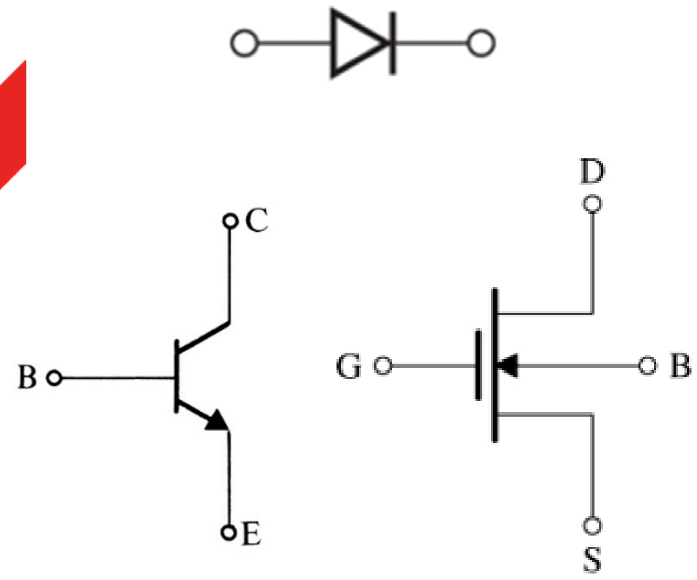
ELEC2005
Electrical and Electronic Systems

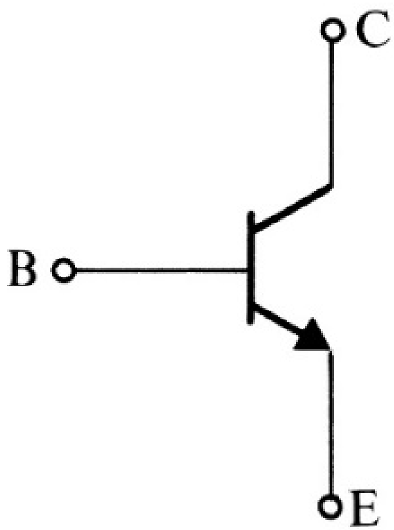
BIPOLAR JUNCTION TRANSISTORS – PART 2

DAVID PAYNE



In Today's Lecture

- Review of BJT characteristics
- Temperature Effects
- BJT Applications
    - ❖ Switches
    - ❖ Amplifiers
        - ❖ Biassing
        - ❖ Small signals



Lecture 4

1. **Review of BJT Characteristics**
2. Temperature Effects
3. BJT Applications

The Bipolar Junction Transistor

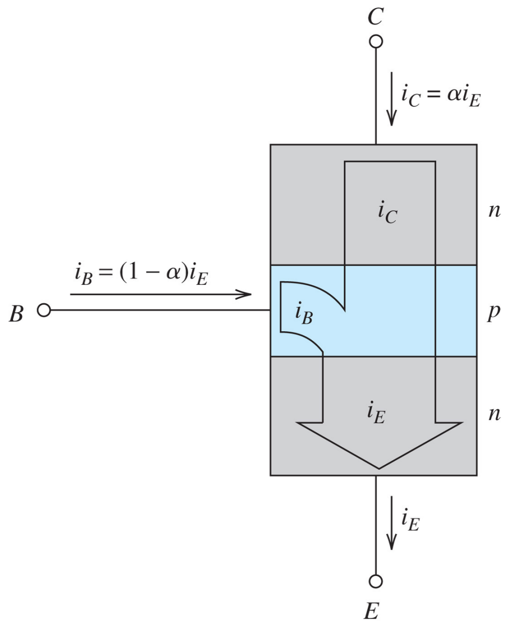
OVERVIEW

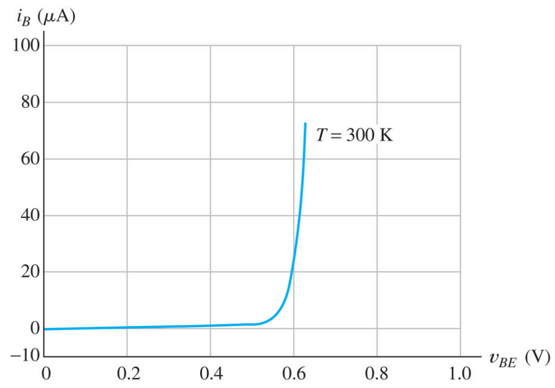
PNP, NPN

Load-line analysis

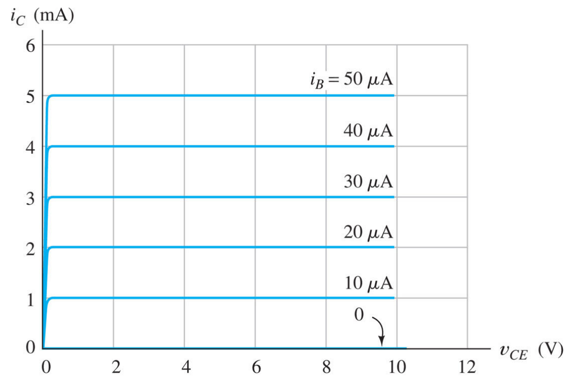
Circuit analysis

Modes of operation
- Cut-off
- Active
- Saturation





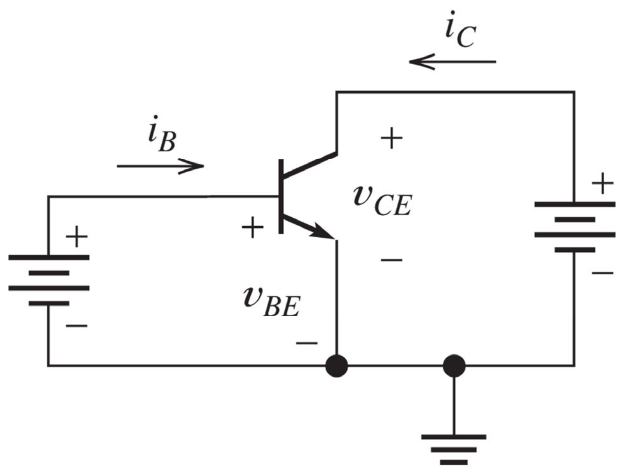
(a) Input characteristic



(b) Output characteristics

BJT Amplifiers

BJT Switches



The Bipolar Junction Transistor

MODES OF OPERATION

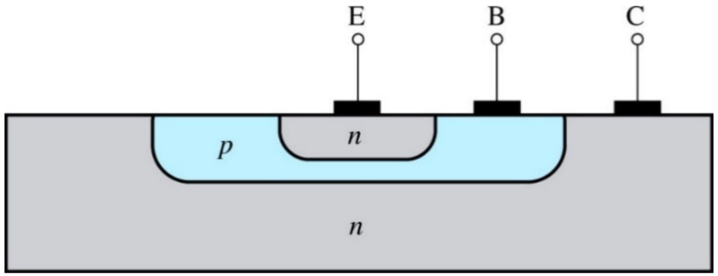
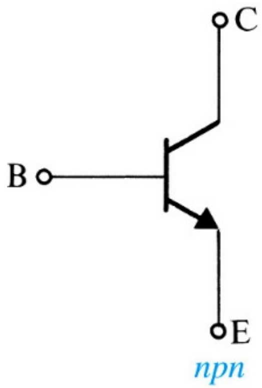
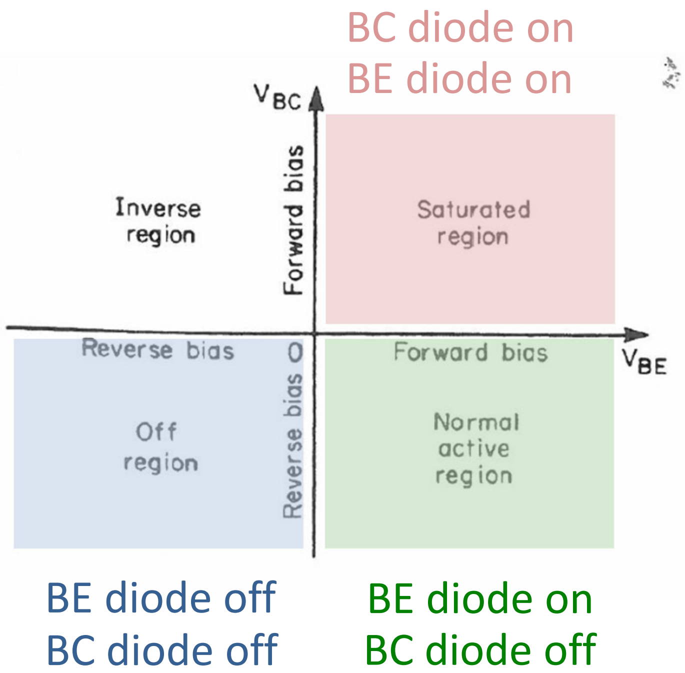


Diagram of physical npn BJT on wafer





Operating mode depends on dc biasing or large signal voltages and currents:

- active mode – used for ac amplification
- cutoff and saturation modes – used for switching.
- BJT is not symmetrical – inverse region is not normally used

The Bipolar Junction Transistor

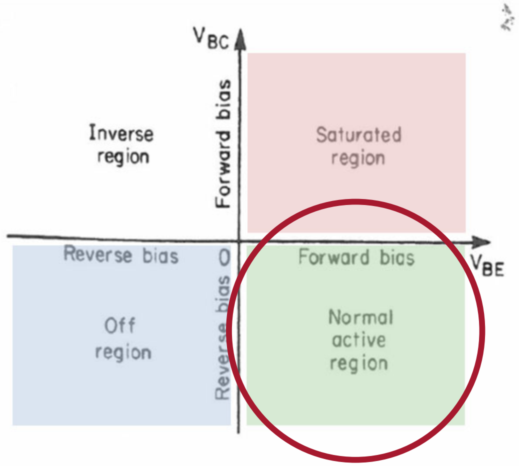
ACTIVE REGION

In Active region, BE = Forward biased, BC = Reverse biased

From Kirchoff: $i_E = i_C + i_B$

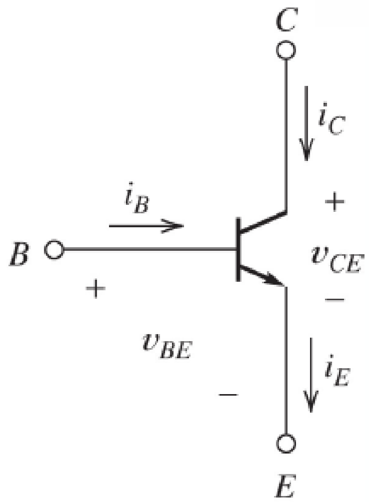
Base current is much smaller than collector current

We define: $\boxed{i_C = \beta i_B}$ $\quad i_C = \alpha i_E \quad \alpha = \dfrac{\beta}{\beta + 1}$



Typical value: β=100 $\quad \alpha$=0.9 - 0.99

$$i_E = \left(\frac{I_S}{\alpha}\right)\left(e^{v_{BE}/V_T} - 1\right) \approx \left(\frac{I_S}{\alpha}\right) e^{v_{BE}/V_T}$$



$$i_B \approx \left(\frac{I_S}{\beta}\right) e^{v_{BE}/V_T}$$

$$i_C \approx I_S e^{v_{BE}/V_T}$$

Base-emitter voltage controls the collector current!

Emitter current is the total current.

$$i_E = i_B + i_C = \frac{i_C}{\alpha}$$

The Bipolar Junction Transistor

LARGE SIGNALS CURRENT SUMMARY

On the formula sheet!

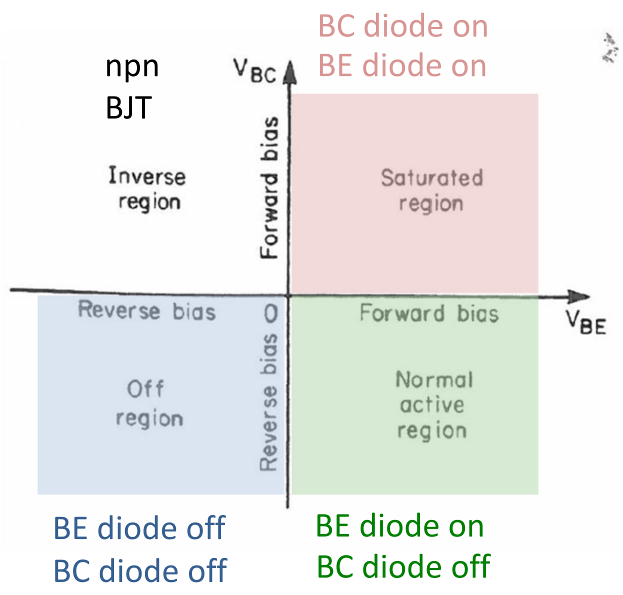
$$V_{CE} > 0 \qquad V_A = \infty \qquad V_T = \frac{kT}{q} \cong 25 \text{ mV at room temperature}$$

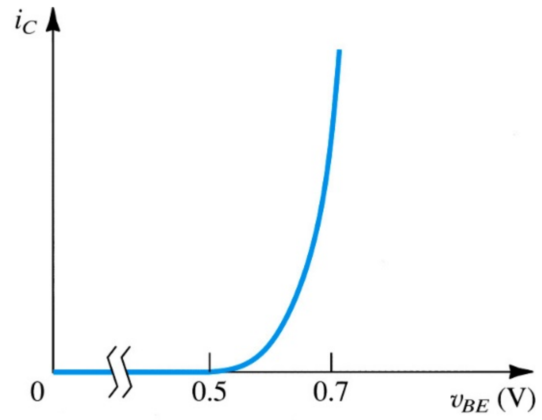
V_{BE}	V_{BC}	$V_{CE}\,(>0)$	Mode	$I_C(V_{BE}, V_{CE})$
< 0.5	< 0.4	> 0	cut-off	$I_C \cong 0$
~ 0.7	> 0.4	< 0.3	saturation	$V_{CE} \cong 0.2$ or $I_C = I_S e^{V_{BE}/V_T} - I_{SC} e^{V_{CE}/V_T}$
~ 0.7	~ 0.4	~ 0.3	edge of saturation and active	$I_C = I_S e^{V_{BE}/V_T}$
~ 0.7	< 0.4	> 0.3	active	$I_C = I_S e^{V_{BE}/V_T}$

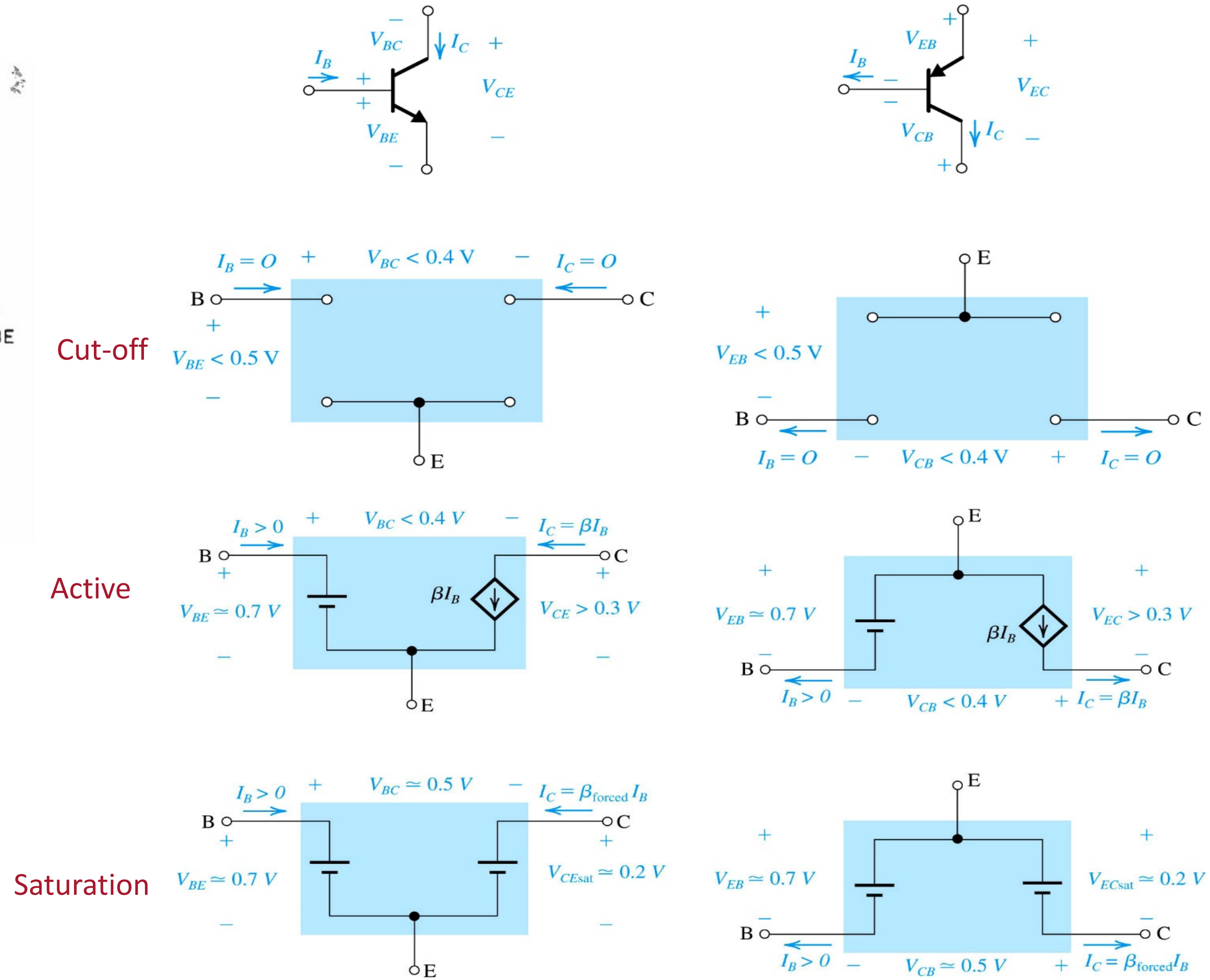
For pnp BJT use the same current equations but with reversed voltage polarities

The Bipolar Junction Transistor

SUMMARY OF SIMPLE BJT MODELS







Remember these models are only approximate!

