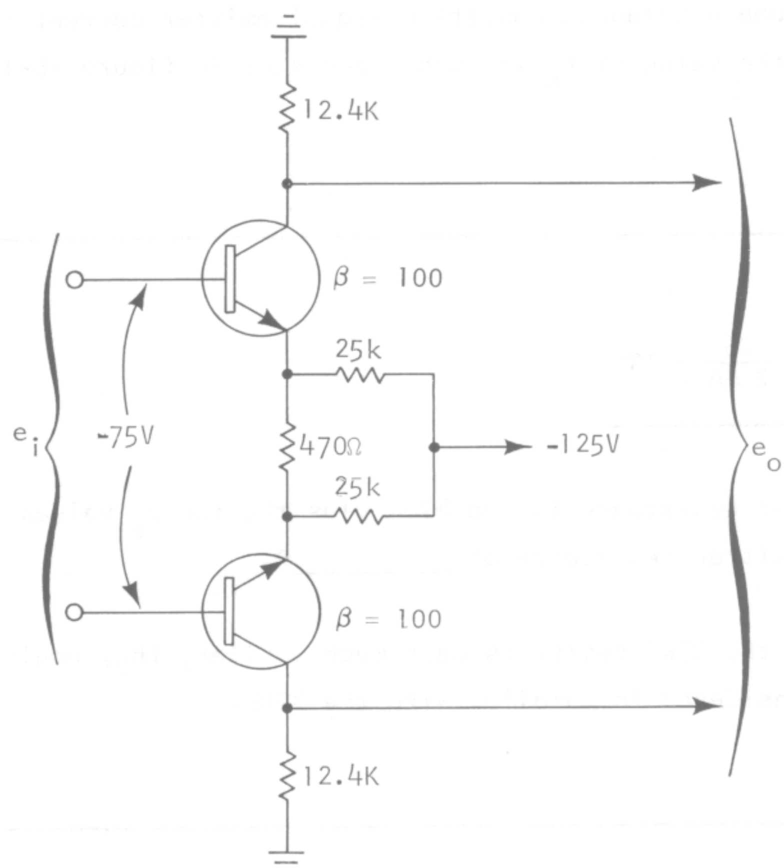
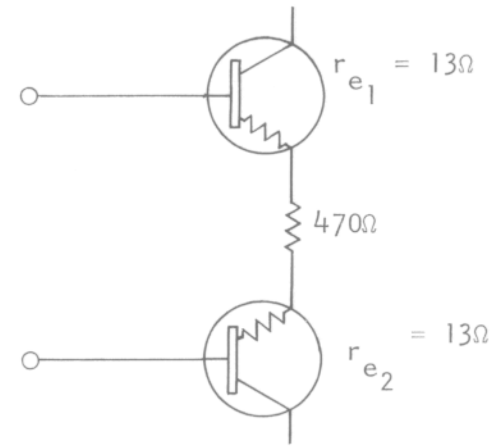


FIGURE 16-1

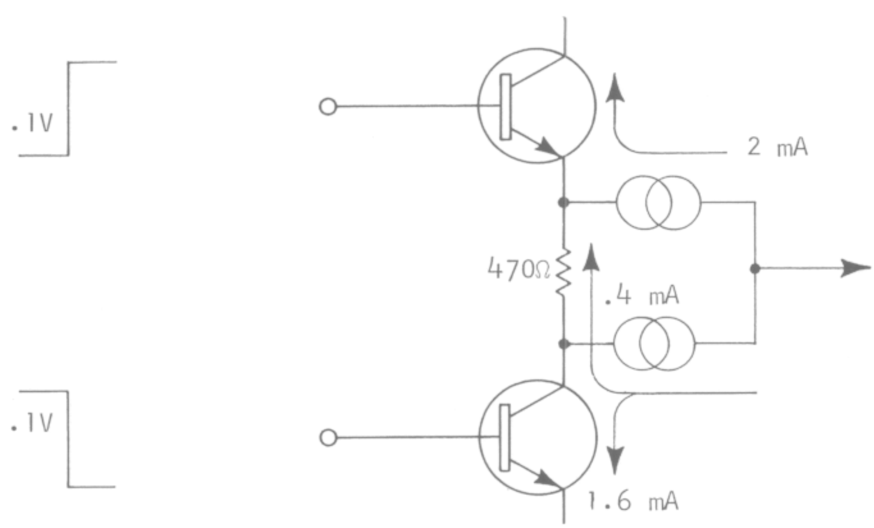
The value of r_e in each transistor is now $\frac{26}{2\ mA} = 13\Omega$. The signal current will see the emitter circuit below.



TOTAL EMITTER RESISTANCE

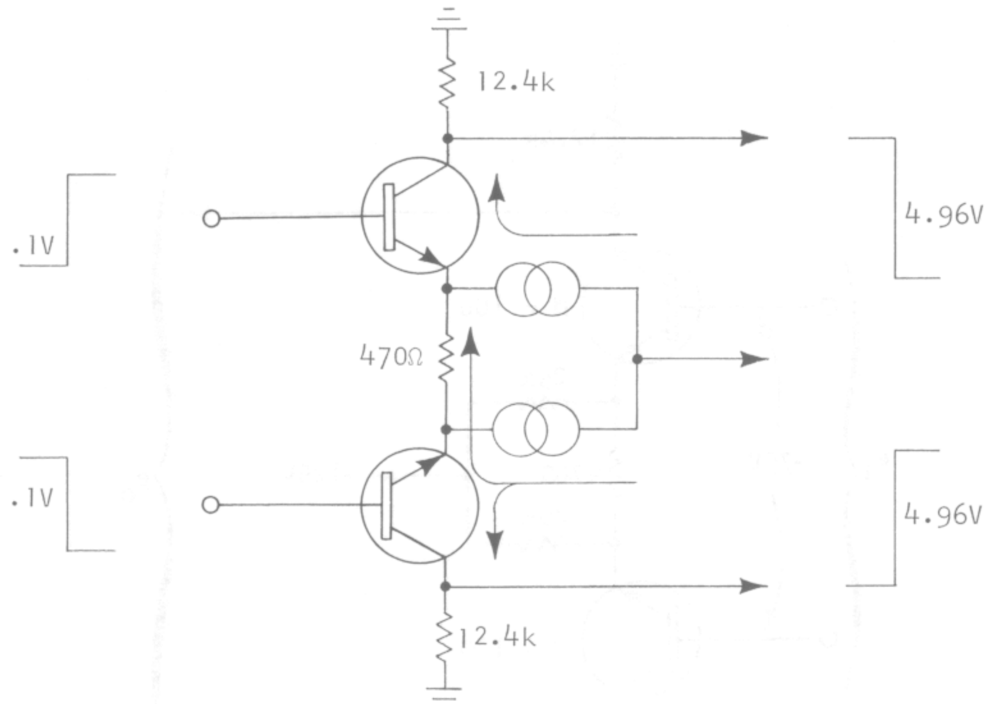
$13\Omega + 470\Omega + 13\Omega = 496\Omega$