Lecture 4

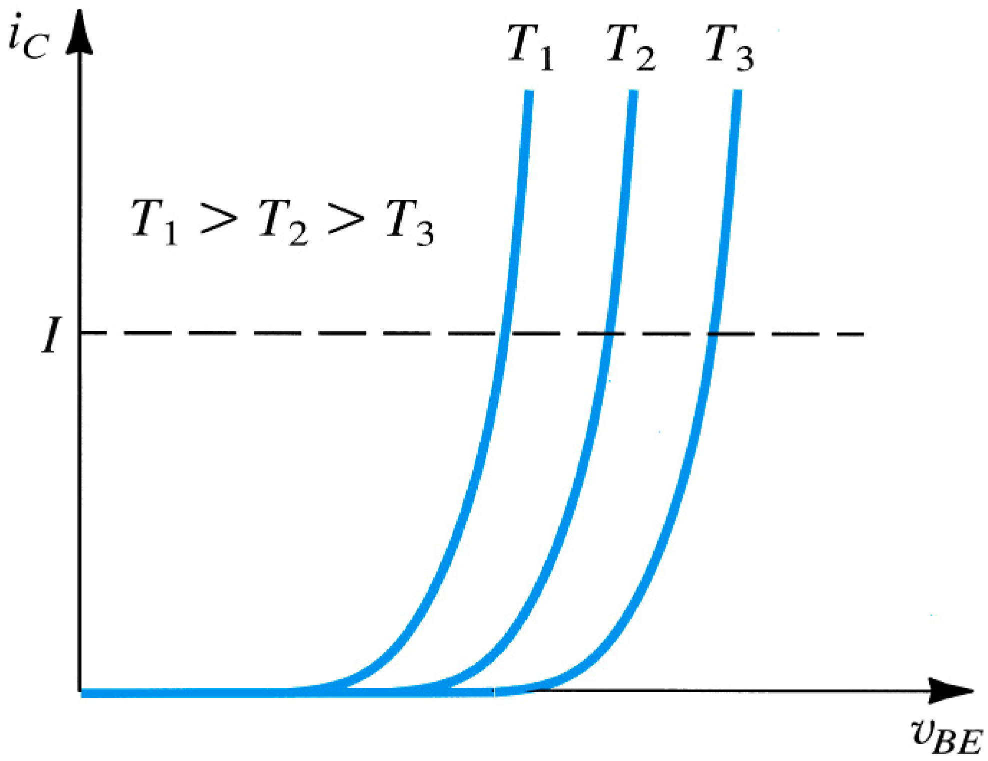
1. Review of BJT Characteristics
2. **Temperature Effects**
3. BJT Applications

The Bipolar Junction Transistor

TEMPERATURE EFFECTS

Temperature has an impact on BJT characteristics

i_C vs v_{BE}

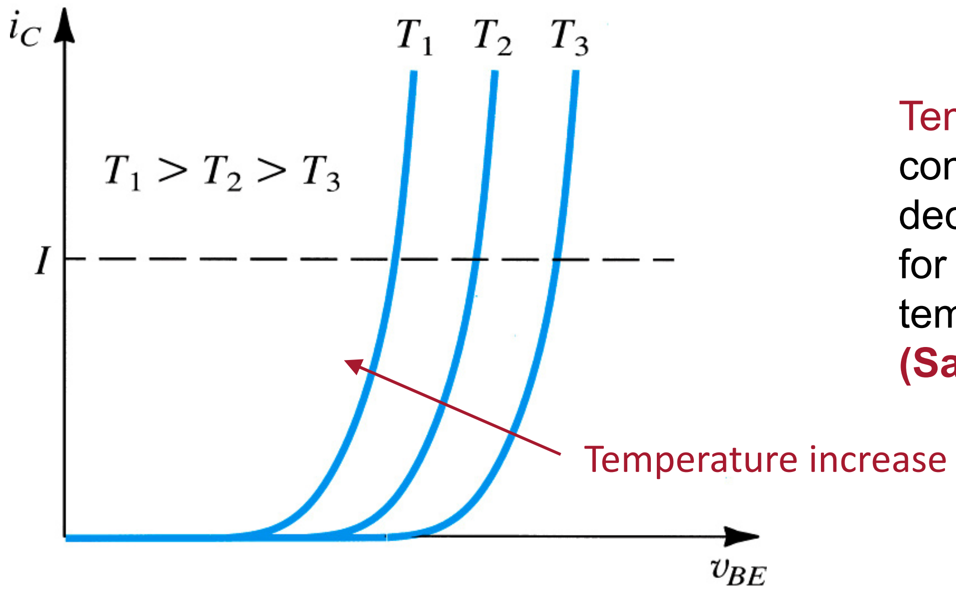


The Bipolar Junction Transistor

TEMPERATURE EFFECTS

Temperature has an impact on BJT characteristics

i_C vs v_{BE}



Temperature dependence: At a constant current, the voltage decreases by approximately 2 mV for every 1°C increase in temperature.
(Same as the pn junction diode)

Adding a positive voltage source at the B-E junction will cause collector current to keep increasing until burnout!

Add a resistor at the emitter to stop the current increase
(Or use a constant current source)

Lecture 4

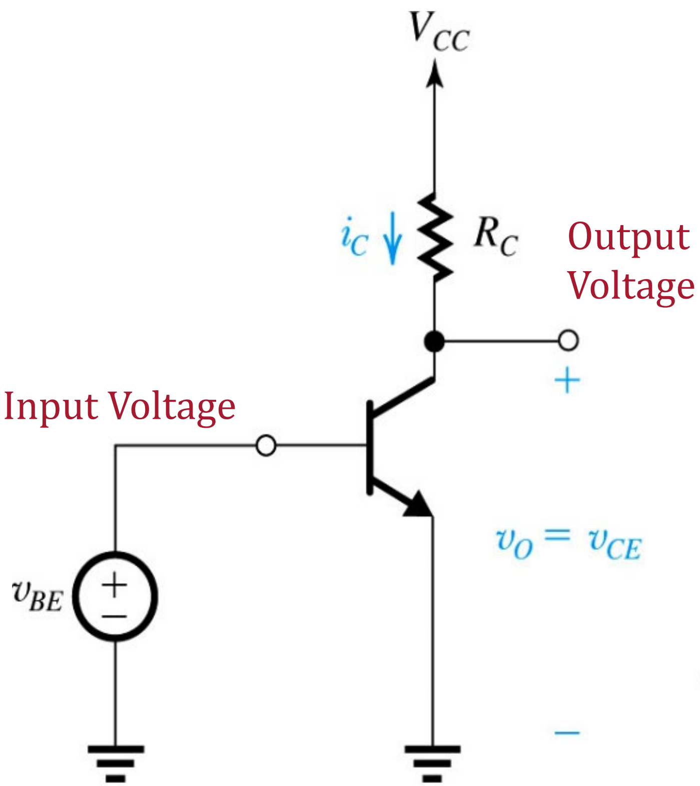
1. Review of BJT Characteristics
2. Temperature Effects
3. **BJT Applications**

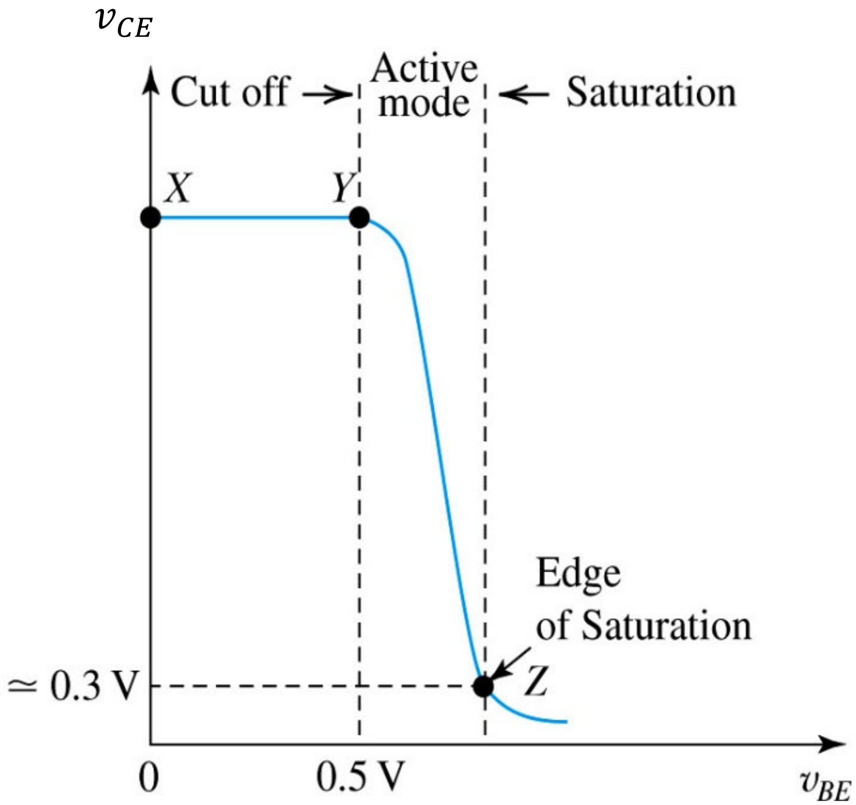
The Bipolar Junction Transistor

BJT AS A SWITCH

BJTs can be setup to work as switches or as amplifiers

BJT Switch:



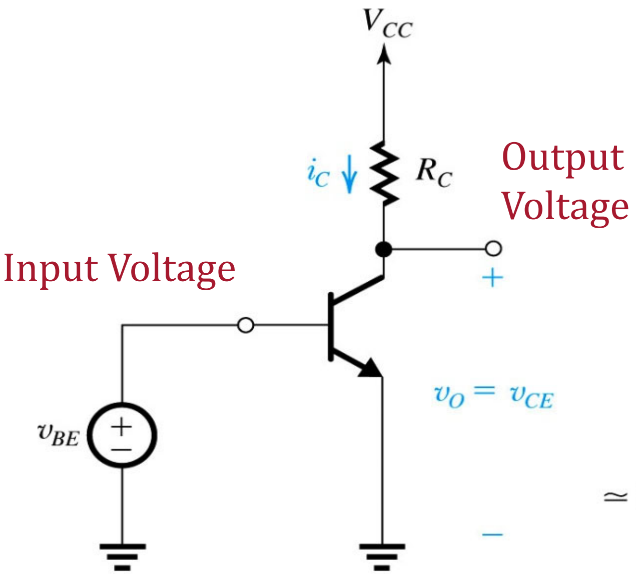


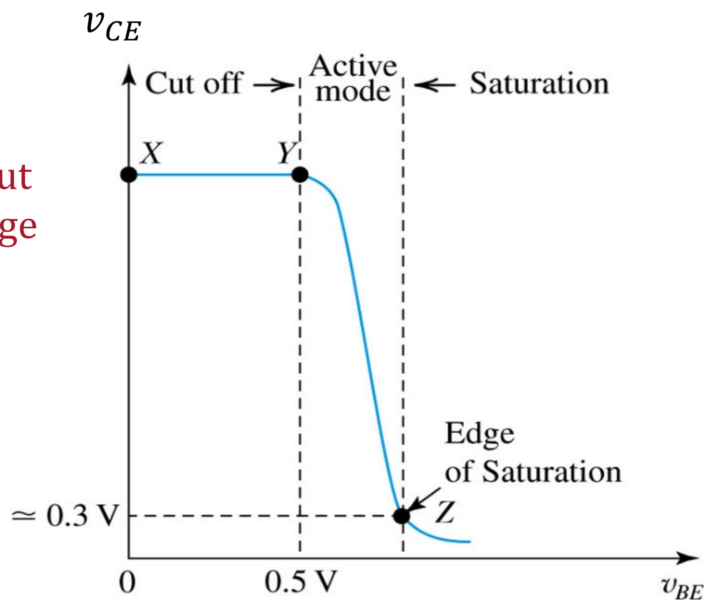
The Bipolar Junction Transistor

BJT AS A SWITCH

BJTs can be setup to work as switches or as amplifiers

BJT Switch:





Voltage Transfer Characteristic

If we increase the input voltage from low to high, output voltage will switch from high to low.

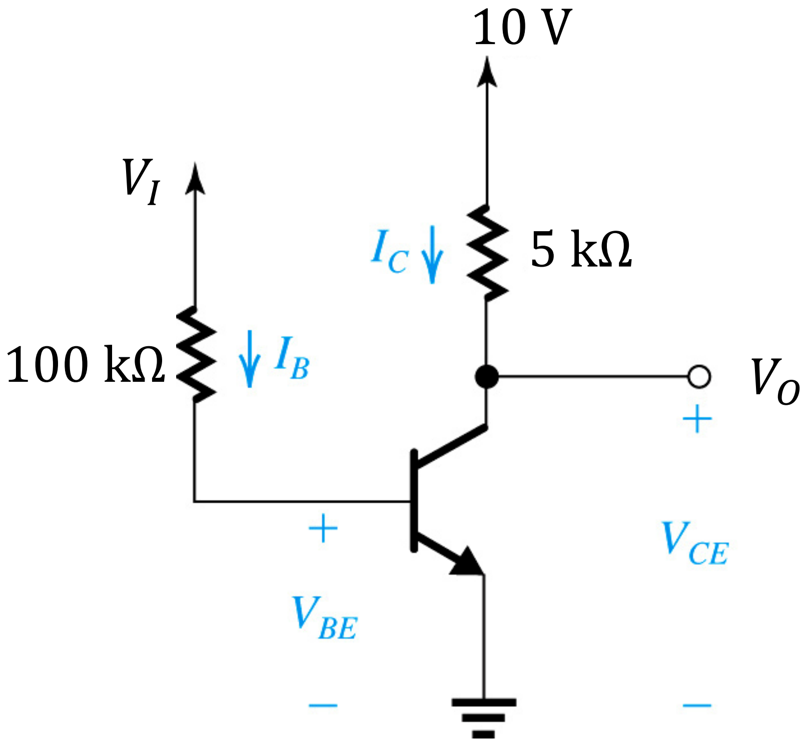
$$i_C = I_s e^{v_{BE}/V_T}$$

$$v_O = v_{CE} = V_{CC} - R_C i_C$$

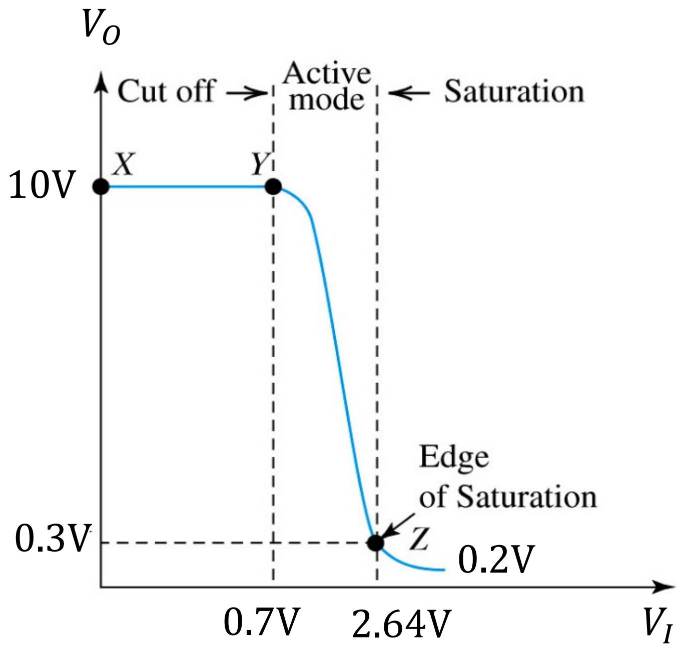
The Bipolar Junction Transistor

EXAMPLE

Using the simple BJT model:



$\beta = 100$



BJT Applications

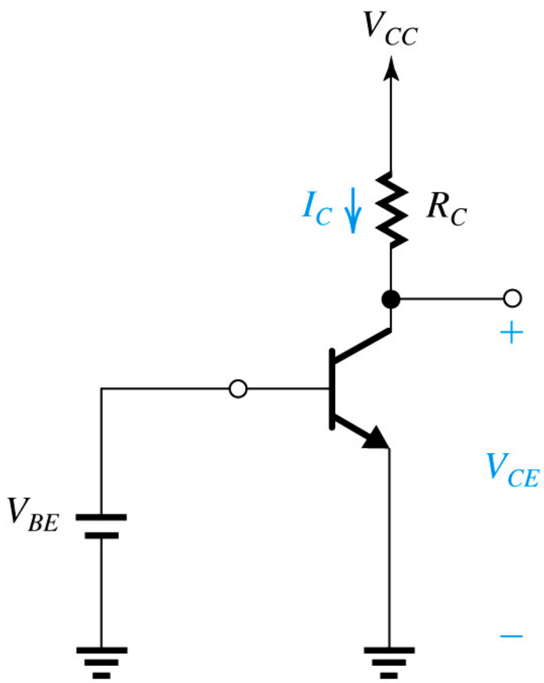
BJT AMPLIFIER

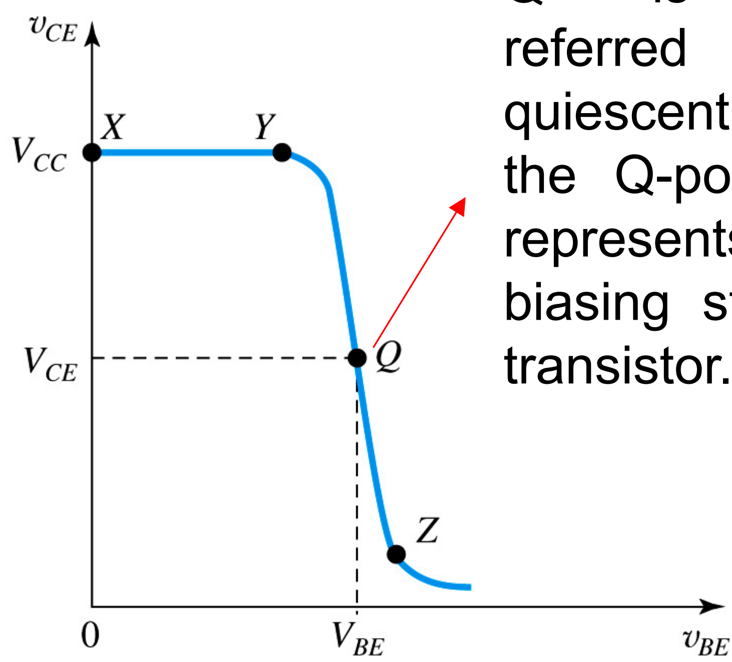
- BJT as an amplifier
- **Biasing** the BJT for linear amplification (small signal)
- The **common emitter** amplifier – load line analysis
- **Small-signal** equivalent circuit
- Examples- Design, Analyse

BJT Amplifier

RECAP – FROM ONLINE CONTENT VIDEOS

We can use V_{BE} to Bias the transistor into active mode (Q)





Q is normally referred to as the quiescent point or the Q-point. And it represents the biasing state of the transistor.