If the base potential of the top transistor is increased .1V and the base potential of the bottom transistor is decreased .1V, the current will increase through the top transistor and decrease through the bottom transistor. The 25kΩ emitter resistors still act as 2 mA current generators, because the differences in transistor currents flow through the 470Ω resistor (see figure below).



≈ .4 mA of current will flow through the 496Ω (total emitter resistance) to lift the top emitter .1V and drop the bottom emitter .1V. The total emitter current is still 4 mA, 2 mA from each 25kΩ resistor.

The .4 mA of current that flows through the 496Ω emitter resistance is the signal current. The signal current is robbed from the bottom transistor and 12.4kΩ resistor and added to the top transistor and 12.4kΩ resistor. The voltage drop across the bottom 12.4kΩ resistor will decrease 4.96V and the voltage drop across the top 12.4kΩ resistor will increase 4.96V.



The example input to figure 16-1 is .2V, .1V to each side, and the output is 9.92V, 4.96 on each side. The voltage gain is:

$$A_v = \frac{e_o}{e_i} = \frac{9.92}{.2} = 49.6$$

The input voltage is developed across the total emitter resistance (496Ω) and the output voltage is developed across the collector load resistors (12.4kΩ + 12.4kΩ = 24.8kΩ). If we ignore base current, the same signal current would flow in the emitter resistance and the collector resistors. The voltage gain of the circuit should then equal the ratio of collector resistors to emitter resistance;

$$A_v \approx \frac{R_{L_1} + R_{L_2}}{r_{e_1} + R_E + r_{e_2}} = \frac{24.8k\Omega}{496\Omega} = 50$$

as compared to 49.6 above.

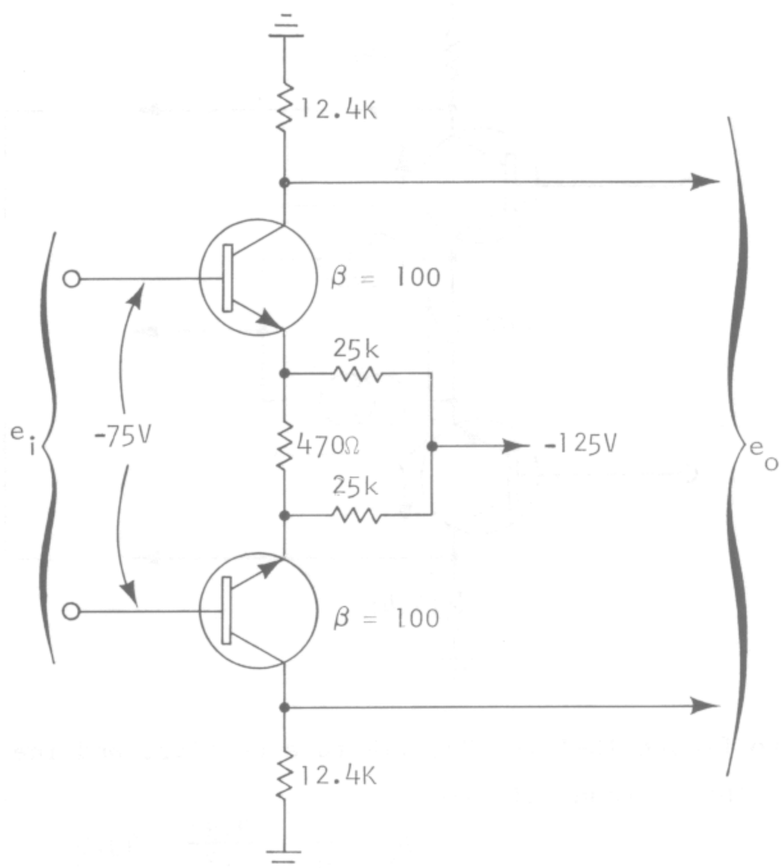


FIGURE 16-1

16.4 If we again ignore base current, the collector signal current will be equal to the ____________________ signal current.

---

emitter

16.5 The approximate voltage gain of the circuit in figure 16-1 is again simply the ratio of collector resistance to ________________ resistance.

---

emitter

16.6 The total emitter resistance in figure 16-1 is __________Ω.

496Ω

16.7 The total collector resistance, if we assume $1/h_{oe}$ to be large, is __________Ω.

12.4kΩ + 12.4kΩ = 24.8kΩ

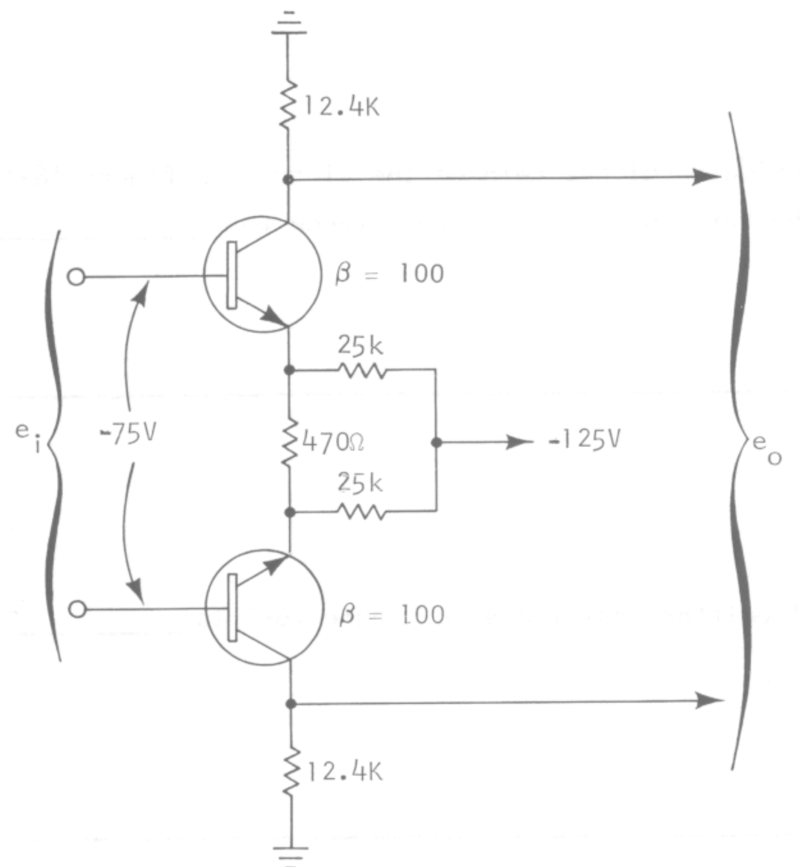


FIGURE 16-1

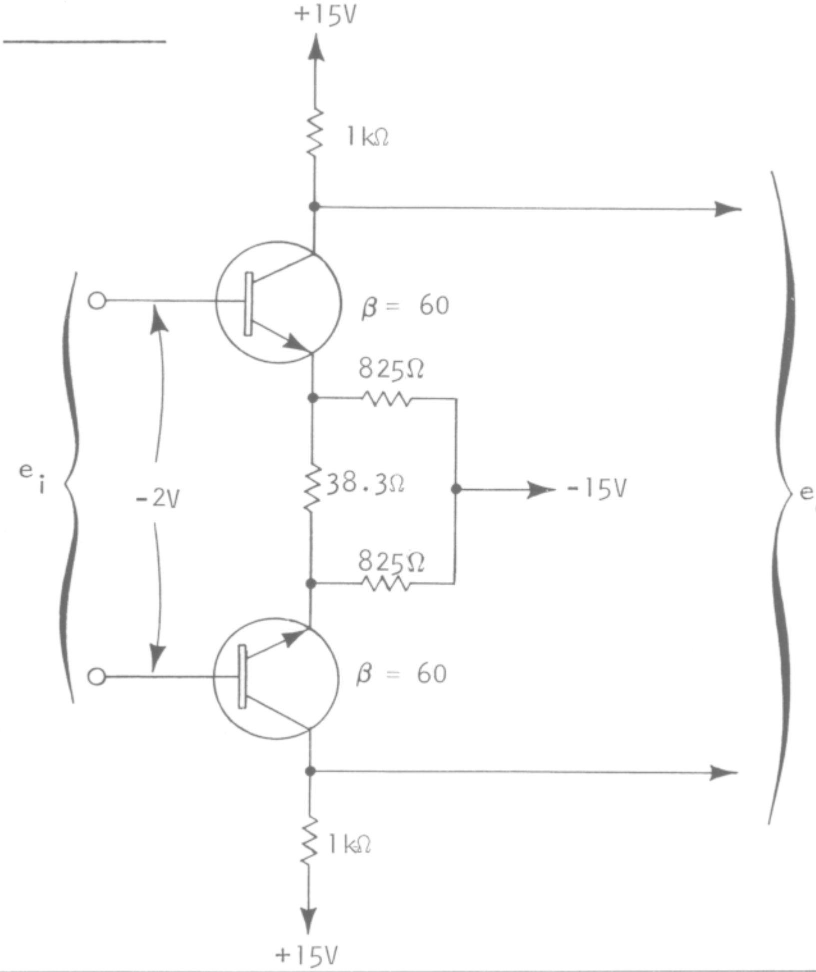
16.8 The voltage gain for the circuit in figure 16-1 is ________.

$A_v \approx 50$

16.9** Determine the A_v and r_i for the circuit below.

r_i = ________

A_v = ________



$r_i \approx 2.5k\Omega$

$A_v \approx 47.6$

Set 16 Summary

In Set 16, we have adapted the approximating formulas used to determine r_i and A_v in a single ended stage to determine r_i and A_v in a push-pull circuit. r_i again is β times the emitter resistance. However, in the push-pull circuit, we have the value of r_e for the two transistors. A_v again is the ratio of collector load resistance to emitter resistance. In the push-pull circuit, the emitter resistance includes the value of r_e for two transistors. The load resistance is the sum of the two load resistances.