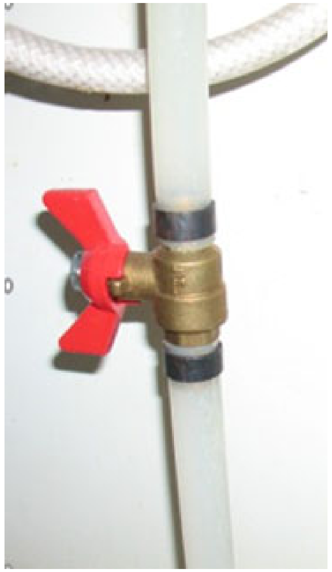
$$I_C = I_S e^{V_{BE}/V_T}$$

$$V_{CE} = V_{CC} - R_C I_S e^{V_{BE}/V_T}$$

Understanding DC biasing

EXAMPLE

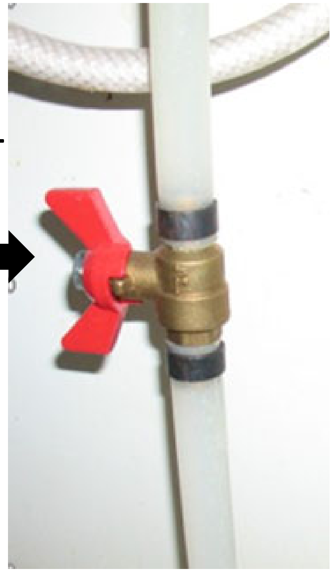
Analogy for an amplifier circuit.



Analogy for DC bias

Water in

Position half-way through



Water out

Analogy for DC bias + AC signal

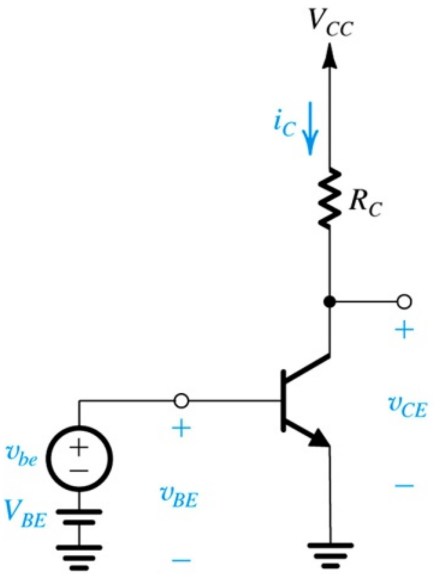
Water in

Valve control

Water out

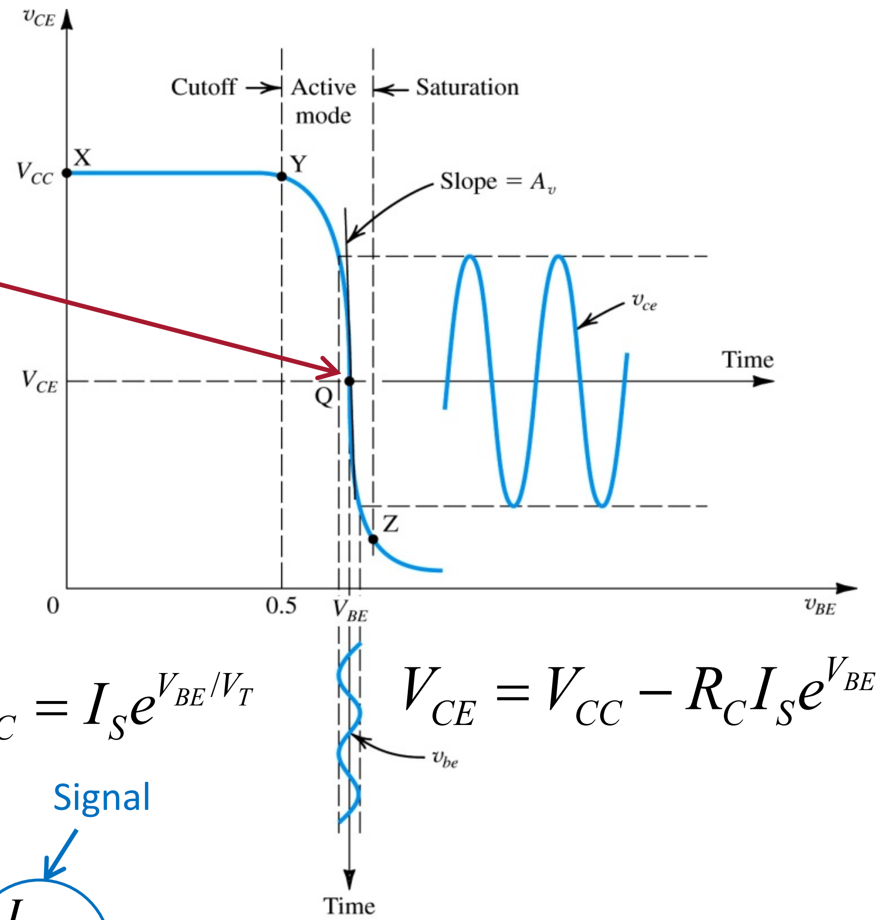
BJT AMPLIFIER

RECAP – FROM ONLINE CONTENT VIDEOS



$$\upsilon_{BE}(t) = V_{BE} + \upsilon_{be}(t)$$

Dc bias to hold BJT in active mode



$$I_C = I_S e^{V_{BE}/V_T}$$

$$V_{CE} = V_{CC} - R_C I_S e^{V_{BE}/V_T}$$

$if\, v_{be} \ll V_T$

Bias

Signal

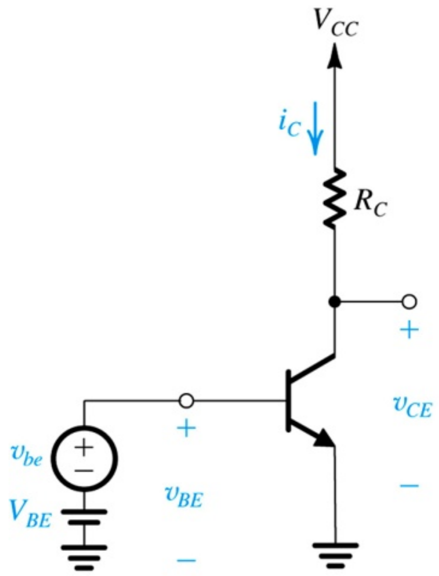
$$i_C = I_S e^{\upsilon_{BE}/V_T} = I_S e^{V_{BE}/V_T} e^{\upsilon_{be}/V_T} \simeq I_C\left(1 + \frac{\upsilon_{be}}{V_T}\right) = \underbrace{I_C}_{\text{Bias}} + \underbrace{\frac{I_C}{V_T}\upsilon_{be}}_{\text{Signal}}$$

Here we make use of the identity,

$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \cdots$ if x<<1

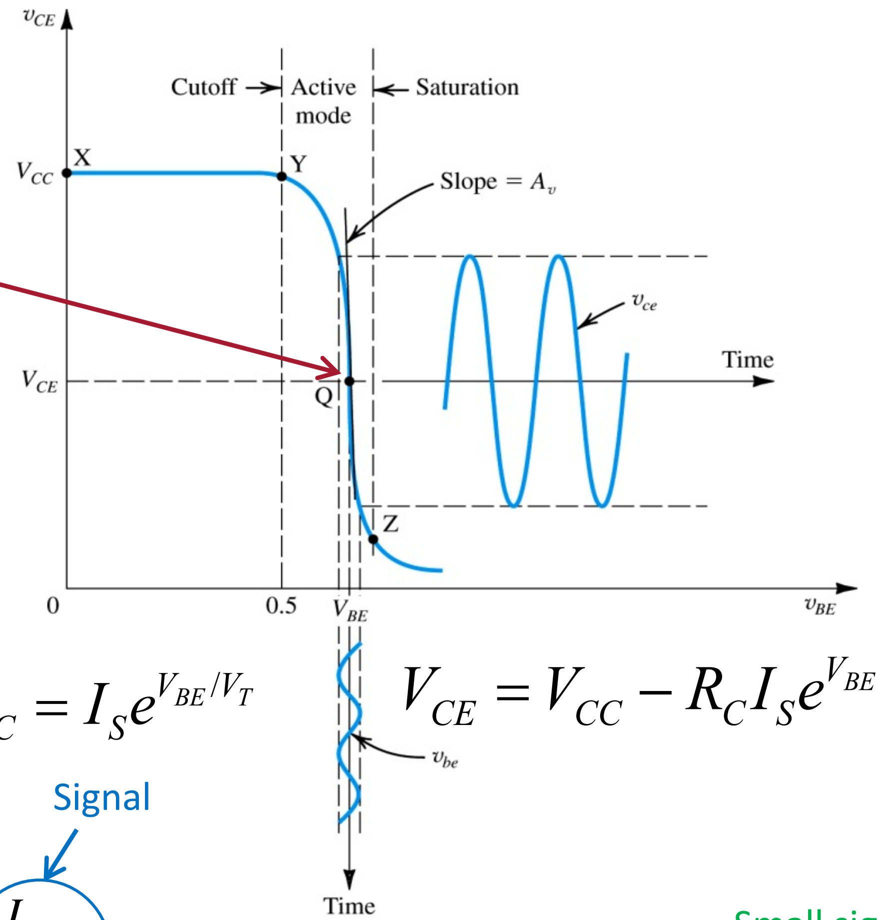
BJT AMPLIFIER

RECAP – FROM ONLINE CONTENT VIDEOS



$$\upsilon_{BE}(t) = V_{BE} + \upsilon_{be}(t)$$

Dc bias to hold BJT in active mode



$$I_C = I_S e^{V_{BE}/V_T} \qquad V_{CE} = V_{CC} - R_C I_S e^{V_{BE}/V_T}$$

$if\, v_{be} \ll V_T$

Bias

Signal

$$i_C = I_S e^{\upsilon_{BE}/V_T} = I_S e^{V_{BE}/V_T} e^{\upsilon_{be}/V_T} \simeq I_C\left(1 + \frac{\upsilon_{be}}{V_T}\right) = I_C + \frac{I_C}{V_T}\upsilon_{be}$$

Small signal gain

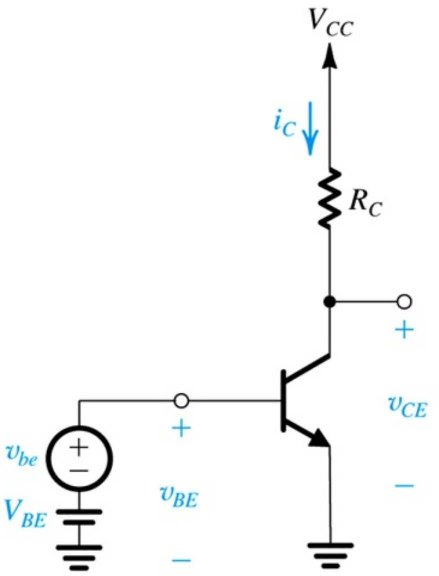
$$\boxed{A_\upsilon = \left.\frac{d\upsilon_{CE}}{d\upsilon_{BE}}\right|_{\upsilon_{BE}=V_{BE}} = -R_C\frac{I_C}{V_T}}$$

Small signal gain

$$v_{CE} = V_{CC} - R_C i_C = V_{CC} - R_C(I_C + \frac{I_C}{V_T}v_{be}) = V_{CE} - R_C\frac{I_C}{V_T}v_{be}$$

BJT AMPLIFIER

BIASING

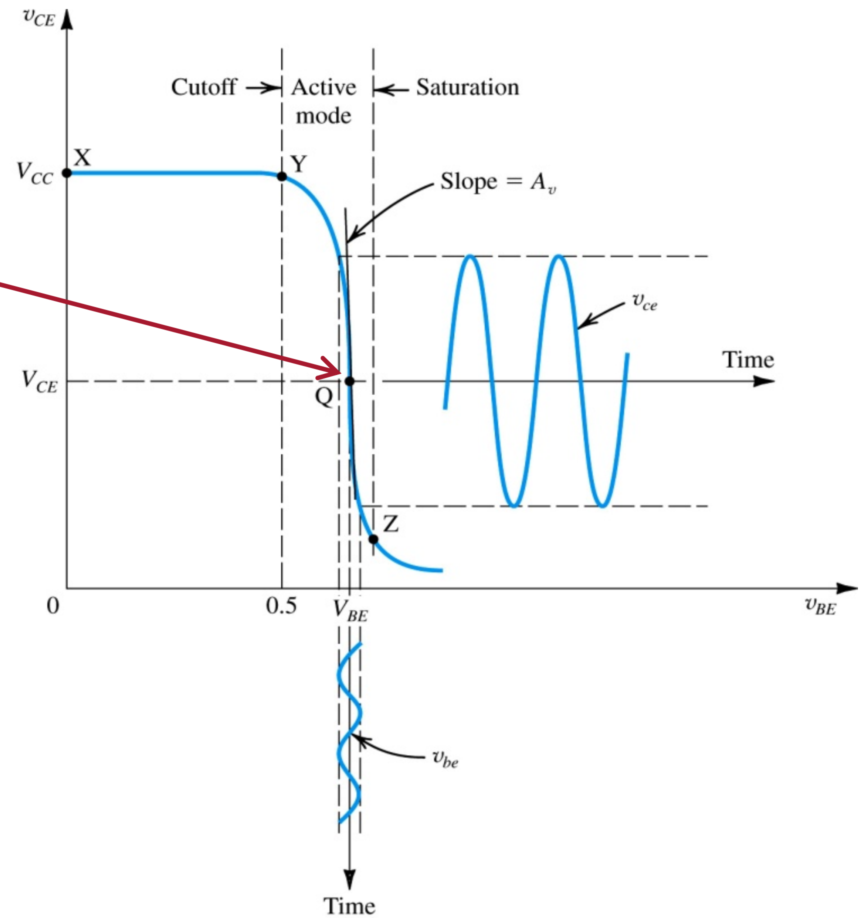


$$v_{BE}(t) = V_{BE} + v_{be}(t)$$

$$v_{be} \ll V_T$$

Small signal voltage gain: $A_v = -R_C \dfrac{I_C}{V_T}$

Dc bias to hold BJT in active mode



- Gain is negative – inverting amplifier
- Gain depends on bias point
- Only valid for small signal!

BJT Small Signal

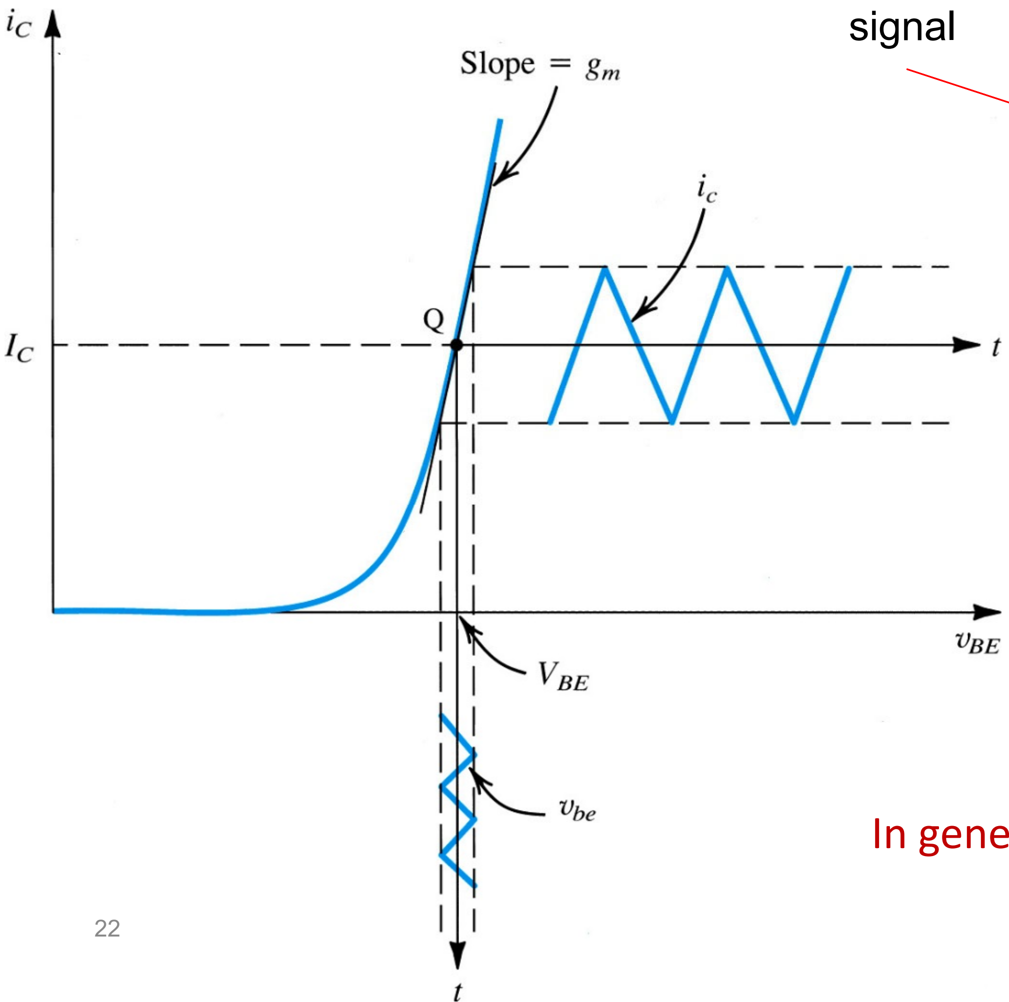
TRANSCONDUCTANCE

Total DC signal

$$i_C = I_C + i_c$$

$$i_C = I_S e^{v_{BE}/V_T} = I_S e^{V_{BE}/V_T} e^{v_{be}/V_T} \simeq I_C \left(1 + \frac{v_{be}}{V_T}\right) = I_C + \frac{I_C}{V_T} v_{be}$$

DC signal



signal

$$i_c = \frac{I_C}{V_T} v_{be}$$

$$i_c = g_m v_{be}$$

$$g_m = \frac{I_C}{V_T}$$

Using truncated Taylor's series approximation for small signals (same as the exponential diode)

In general: $$g_m = \left[\frac{\partial i_C}{\partial v_{BE}}\right]_{i_C = I_C}$$

BJT AMPLIFIER

MORE ON BIASING

Output current and output voltage

DC

$$i_C = I_s e^{v_{BE}/V_T} = I_C e^{v_{be}/V_T} \cong I_C + \frac{I_C}{V_T} v_{be} = I_C + \boxed{g_m v_{be}}$$

$if\, v_{be} \ll V_T$

$$v_{CE} = V_{CC} - R_C i_C = V_{CC} - R_C\left(IC + \frac{I_C}{V_T} v_{be}\right) = V_{CE} - \boxed{R_C \frac{I_C}{V_T} v_{be}}$$

Total (AC+DC) output current
and voltage

AC
(but depends on
DC operating point!)