$$A_v = \frac{R_{L_1} + R_{L_2}}{r_{e_1} + R_E + r_{e_2}}$$

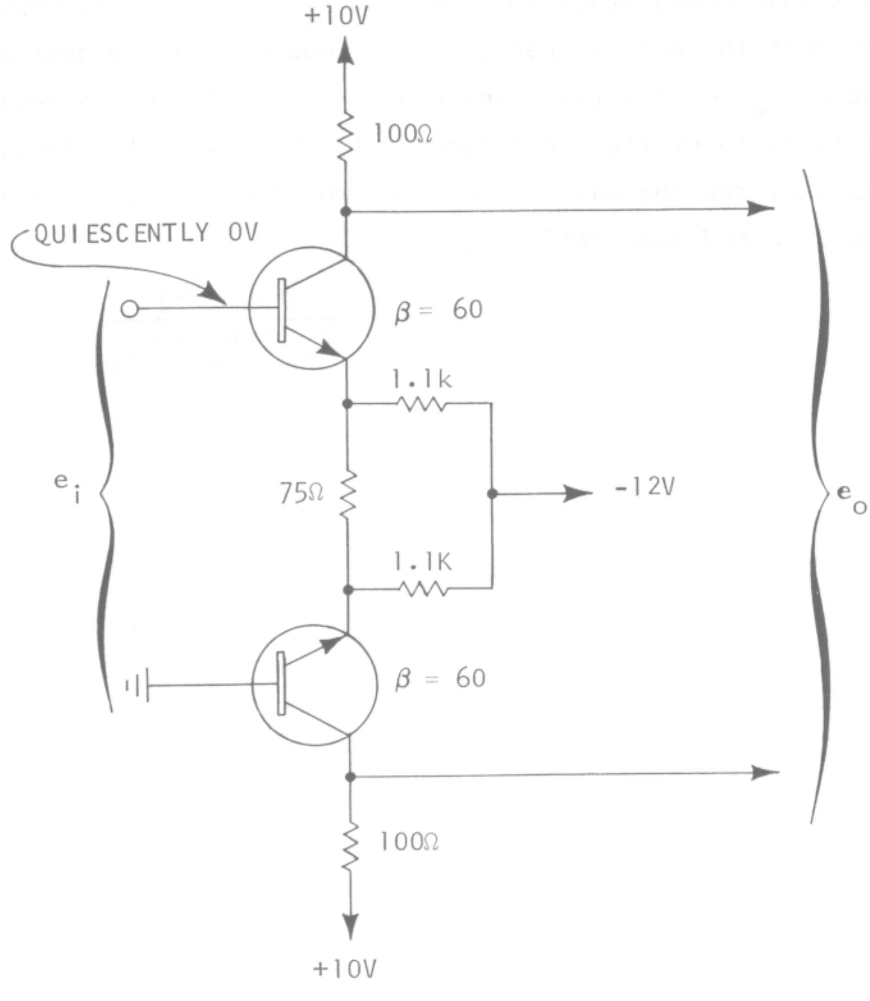


FIGURE 17-1

17.0 Determine the r_i and A_v for the paraphase amplifier in figure 17-1.

r_i = ________Ω

A_v = ________

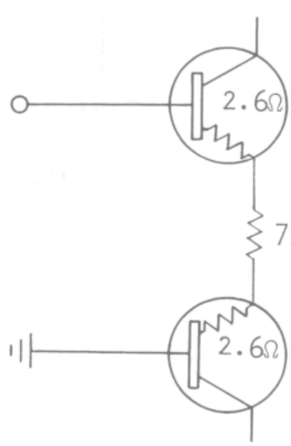
$r_i = \beta(r_{e_1} + R_E + r_{e_2}) = (60)(80.2) \approx 4.8k\Omega$

$A_v \approx 2.5$

The paraphase amplifier has a single sided input and a two sided output.

To determine the input resistance, we must find the emitter resistance and again multiply by β.

There is ≈ 10 mA of current to each transistor. The value of r_e in each transistor is, therefore, $\approx 2.6\Omega \left(\frac{26}{\approx 10\ mA} = 2.6\Omega\right)$. The emitter circuit will look as below to the signal current.



The 1.1kΩ resistors are large enough, compared to the 75Ω emitter resistor, that the emitter resistance can be considered 75Ω.

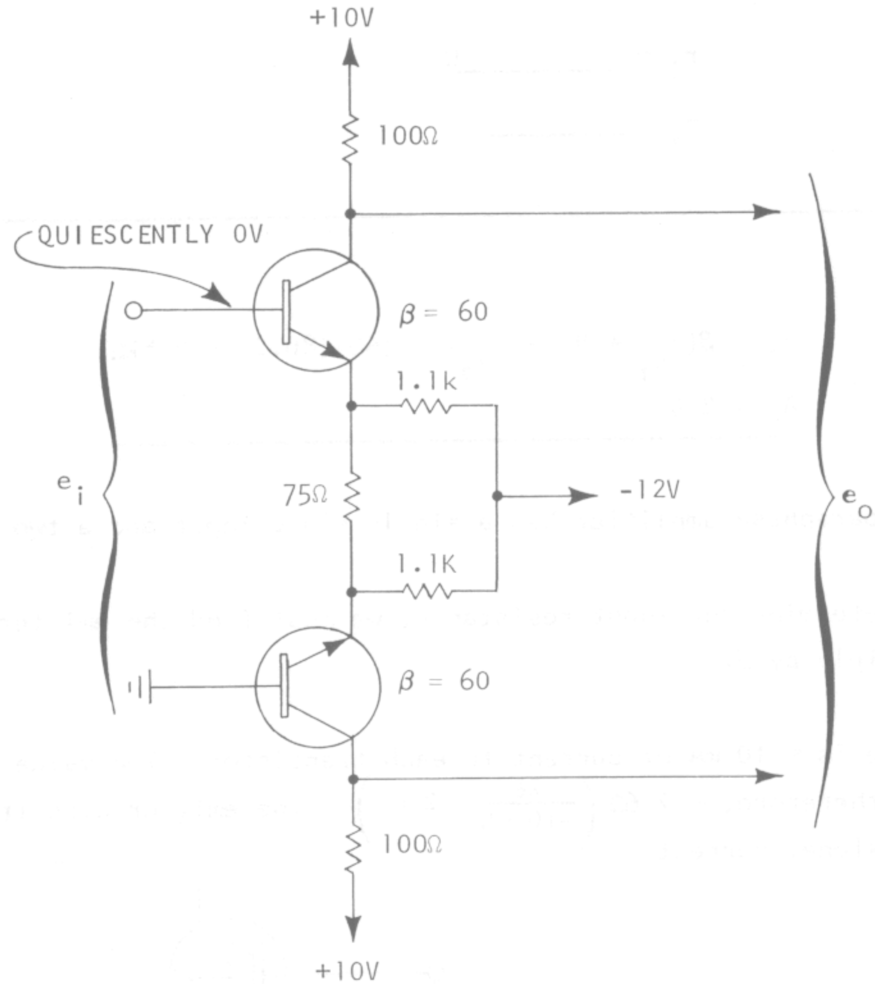
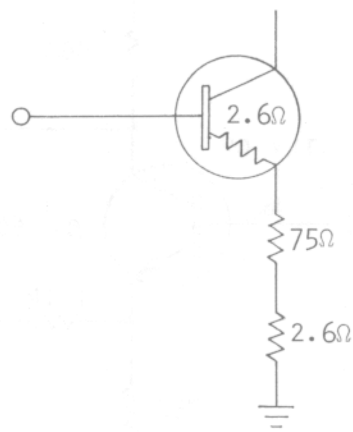


FIGURE 17-1

In Set 11, we said that when we look into the emitter of a transistor, we see any base resistor divided by β in series with r_e. There is no base resistor in the bottom transistor, so we will only see r_e. The emitter circuit now looks as below.