BJT AMPLIFIER

MORE ON BIASING

Output current and output voltage after passing through capacitors

$$if\, v_{be} \ll V_T$$

$$i_c = g_m v_{be}$$

$$v_{ce} = -R_C \frac{I_C}{V_T} v_{be}$$

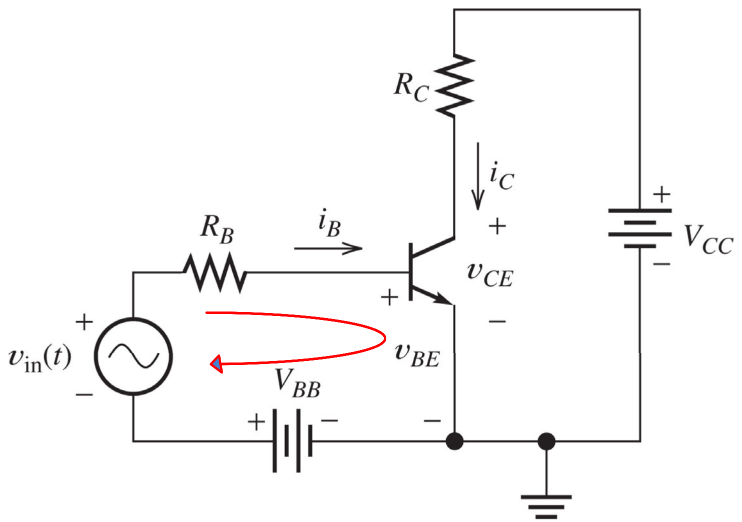
BJT AMPLIFIER

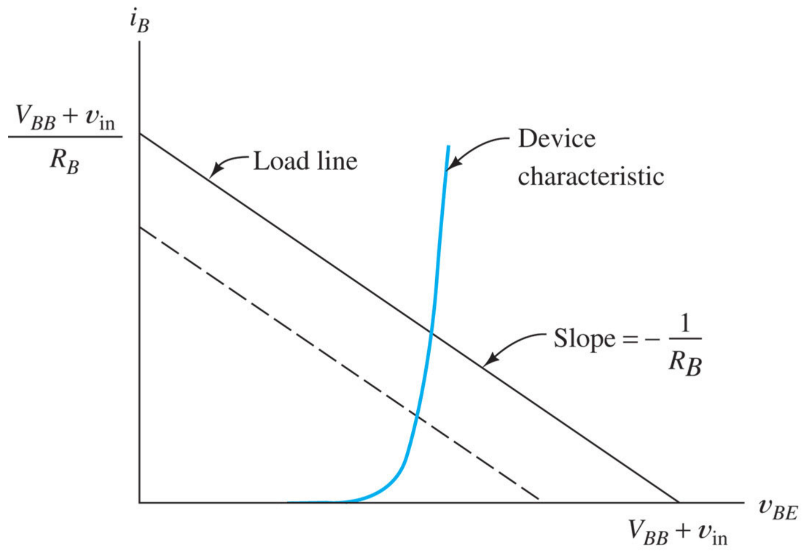
SETTING THE BIAS POINT

Input circuit:

$$V_{BB} + \upsilon_{in}(t) = R_B i_B(t) + \upsilon_{BE}(t)$$

$$i_B(t) = \frac{V_{BB} + \upsilon_{in}(t) - \upsilon_{BE}(t)}{R_B}$$





(a) Input load line (shifts to dashed line for a smaller value of v_{in})

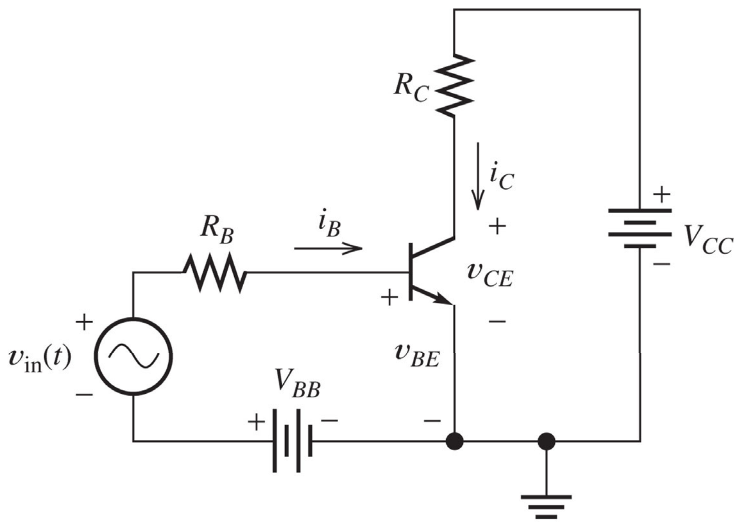
BJT AMPLIFIER

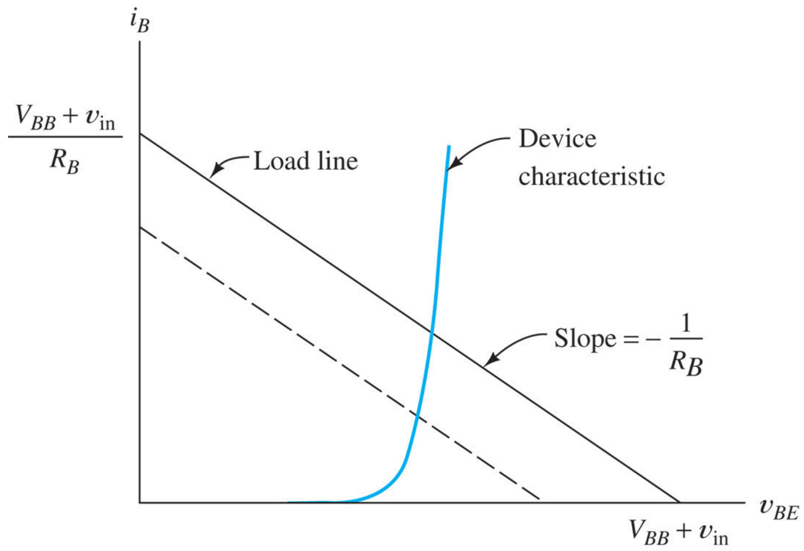
SETTING THE BIAS POINT

Input circuit:

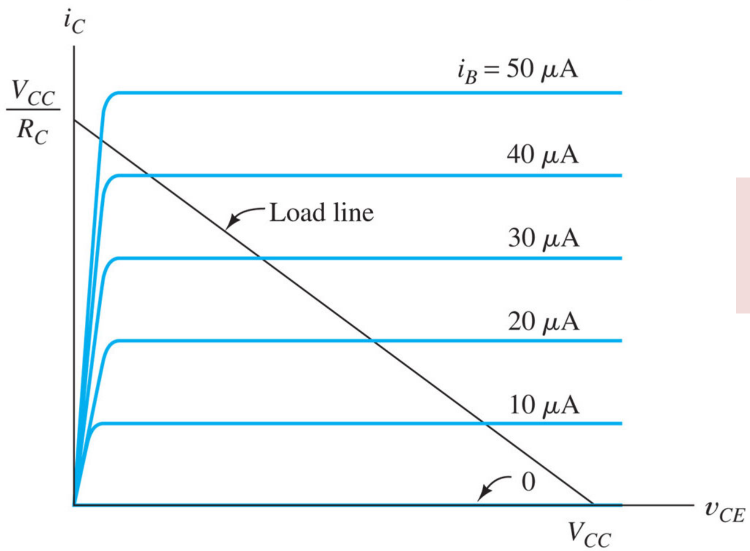
$$V_{BB} + \upsilon_{in}(t) = R_B i_B(t) + \upsilon_{BE}(t)$$

$$i_B(t) = \frac{V_{BB} + \upsilon_{in}(t) - \upsilon_{BE}(t)}{R_B}$$





(a) Input load line (shifts to dashed line for a smaller value of v_{in})



(b) Output

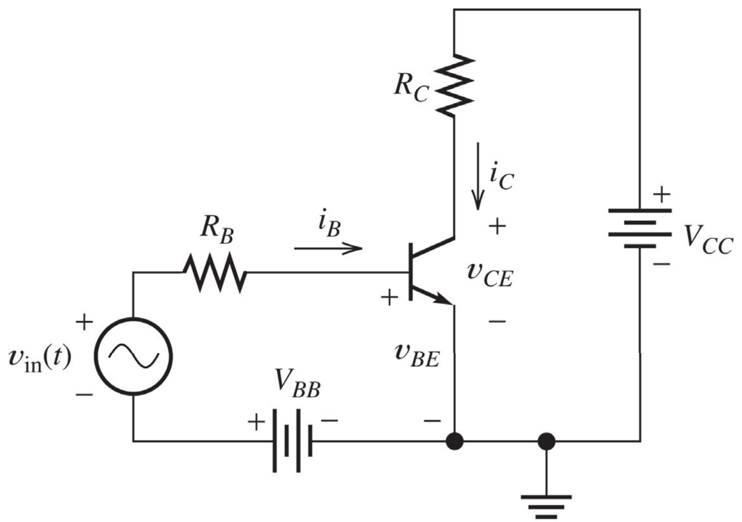
Q point at $\upsilon_{in} = 0$

SETTING THE BIAS POINT

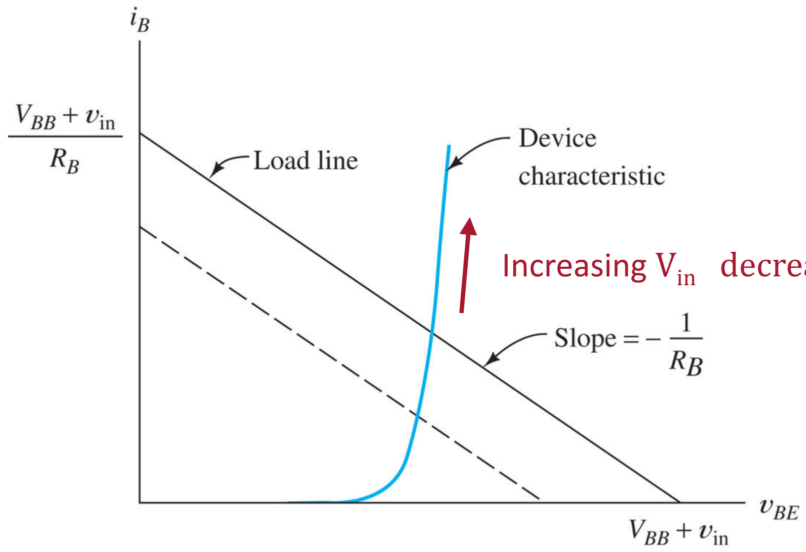
Input circuit:

$$V_{BB} + \upsilon_{in}(t) = R_B i_B(t) + \upsilon_{BE}(t)$$

$$i_B(t) = \frac{V_{BB} + \upsilon_{in}(t) - \upsilon_{BE}(t)}{R_B}$$

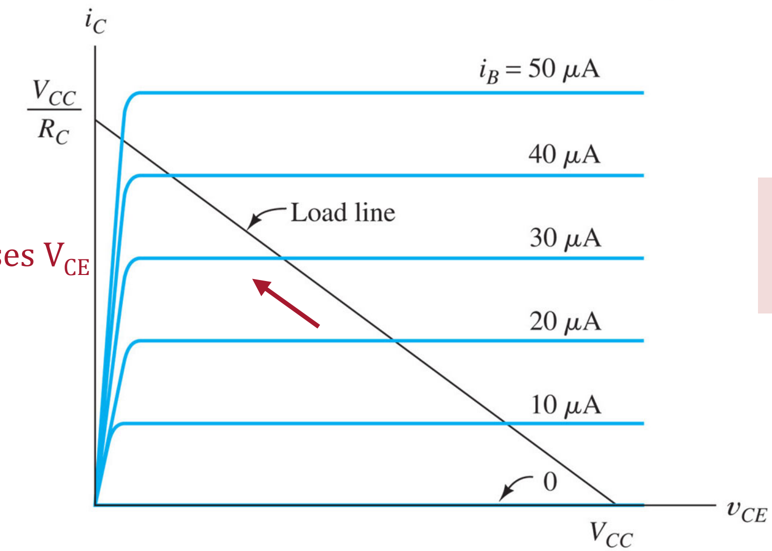


We bias the circuit (set the Q point) assuming 0 small signal voltage



(a) Input load line (shifts to dashed line for a smaller value of v_{in})

Increasing V_{in} decreases V_{CE}

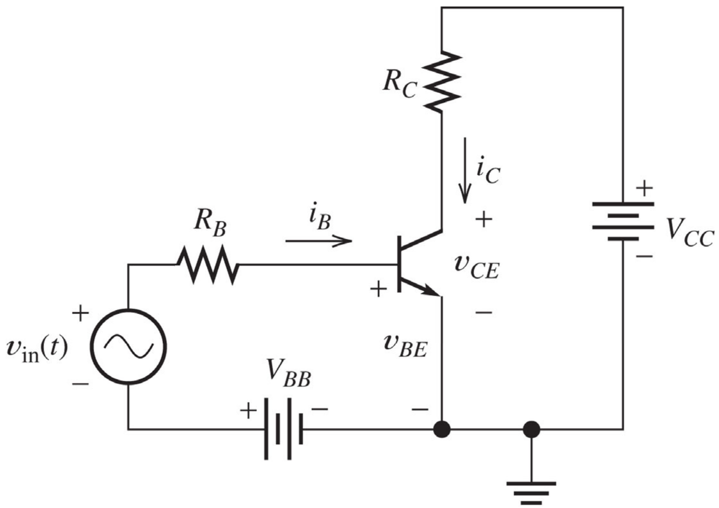


(b) Output

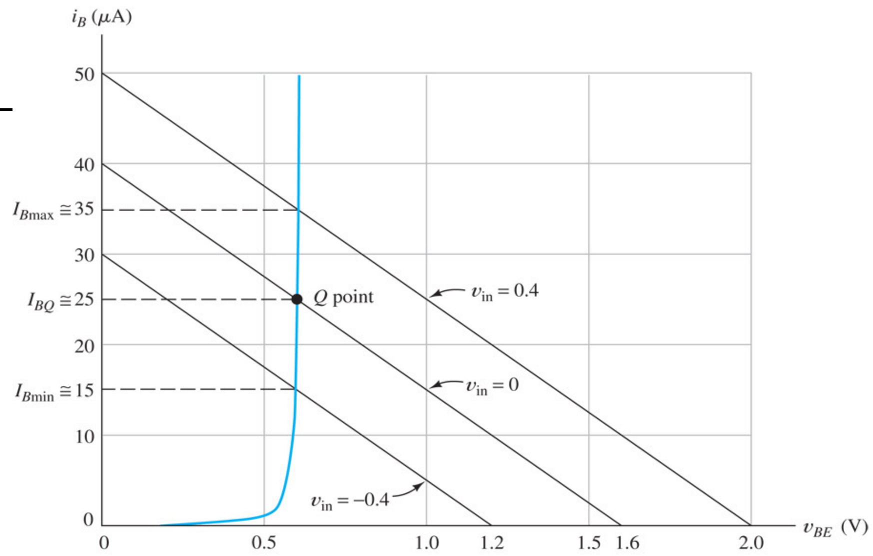
Q point at $\upsilon_{in} = 0$

BJT AMPLIFIER

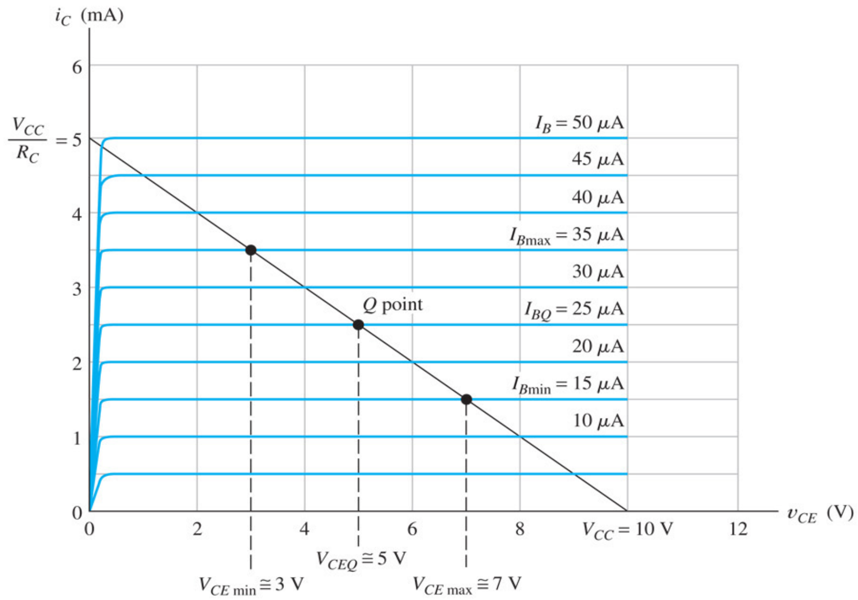
LOAD-LINE ANALYSIS EXAMPLE



$V_{CC} = 10$ V
$V_{BB} = 1.6$ V
$R_B = 40$ KΩ
$R_C = 2$ kΩ
$v_{in}(t) = 0.4 \sin(2000\pi t)$



(a) Input



(b) Output

What is the voltage gain of this amplifier?

0

100 V/V — 0%

5 V/V — 0%

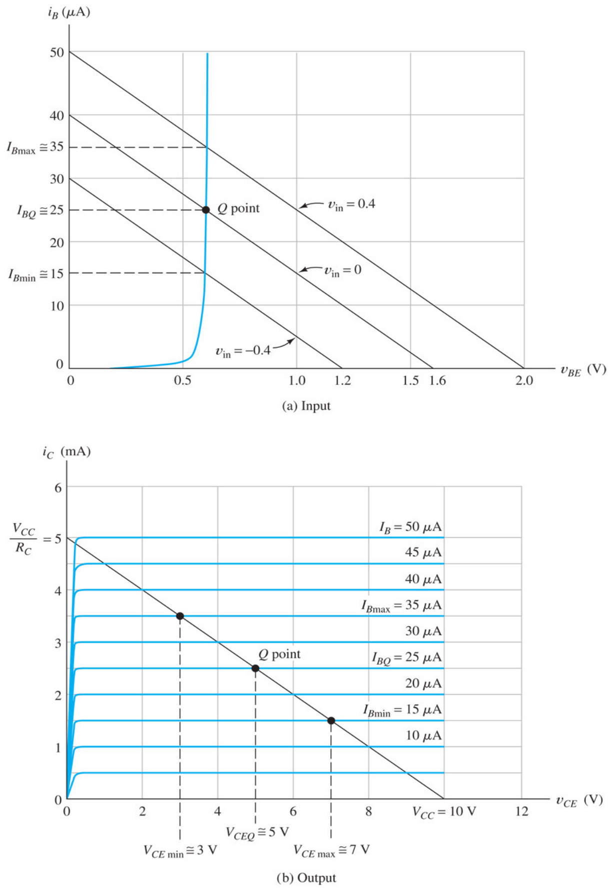
-100 V/V — 0%

-5V/V — 0%

Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

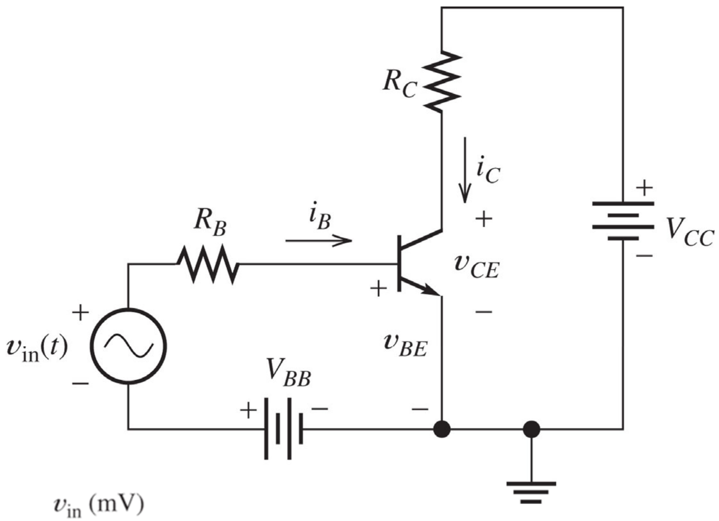
MACQUARIE University

PollEv.com/davidpayne187

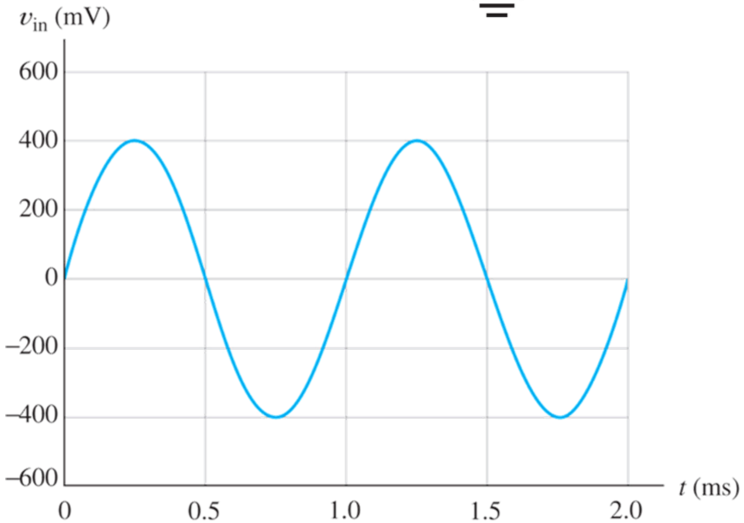


BJT AMPLIFIER

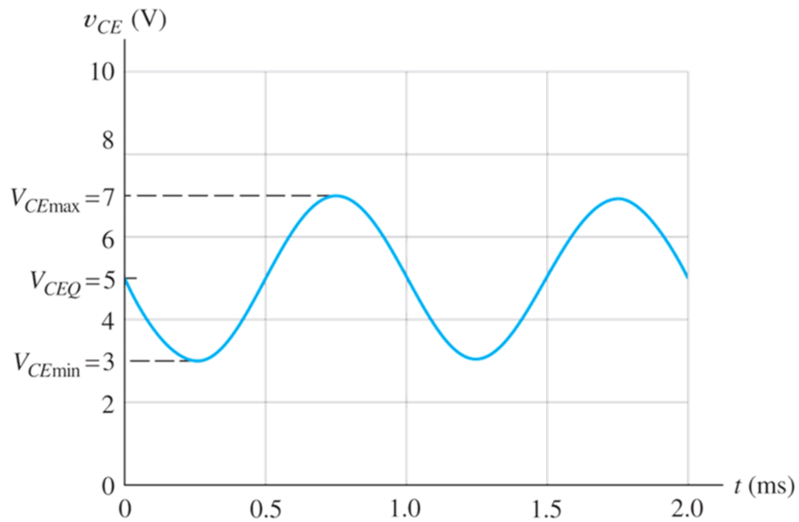
LOAD-LINE ANALYSIS EXAMPLE



$V_{CC} = 10$ V
$V_{BB} = 1.6$ V
$R_B = 40$ KΩ
$R_C = 2$ kΩ
$v_{in}(t) = 0.4 \sin(2000\pi t)$



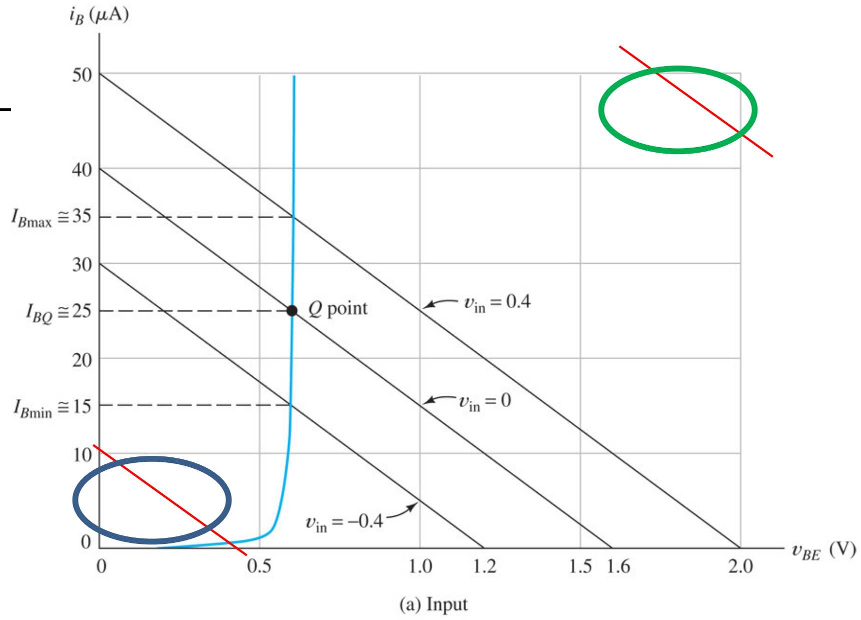
(a) Input



(b) Output

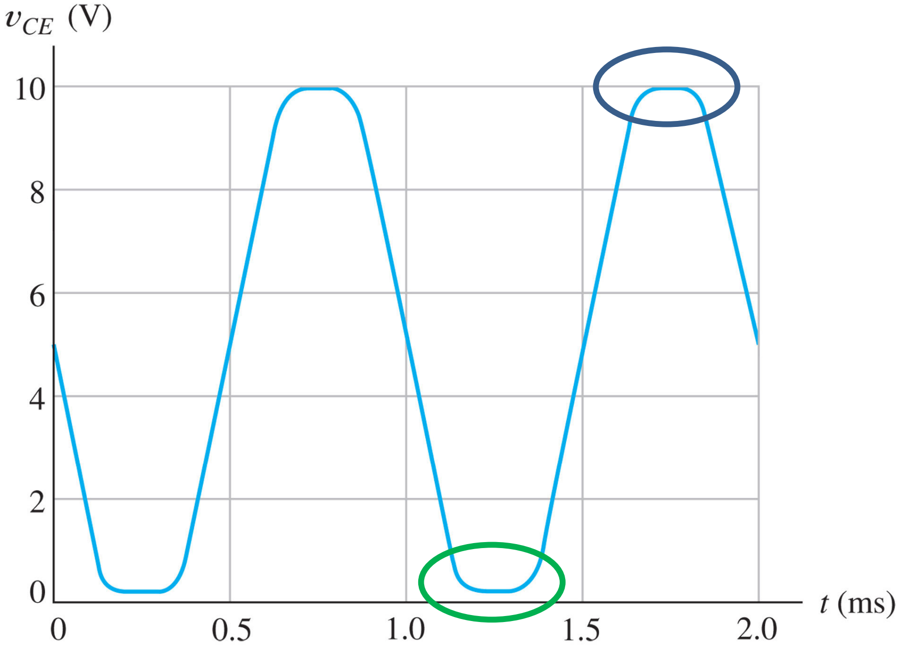
BJT AMPLIFIER

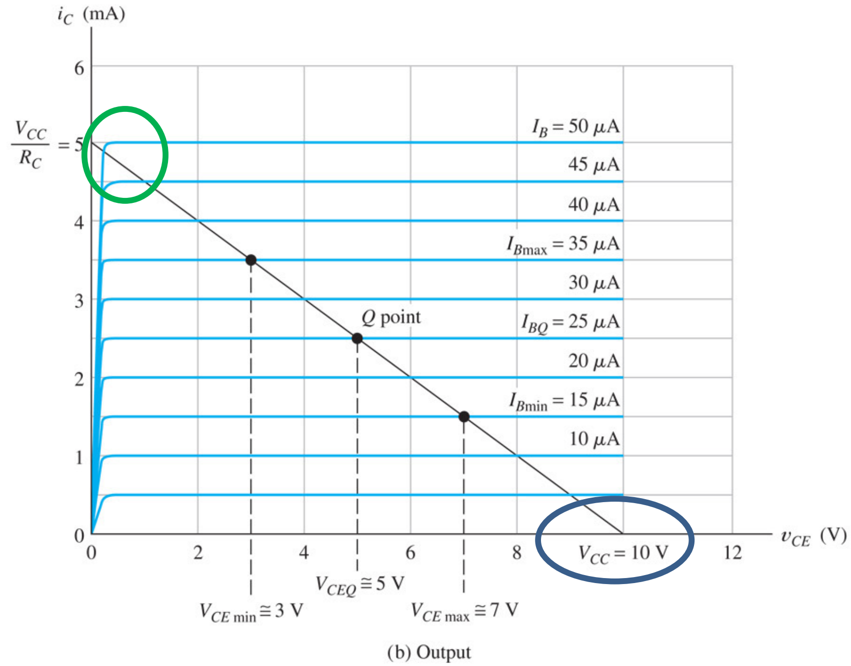
LOAD-LINE ANALYSIS EXAMPLE



(a) Input

$V_{CC} = 10$ V
$V_{BB} = 1.6$ V
$R_B = 40$ KΩ
$R_C = 2$ kΩ
$v_{in}(t) = 1.2 \sin(2000\pi t)$

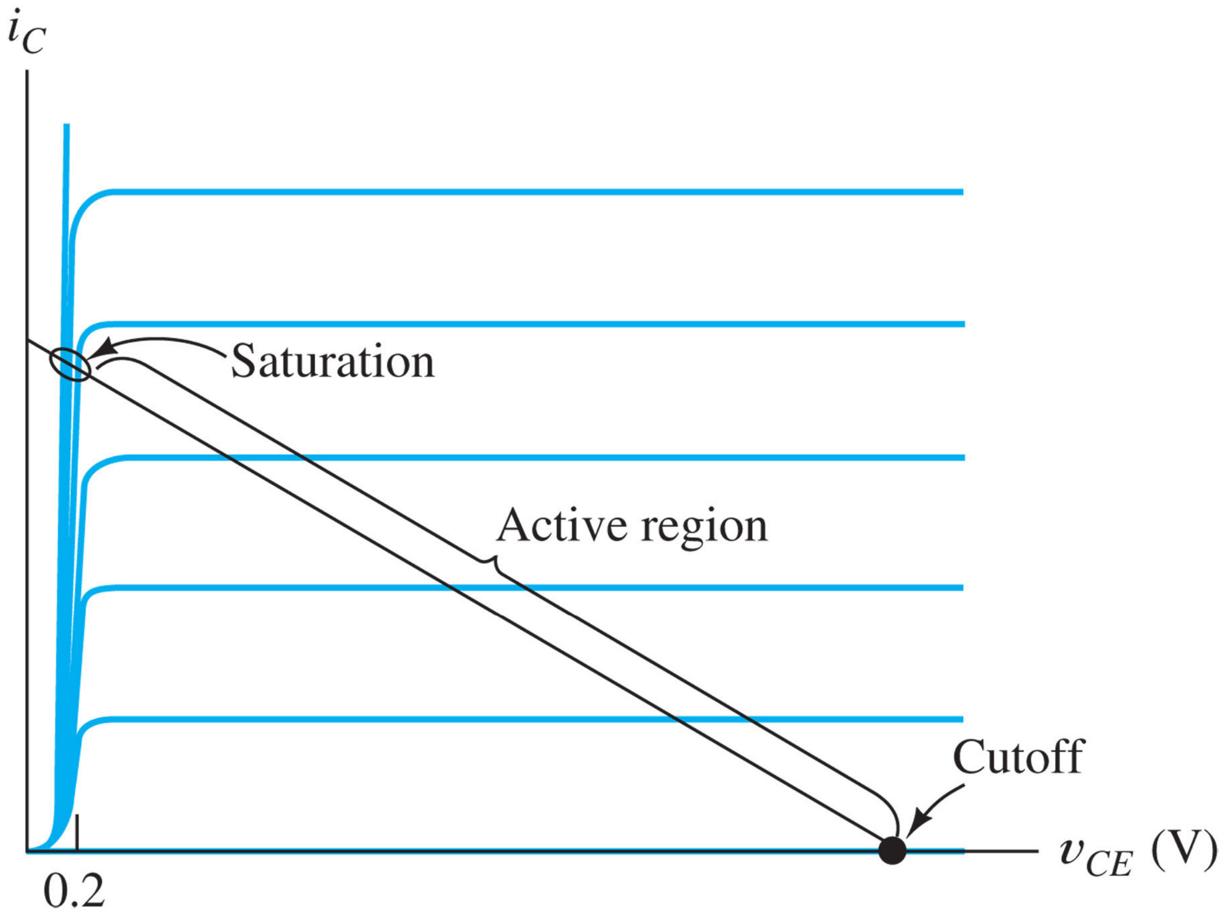




(b) Output

BJT AMPLIFIER

LOAD-LINE ANALYSIS EXAMPLE

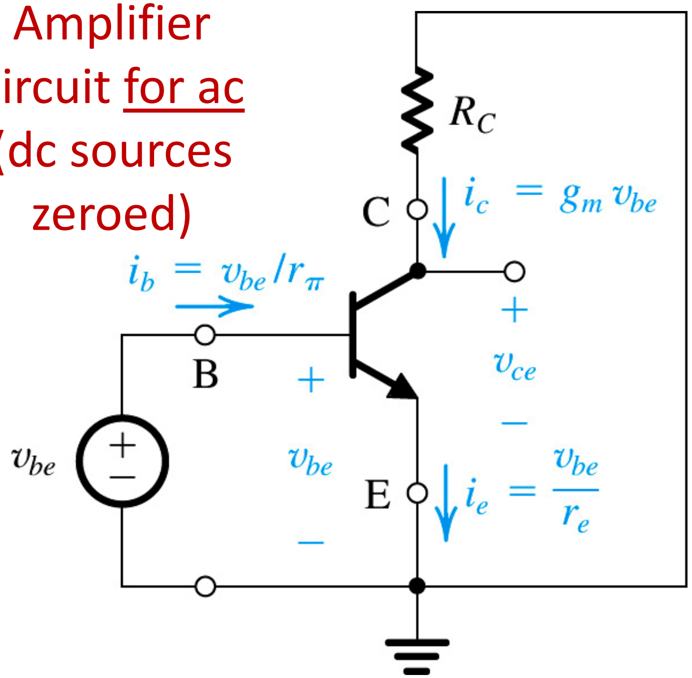


Linear amplification only occurs in the active region

BJT AMPLIFIER

SMALL-SIGNAL AC

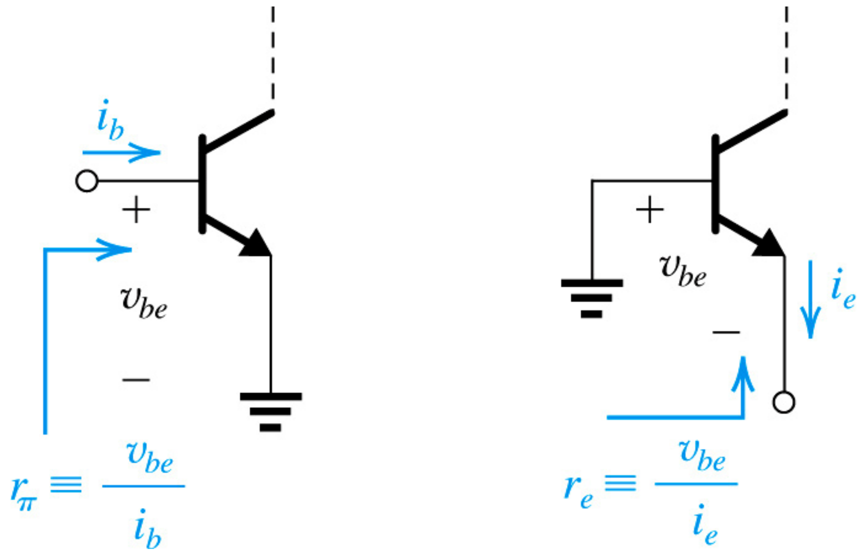
Amplifier circuit for ac (dc sources zeroed)



The amplifier circuit with the dc sources (V_{BE} and V_{CC}) eliminated (short-circuited). Thus only the signal components are present. Note that this is a representation of the signal operation of the BJT and not an actual amplifier circuit.