We can now see that $r_i = \beta \times 80.2\Omega \approx 4.8k\Omega$

The voltage gain in the paraphase amplifier is the same as in the push-pull amplifier.

$$A_v = \frac{R_{L_1} + R_{L_2}}{r_{e_1} + R_E + r_{e_2}}$$

17.1 If we assume a balanced condition, the current flow in each transistor in figure 17-1 is ________ mA.

$\frac{11.3V}{1.1k\Omega} \approx 10$ mA (.7V drop from base to emitter)

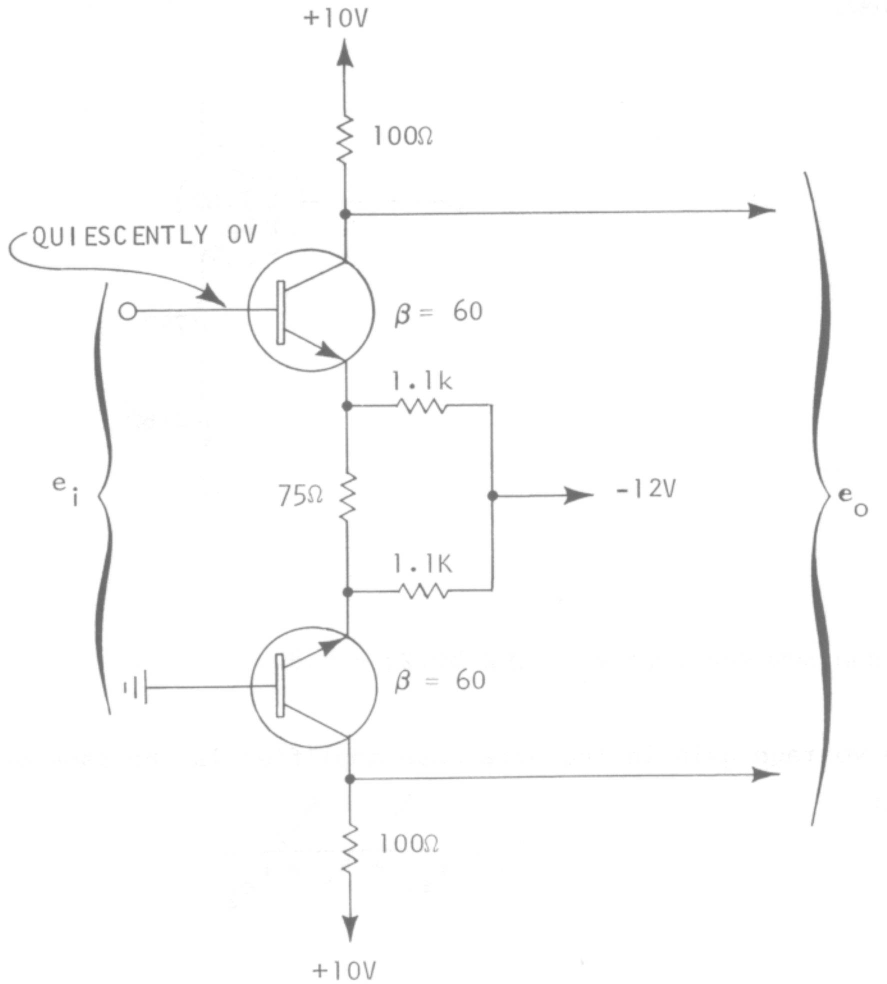


FIGURE 17-1

17.2 The value of r_e in each transistor then is ________ Ω.

$r_e = \frac{26}{10} = 2.6\Omega$

17.3 The total emitter resistance is ________ Ω.

$2.6\Omega + 75\Omega + 2.6\Omega = 80.2\Omega$

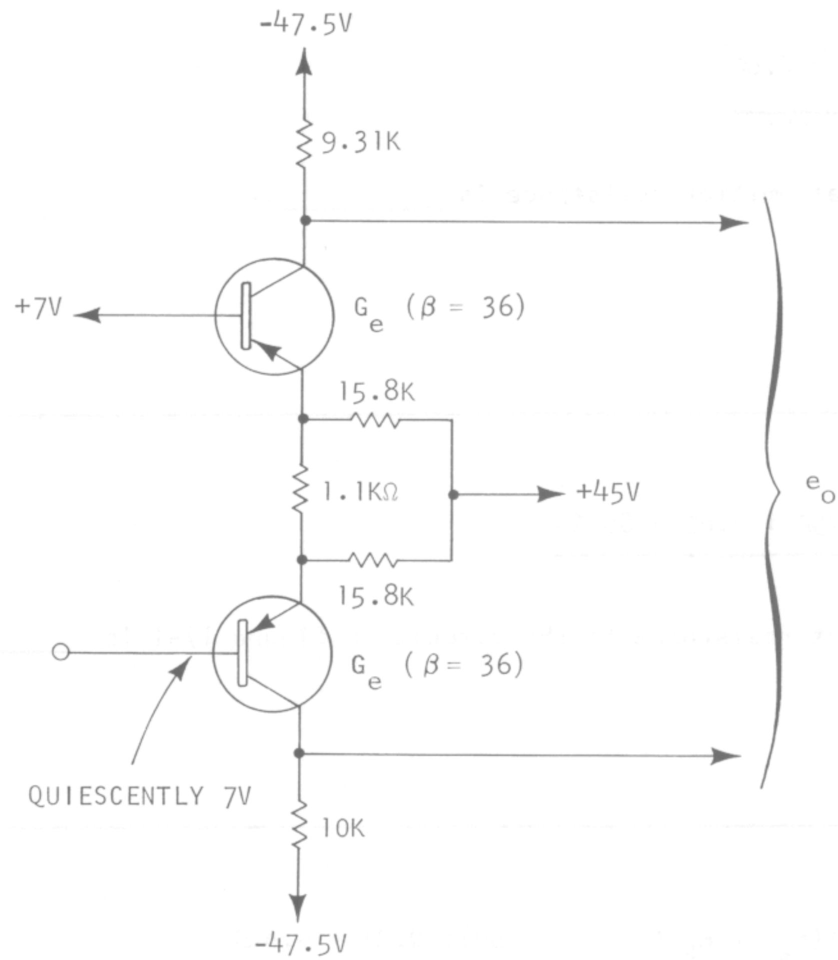
17.4 The input resistance to the circuit in figure 17-1 is ________ Ω.