Small-signal gain of the amplifier

$$v_{ce} = -R_C g_m v_{be} = A_v v_{be}$$



BJT small-signal resistance definitions

BJT Small Signal

RESISTANCE r_π

Small signal resistance looking into the base

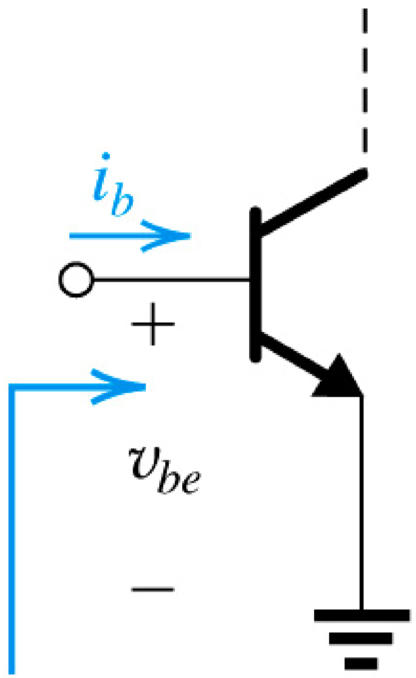
$$i_c = g_m v_{be}$$

$$i_b = \frac{i_c}{\beta} = \frac{g_m}{\beta} v_{be}$$

$$r_\pi = \frac{v_{be}}{i_b}$$

$$r_\pi = \frac{\beta}{g_m} \qquad g_m = \frac{I_C}{V_T}$$

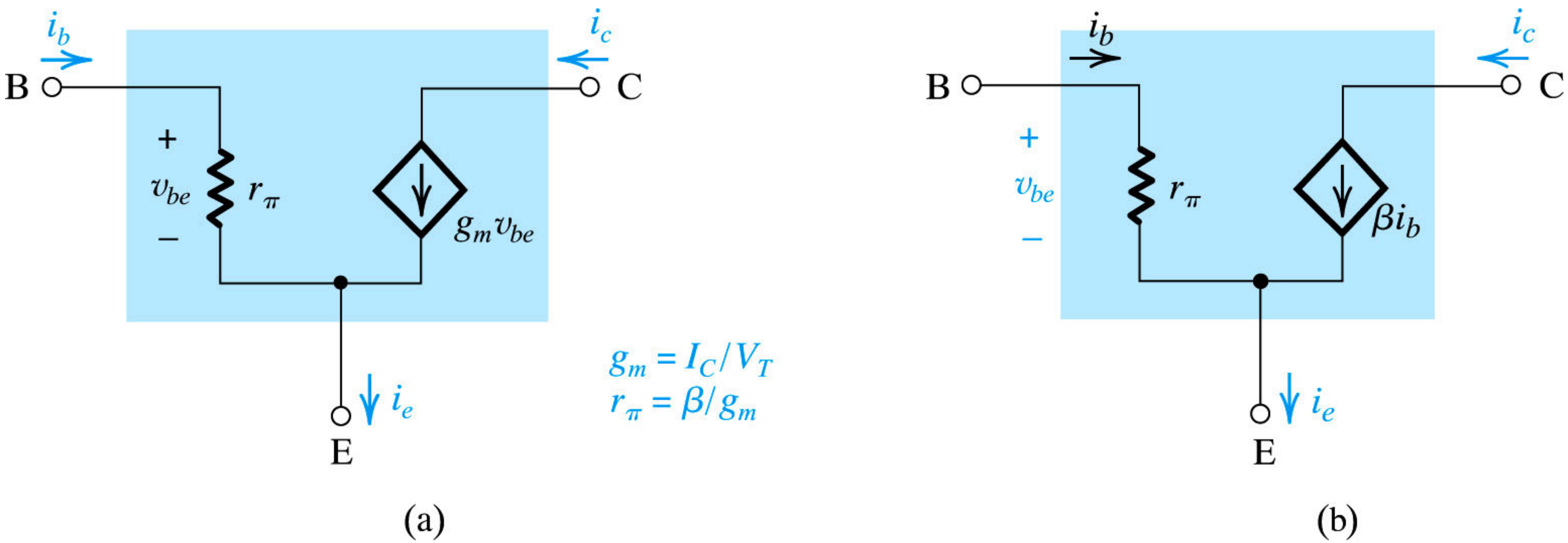
$$r_\pi = \frac{V_T}{I_B}$$



$$r_\pi \equiv \frac{v_{be}}{i_b}$$

BJT Small Signal

MODELS



Two slightly different versions of the hybrid-π model for the small-signal operation of the BJT. The equivalent circuit in **(a)** represents the BJT as a voltage-controlled current source (a transconductance amplifier), and that in **(b)** represents the BJT as a current-controlled current source (a current amplifier).

BJT Small Signal

RESISTANCE r_e

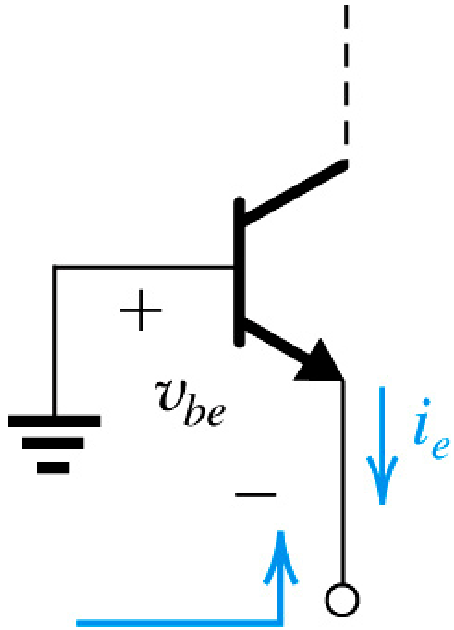
$$i_c = \frac{I_C}{V_T} v_{be}$$

$$i_e = \frac{i_c}{\alpha} = \frac{I_C}{\alpha V_T} v_{be} = \frac{I_E}{V_T} v_{be}$$

$$r_e = \frac{v_{be}}{i_e}$$

$$r_e = \frac{V_T}{I_E} = \frac{\alpha V_T}{I_C} = \frac{\alpha}{g_m} \simeq \frac{1}{g_m}$$

Small signal resistance looking into the emitter



$$r_e \equiv \frac{v_{be}}{i_e}$$

BJT Small Signal

MODELS

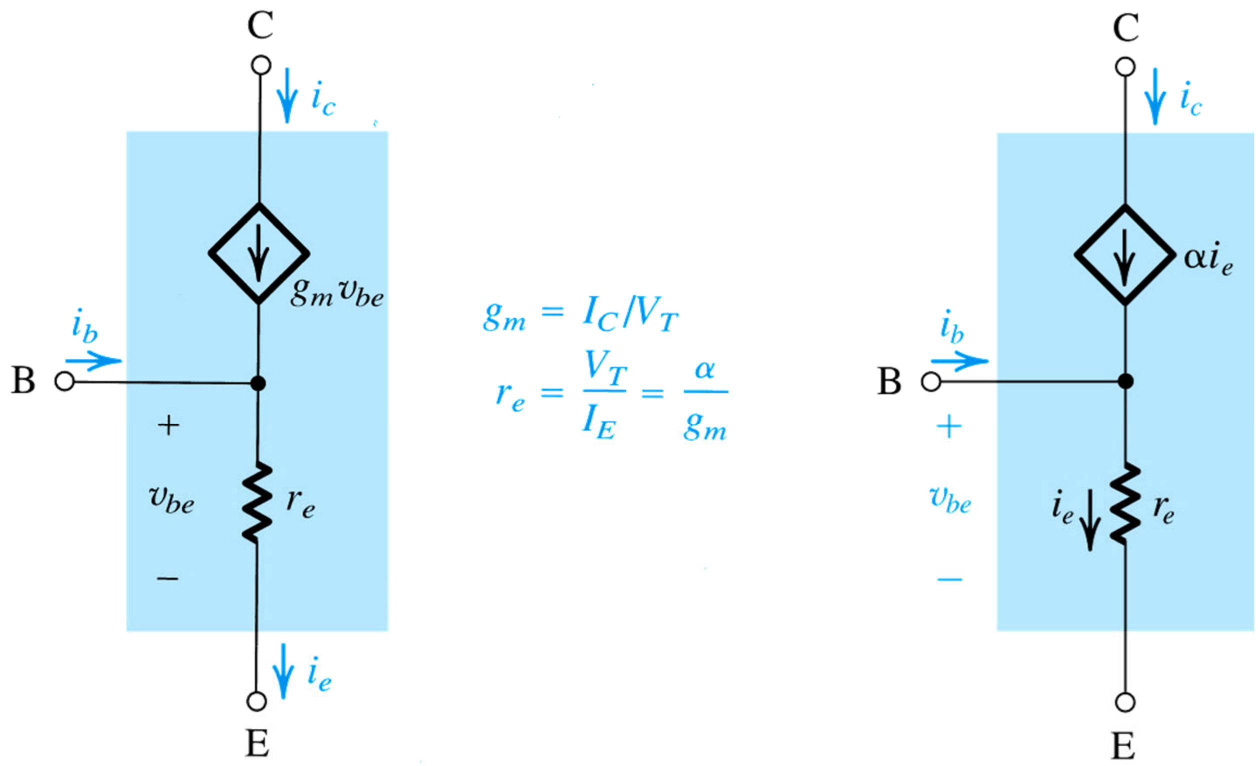


Figure 6.41 Two slightly different versions of what is known as the *T model* of the BJT. The circuit in **(a)** is a voltage-controlled current source representation and that in **(b)** is a current-controlled current source representation. These models explicitly show the emitter resistance *re* rather than the base resistance r_π featured in the hybrid-π model.

Which is the larger value, r.pi or r.e?

0

r.pi

0%

r.e

0%

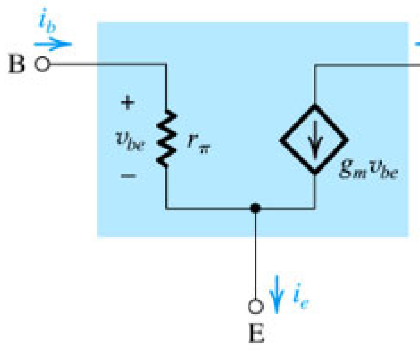
Both are equal

0%

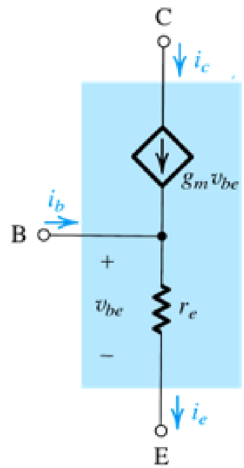
Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

MACQUARIE University

PollEv.com/davidpayne187



$g_m = I_C / V_T$
$r_\pi = \beta / g_m$



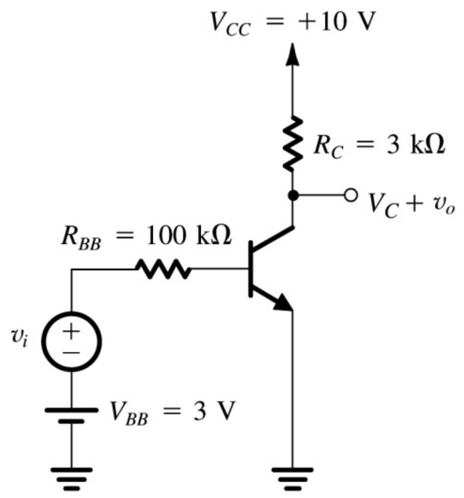
$g_m = I_C / V_T$
$r_e = \frac{V_T}{I_E} = \frac{\alpha}{g_m}$

BJT Small Signal

EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



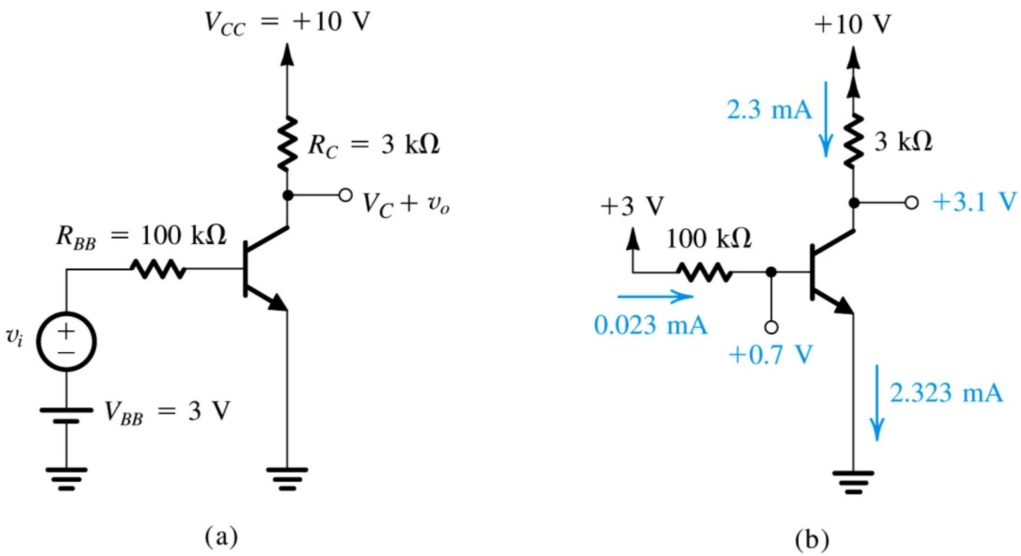
(a)

BJT Small Signal

EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details

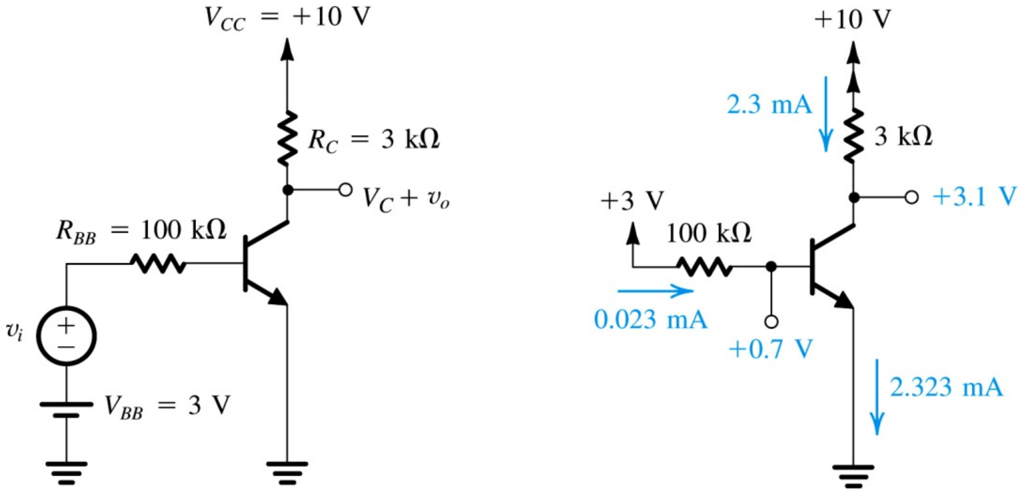


BJT Small Signal

EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



(a) (b)

$$g_m = \frac{I_C}{V_T} = \frac{2.3 \text{ mA}}{25 \text{ mV}} = 92 \text{ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{92} \text{ k}\Omega = 1.09 \text{ k}\Omega$$

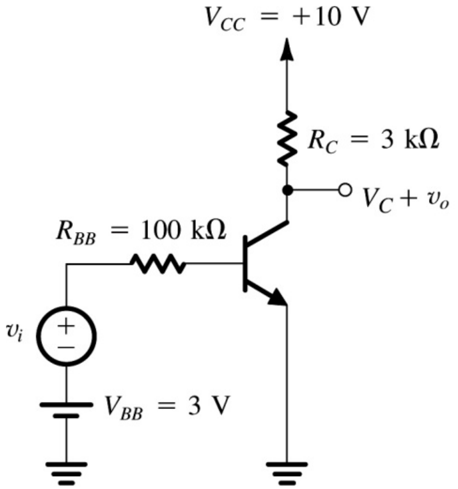
$$r_e = \frac{V_T}{I_E} = \frac{25 \text{ mV}}{(2.3/0.99) \text{ mA}} = 10.8\ \Omega$$

BJT Small Signal

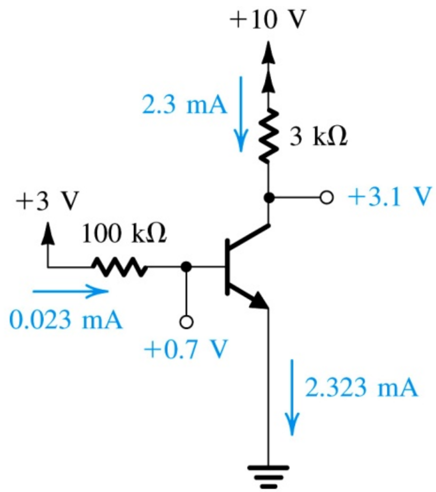
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



(a)

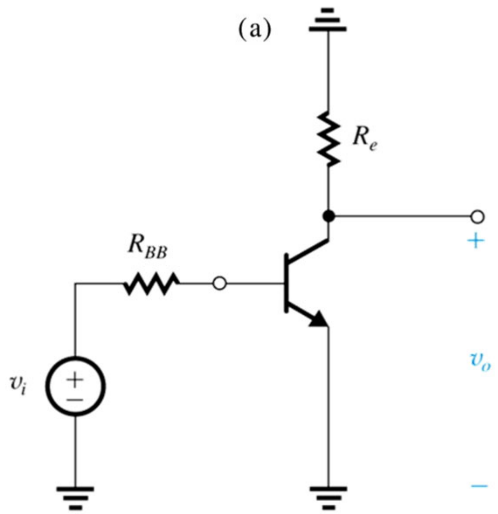


(b)

$$g_m = \frac{I_C}{V_T} = \frac{2.3\text{ mA}}{25\text{ mV}} = 92\text{ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{92}\text{ k}\Omega = 1.09\text{ k}\Omega$$

$$r_e = \frac{V_T}{I_E} = \frac{25\text{ mV}}{(2.3/0.99)\text{ mA}} = 10.8\ \Omega$$



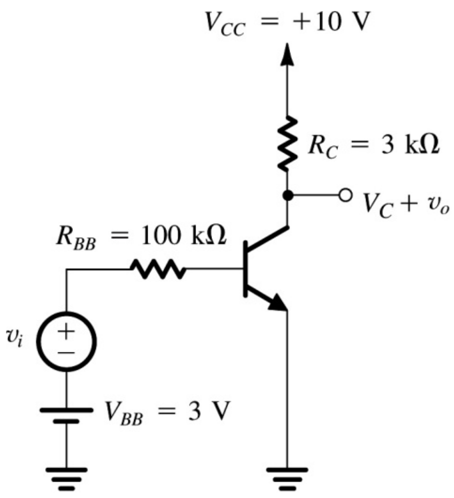
(c)

BJT Small Signal

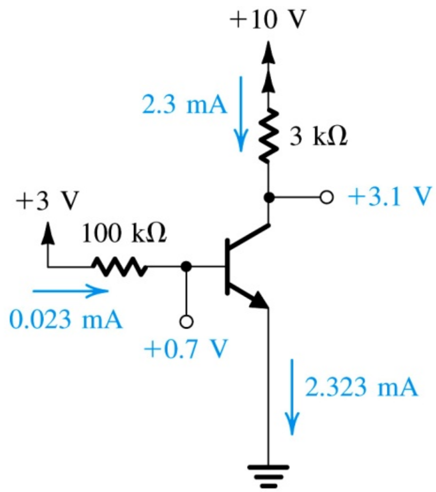
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



(a)

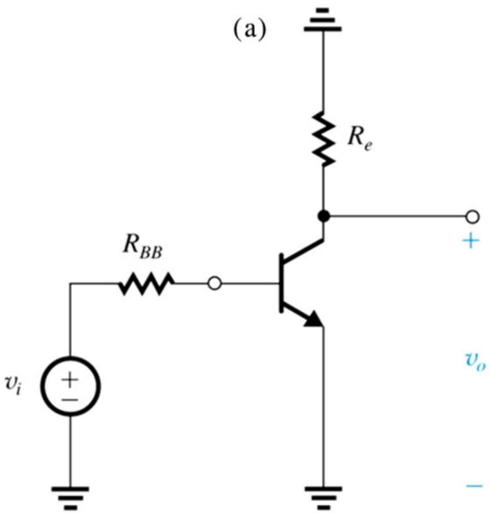


(b)

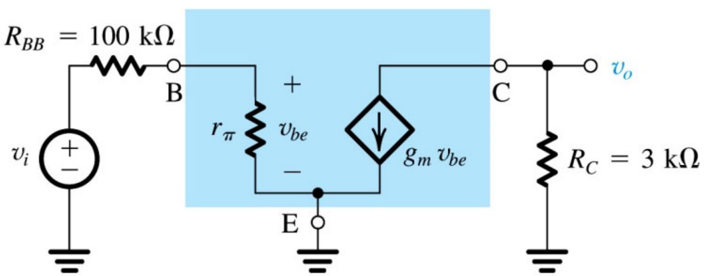
$$g_m = \frac{I_C}{V_T} = \frac{2.3\text{ mA}}{25\text{ mV}} = 92\text{ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{92}\text{ k}\Omega = 1.09\text{ k}\Omega$$

$$r_e = \frac{V_T}{I_E} = \frac{25\text{ mV}}{(2.3/0.99)\text{ mA}} = 10.8\ \Omega$$



(c)



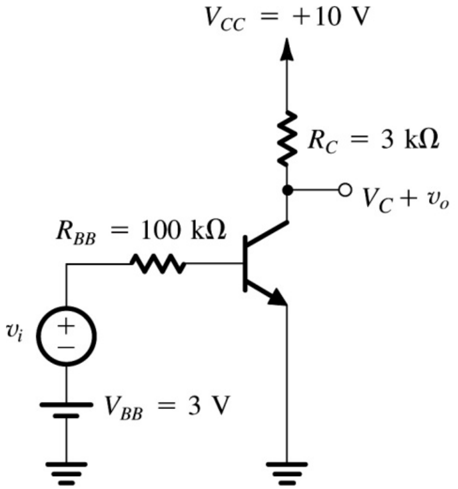
(d)

BJT Small Signal

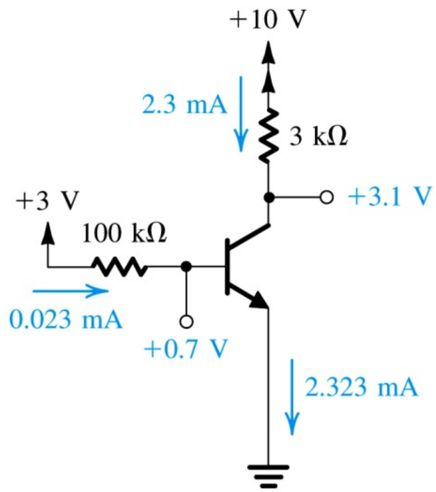
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



(a)

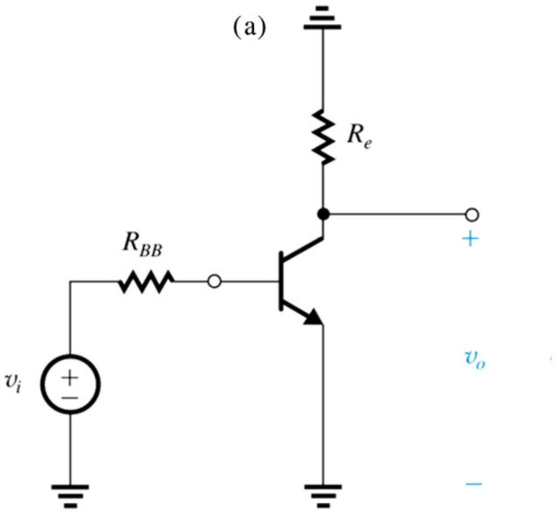


(b)

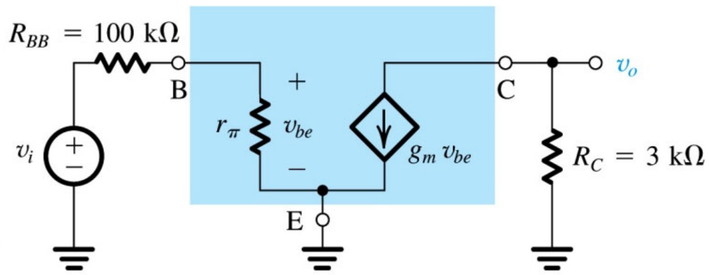
$$g_m = \frac{I_C}{V_T} = \frac{2.3\ \text{mA}}{25\ \text{mV}} = 92\ \text{mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{92}\ \text{k}\Omega = 1.09\ \text{k}\Omega$$

$$r_e = \frac{V_T}{I_E} = \frac{25\ \text{mV}}{(2.3/0.99)\ \text{mA}} = 10.8\ \Omega$$



(c)



(d)

$$\upsilon_{be} = \upsilon_i \frac{r_\pi}{R_{BB} + r_\pi} = 0.011\upsilon_i$$

$$\upsilon_o = -R_C g_m \upsilon_{be} = -3.04\upsilon_i$$

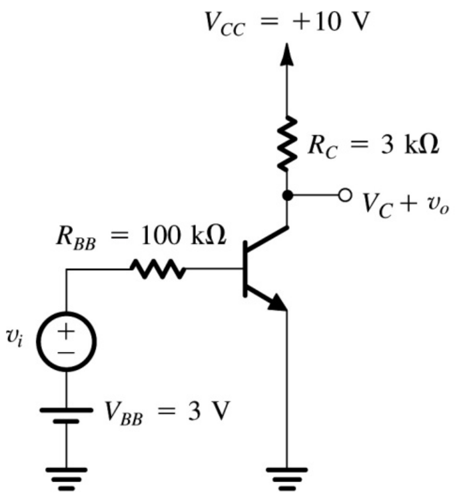
$$A_\upsilon = \frac{\upsilon_o}{\upsilon_i} = -3.04$$

BJT Small Signal

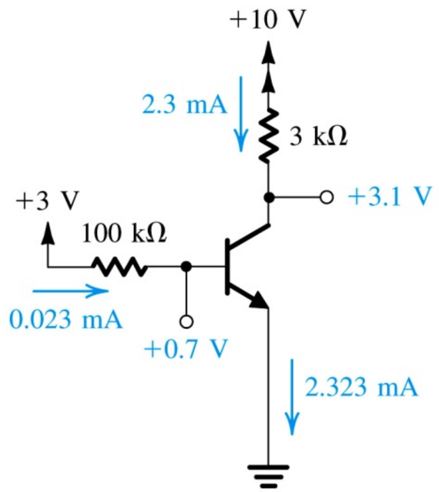
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



(a)

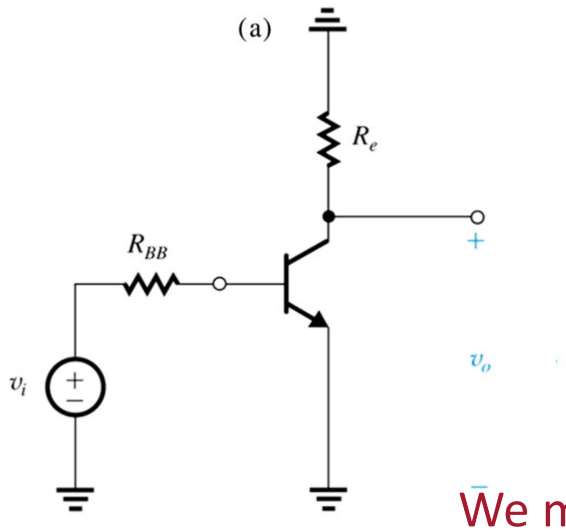


(b)

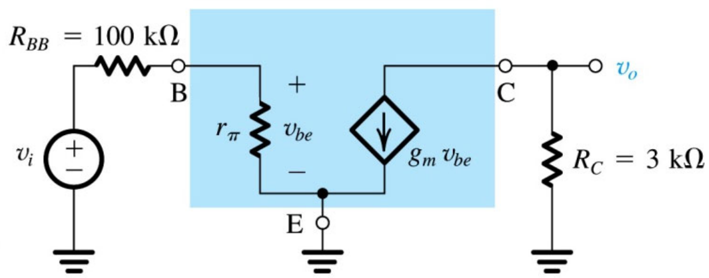
$$g_m = \frac{I_C}{V_T} = \frac{2.3\text{ mA}}{25\text{ mV}} = 92\text{ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{92}\text{ k}\Omega = 1.09\text{ k}\Omega$$

$$r_e = \frac{V_T}{I_E} = \frac{25\text{ mV}}{(2.3/0.99)\text{ mA}} = 10.8\ \Omega$$



(c)



(d)

$$\upsilon_{be} = \upsilon_i \frac{r_\pi}{R_{BB} + r_\pi} = 0.011\upsilon_i$$

$$\upsilon_o = -R_C g_m \upsilon_{be} = -3.04\upsilon_i$$

$$A_\upsilon = \frac{\upsilon_o}{\upsilon_i} = -3.04$$

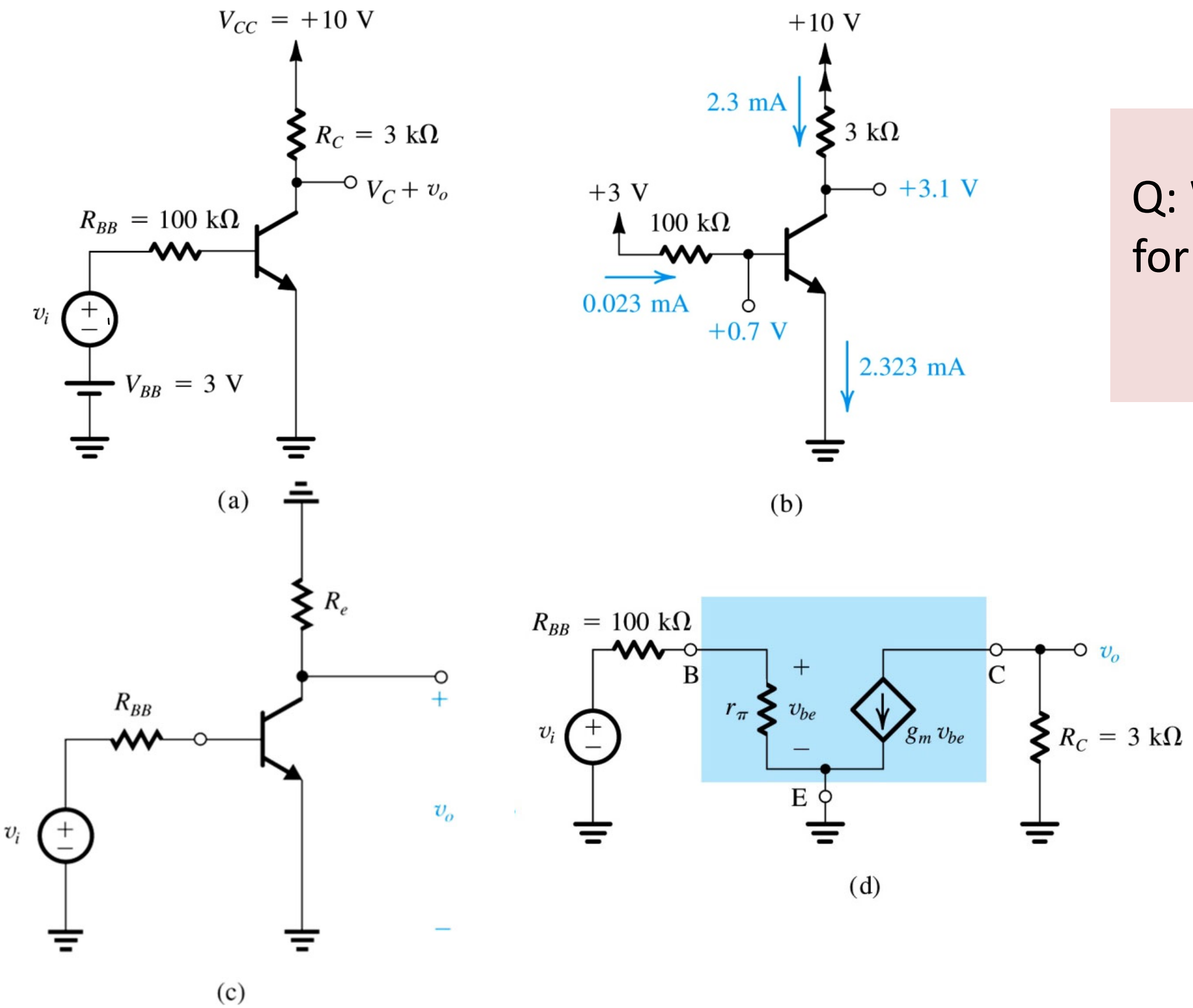
We must make sure the BJT *remains* in active mode!