$r_i = (\beta)(r_{e_1} + R_E + r_{e_2}) = (60)(80.2) \approx 4.8k\Omega$

17.5 The ratio of collector load resistors to emitter resistance determines the ≈ ______________ gain of the circuit.

---

voltage



-47.5V
9.31K
+7V
Ge (β = 36)
15.8K
1.1KΩ
+45V
15.8K
Ge (β = 36)
QUIESCENTLY 7V
10K
-47.5V
eo

17.6 In figure 17-1, this ratio is ________Ω to ________Ω.

---

collector resistance = 200Ω
emitter resistance = 80.2Ω

17.7 The voltage gain for the circuit in figure 17-1 is ≈ ________.

$$A_v \approx \frac{200\Omega}{80.2} \approx 2.5$$

17.8** Determine the r_i and A_v for the circuit on the facing page.

r_i = ________Ω

A_v = ________

---

r_i = 39.6kΩ
$A_v \approx 17.6$

Set 17 Summary

In Set 17, we have applied the approximating formulas for input resistance and voltage gain to the paraphase amplifier. The r_i is β times the emitter resistance. The r_e of the transistor with the fixed base can be considered tied to AC ground when determining r_i. The A_v of the paraphase amplifier is determined the same way as the A_v of the push-pull amplifier.

$$A_v = \frac{R_{L_1} + R_{L_2}}{r_{e_1} + R_E + r_{e_2}}$$

POST TEST

1. The h_{ib} parameter is the input ____________________ of a transistor in the common ____________________ configuration.

2. The h_{fe} parameter is the ____________________ ____________________ transfer ratio of a transistor in the common ________________________ configuration.

3. The h_{ob} parameter is the ______________________ conductance of a transistor in the common ____________________ configuration.

4. The h_{re} parameter is the ____________________ ____________________ transfer ratio of a transistor in the common _____________________ configuration.

5. The input resistance to a transistor is lowest when the transistor is in the common _______________________ configuration.

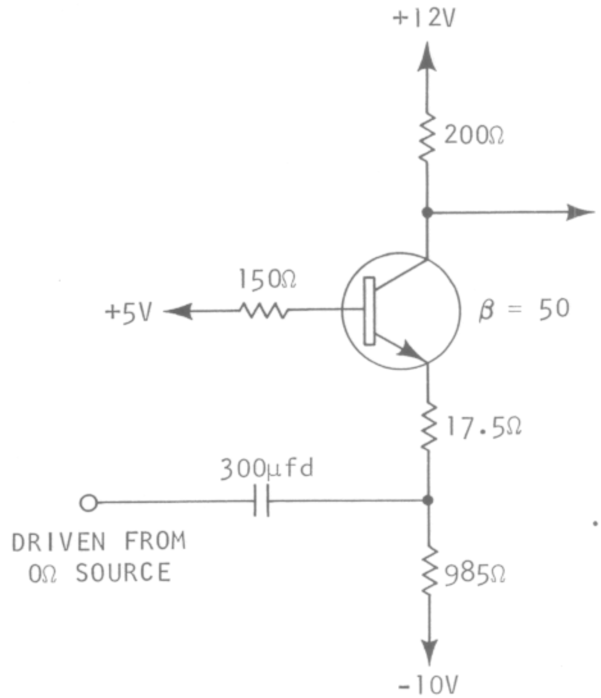
6. The output conductance of a transistor is lowest when the transistor is in the common _______________________ configuration.

7. The reverse voltage feedback is greatest when the transistor is in the common ________________________ configuration.

8. The forward current transfer ratio or current gain of a transistor is always less than one when in the common ____________________ configuration.

9. The "h" parameters of a given transistor will change as either the _____________________, the ______________________ current, or the _____________________ voltage changes.

10. Determine the r_i and r_o in the circuit below.



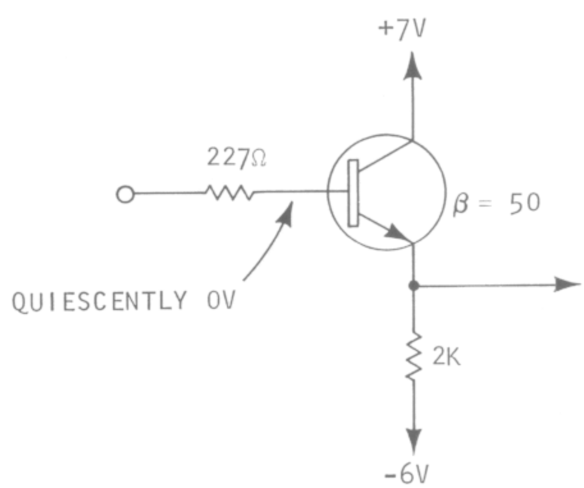
r_i = ____________Ω

r_o = ____________Ω

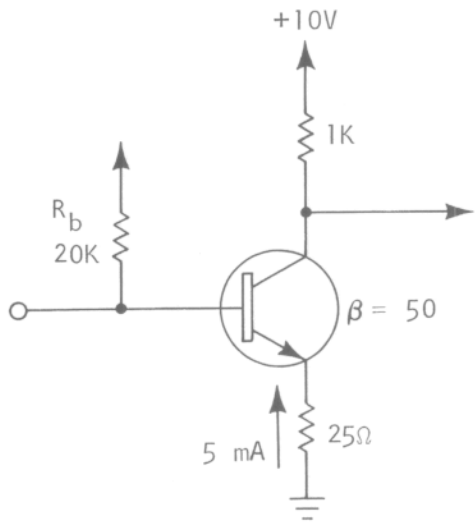
11. Determine the r_i and r_o in the circuit below.

r_i = ____________Ω

r_o = ____________Ω



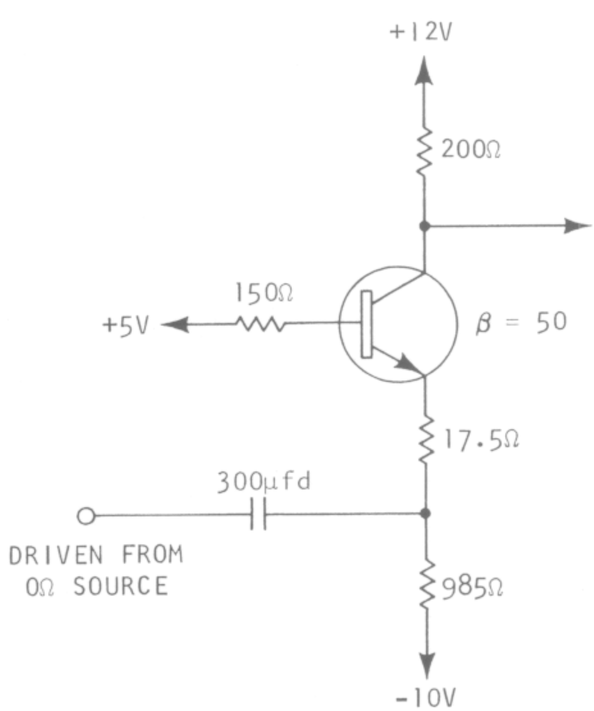
12. Determine the r_i and r_o in the circuit below.



r_i = ________Ω

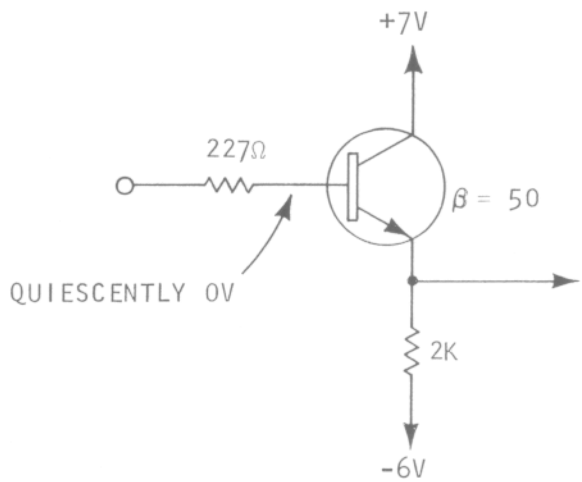
r_o = ________Ω

13. Determine the transimpedance for the circuit below.



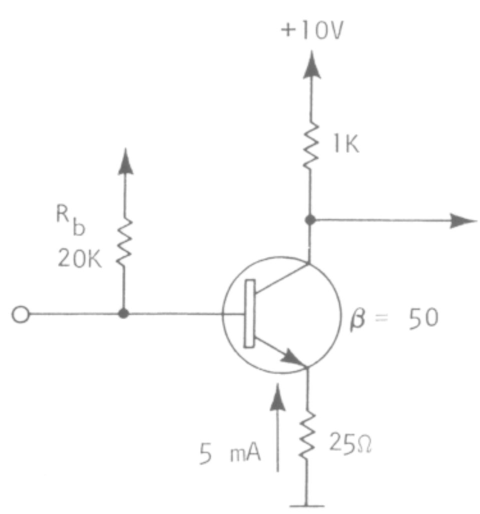
T_z = ________Ω

14. Determine the circuit A_v for the circuit below.



A_v = ____________

15. Determine the circuit A_v for the circuit below.

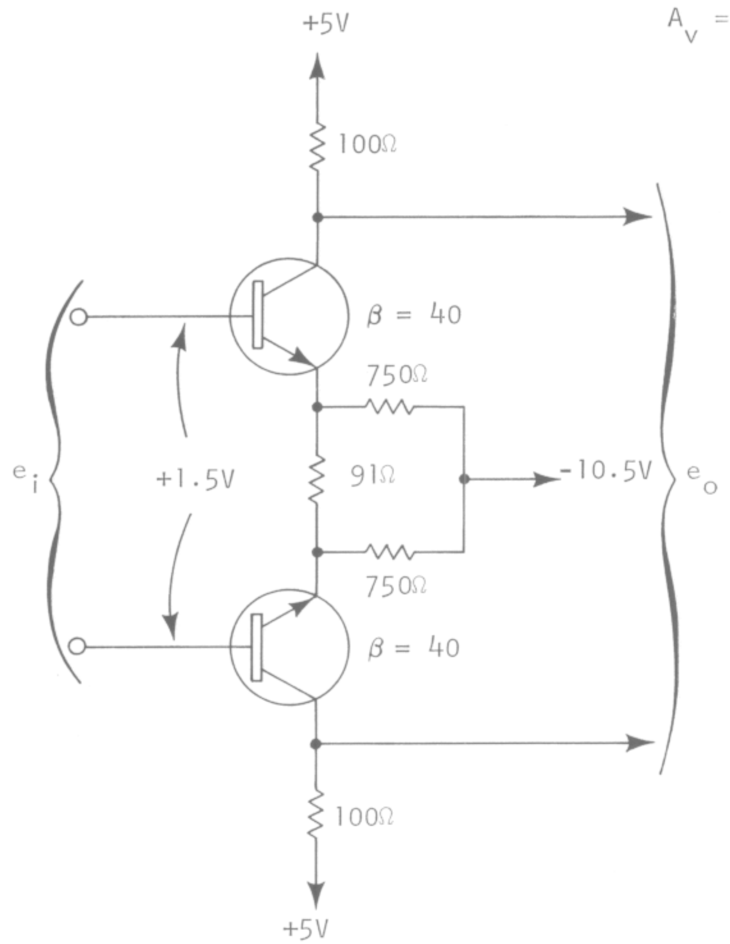


A_v = ____________

16. Determine the r_i and A_v for the circuit below.

r_i = ________ Ω

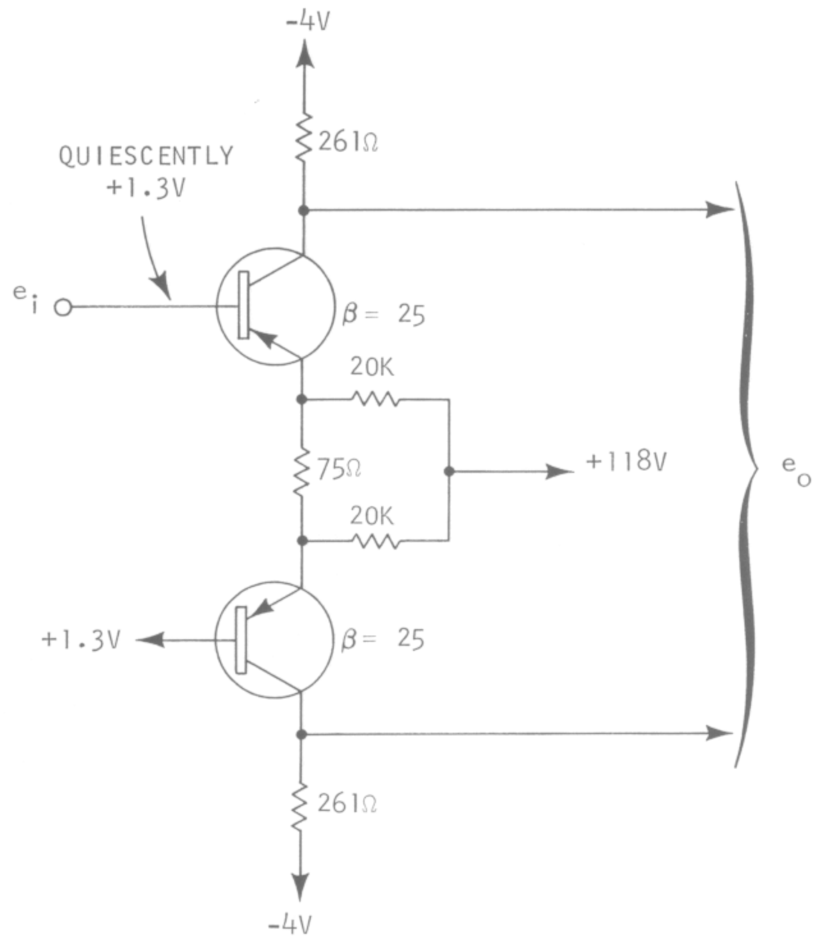
A_v = ________



17. Determine the r_i and A_v for the circuit below.

r_i = __________ Ω

A_v = __________



POST TEST ANSWERS

1. resistance (Set 3)
   base

2. forward current (Set 4)
   emitter

3. output (Set 5)
   base

4. reverse voltage (Set 6)
   emitter

5. base (Set 3)

6. base (Set 5)

7. collector (Set 6)

8. base (Set 4)

9. temperature (Set 8)
   emitter
   collector

10. $r_i \approx 22.2\Omega$ (Set 10)

$r_o = 200\Omega$

11. $r_i \approx 100k\Omega$ (Set 11)

$r_o \approx 14.3\Omega$

12. $r_i = 1.25k\Omega$ (Set 12)

$r_o = 1k\Omega$

13. $t_z = 200\Omega$ (Set 13)

14. circuit $A_v \approx 1$ (Set 14)

15. circuit $A_v \approx 33$ (Set 15)
transistor $A_i = 50$

16. $A_v = 2.12$ (Set 16)

$r_i \approx 3.8k\Omega$

17. $A_v \approx 6.2$ (Set 17)

$r_i = 2.1k\Omega$

KNOWLEDGE LEVELS

I. RECOGNIZE

At this level, when asked a multiple choice type question, the student will be able to tie two related bits of information together.

An example might be:

The symbol for a resistor is figure __________ below.

a. 

b. 

c. 

If the student chooses figure (b), then he has the ability to recognize the symbol for a resistor.

II. RECALL

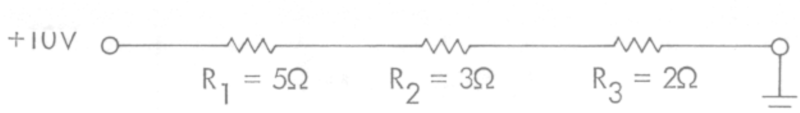
When a student has achieved this level, he might be asked for a specific bit of information or a fact, and he should be able to recall from memory that information needed.

Example: What is Ohm's Law?

If the student can give the answer that it is a relationship between voltage, current, and resistance expressed as $E = IR$ from memory, he has recalled the information that was requested.

III. RECALL AND PUT TO USE

When a student has achieved this level, he might be confronted with a problem where a certain theory must be used. To solve the problem, he must recall the theory, extract the information that he needs from the circuit, and solve the problem.



If the trainee can recall that he must have either E or I as well as the size of R_2, solve for E or I by using Ohm's Law, and then plug in the figures he needs from the circuit to arrive at the answer $P_{R_2} = 3w$, then he has been able to interrelate these concepts.