BJT Small Signal

EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.14 for more details



Q: What is the criterion for the BJT to remain in active mode?

$$\upsilon_{be} = \upsilon_i \frac{r_\pi}{R_{BB} + r_\pi} = 0.011\upsilon_i$$

$$\upsilon_o = -R_C g_m \upsilon_{be} = -3.04\upsilon_i$$

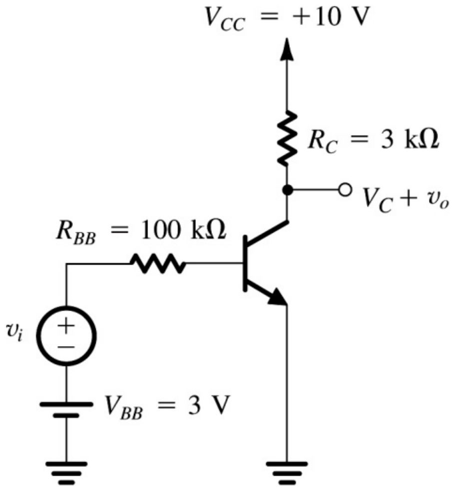
$$A_\upsilon = \frac{\upsilon_o}{\upsilon_i} = -3.04$$

BJT Small Signal

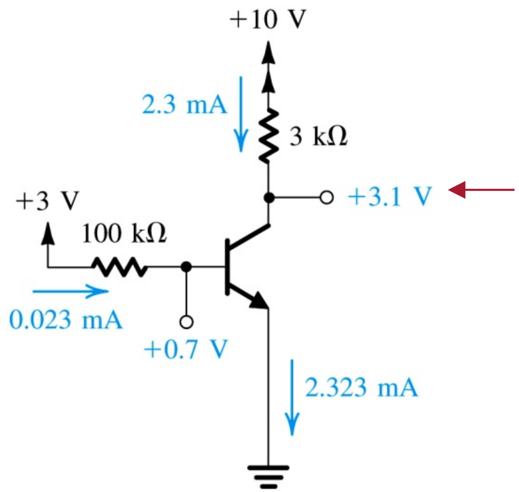
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.15 for more details



(a)



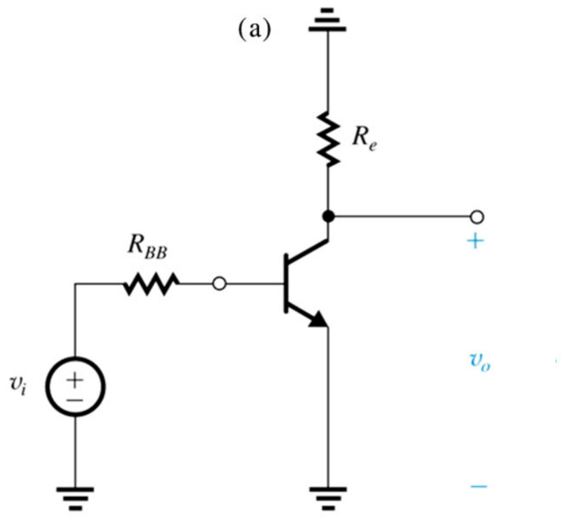
(b)

>0.4 V

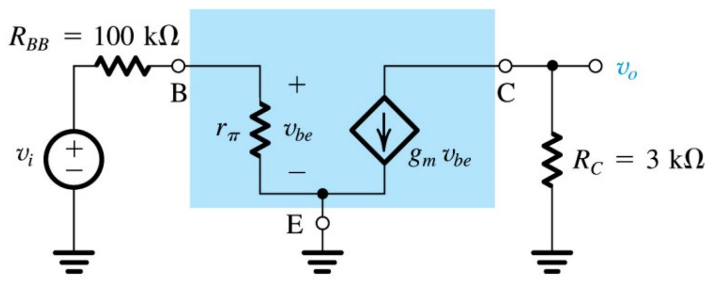
$$\upsilon_o = 2.7\text{ V} \quad \text{(swing)}$$

$$\upsilon_i = \upsilon_o / \text{gain} = 0.88\text{ V}$$

$$\upsilon_{be} = 0.011\upsilon_i = 9.6\text{ mV}$$



(c)



(d)

$$\upsilon_{be} = \upsilon_i \frac{r_\pi}{R_{BB} + r_\pi} = 0.011\upsilon_i$$

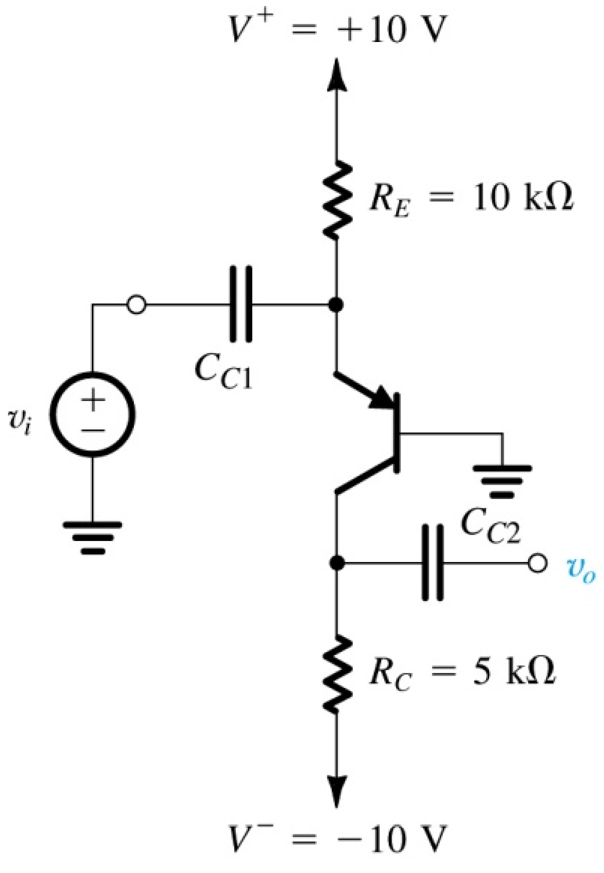
$$\upsilon_o = -R_C g_m \upsilon_{be} = -3.04\upsilon_i$$

$$A_\upsilon = \frac{\upsilon_o}{\upsilon_i} = -3.04$$

BJT Small Signal

EXAMPLE

Find the voltage gain of the following amplifier (β=100)



(a)

What type of amplifier configuration is this?

Common Emitter

0%

Common Base

0%

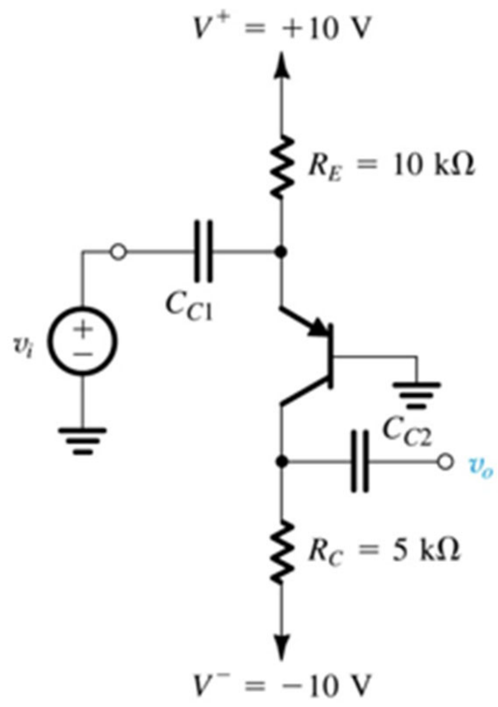
Common Collector

0%

Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

MACQUARIE University

PollEv.com/davidpayne187

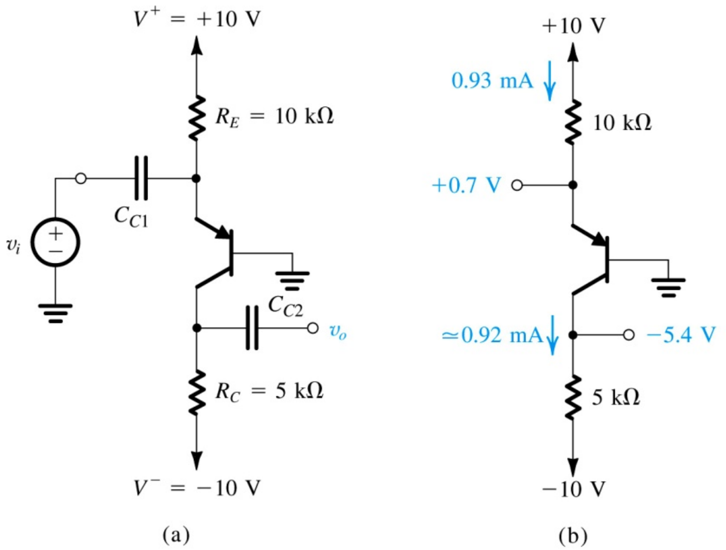


BJT Small Signal

EXAMPLE

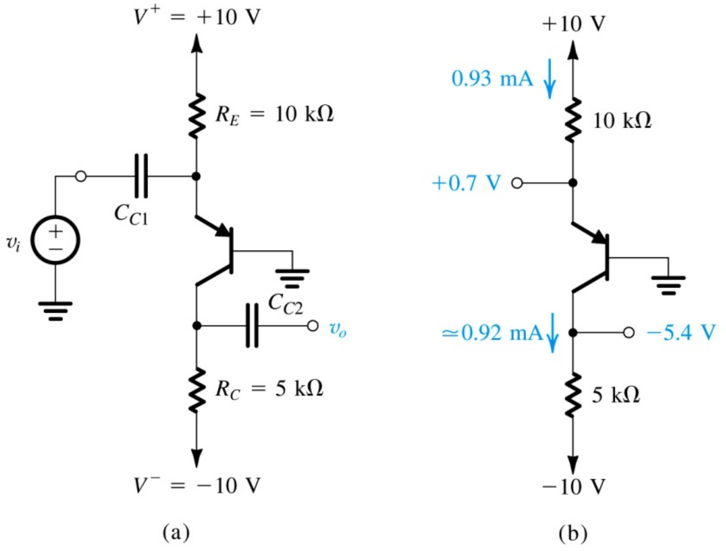
Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.16 for more details



Find the voltage gain of the following amplifier (β=100)

See Sedra example 6.16 for more details



$$g_m = \frac{I_C}{V_T} = \frac{0.92 \text{ mA}}{0.025 \text{ V}} = 36.8 \text{ mA/V}$$

$$r_e = \frac{V_T}{I_E} = \frac{0.025 \text{ V}}{0.92 \text{ mA}} = 27.2\ \Omega$$

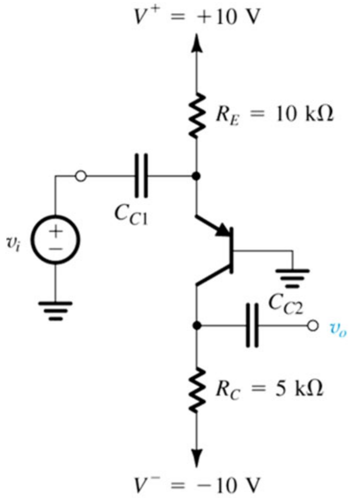
$$\beta = 100 \qquad \alpha = 0.99$$

BJT Small Signal

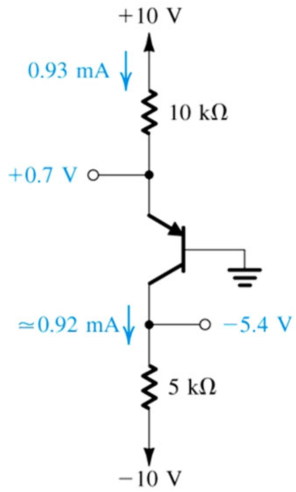
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

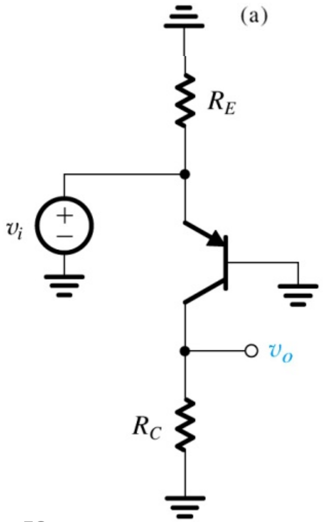
See Sedra example 6.16 for more details



(a)



(b)



(c)

$$g_m = \frac{I_C}{V_T} = \frac{0.92 \text{ mA}}{0.025 \text{ V}} = 36.8 \text{ mA/V}$$

$$r_e = \frac{V_T}{I_E} = \frac{0.025 \text{ V}}{0.92 \text{ mA}} = 27.2\ \Omega$$

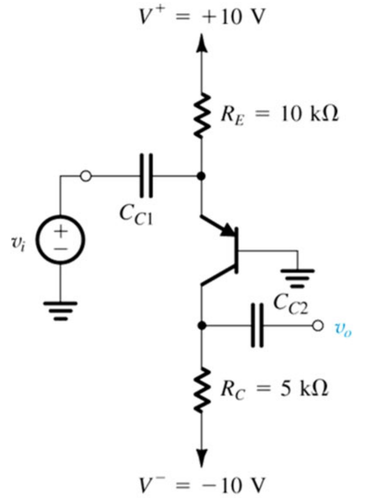
$$\beta = 100 \qquad \alpha = 0.99$$

BJT Small Signal

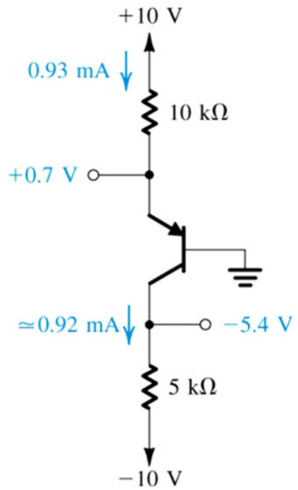
EXAMPLE

Find the voltage gain of the following amplifier (β=100)

See Sedra example 4.16 for more details



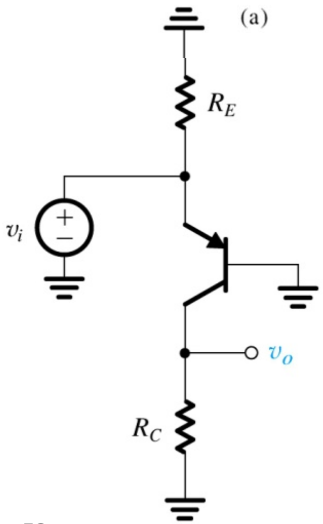
(a)



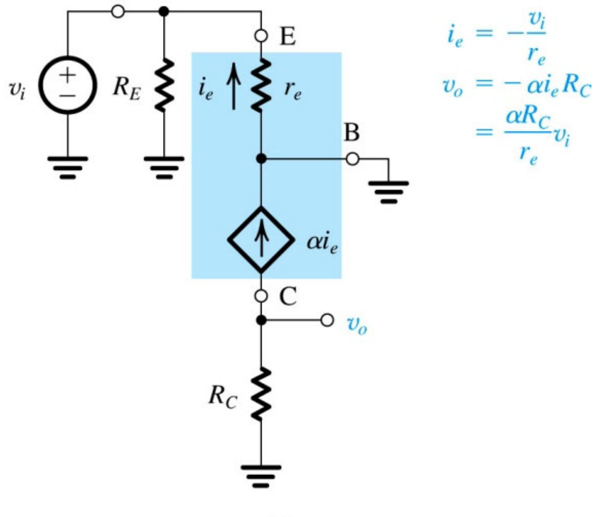
$$g_m = \frac{I_C}{V_T} = \frac{0.92 \text{ mA}}{0.025 \text{ V}} = 36.8 \text{ mA/V}$$

$$r_e = \frac{V_T}{I_E} = \frac{0.025 \text{ V}}{0.92 \text{ mA}} = 27.2\ \Omega$$

$$\beta = 100 \qquad \alpha = 0.99$$



(c)



(d)

$$i_e = -\frac{v_i}{r_e}$$

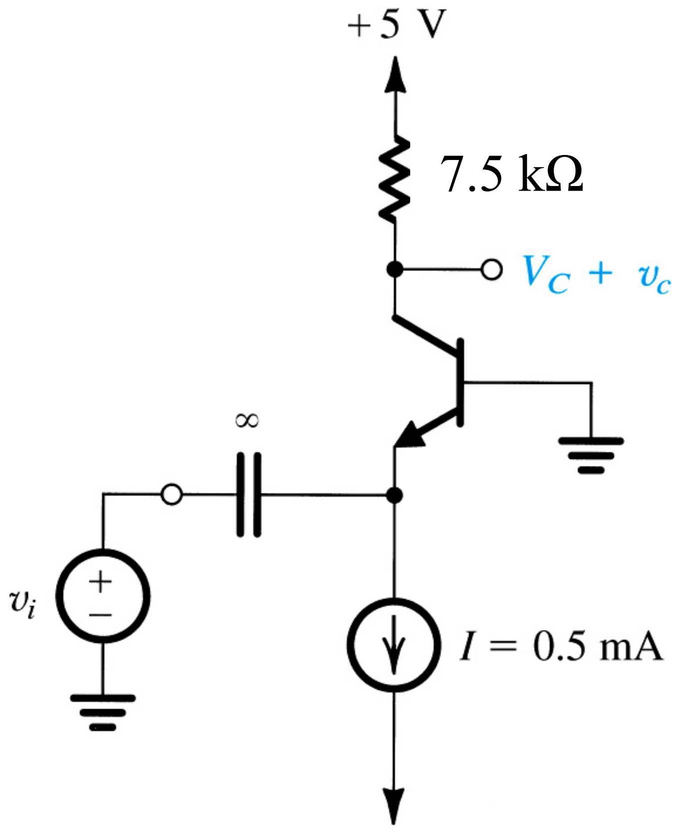
$$v_o = -\alpha i_e R_C = \alpha R_C \frac{v_i}{r_e}$$

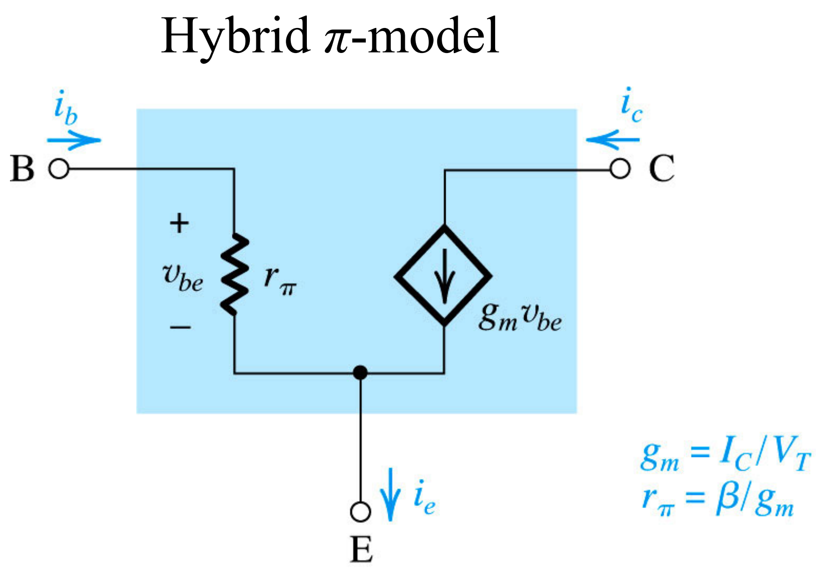
$$A_v = \frac{v_o}{v_i} = 182$$

BJT Small Signal

BIASING WITH A CURRENT SOURCE

The transistor amplifier below is biased with a current source and has a very high β. Find the dc voltage at the collector, V_C. Find the value of g_m.
Replace the transistor with the simplifier hybrid π-model shown and use it to find the voltage gain.





(a)

This week

TUTORIAL + FIRST ASSIGNMENT

Tutorial Workshop:

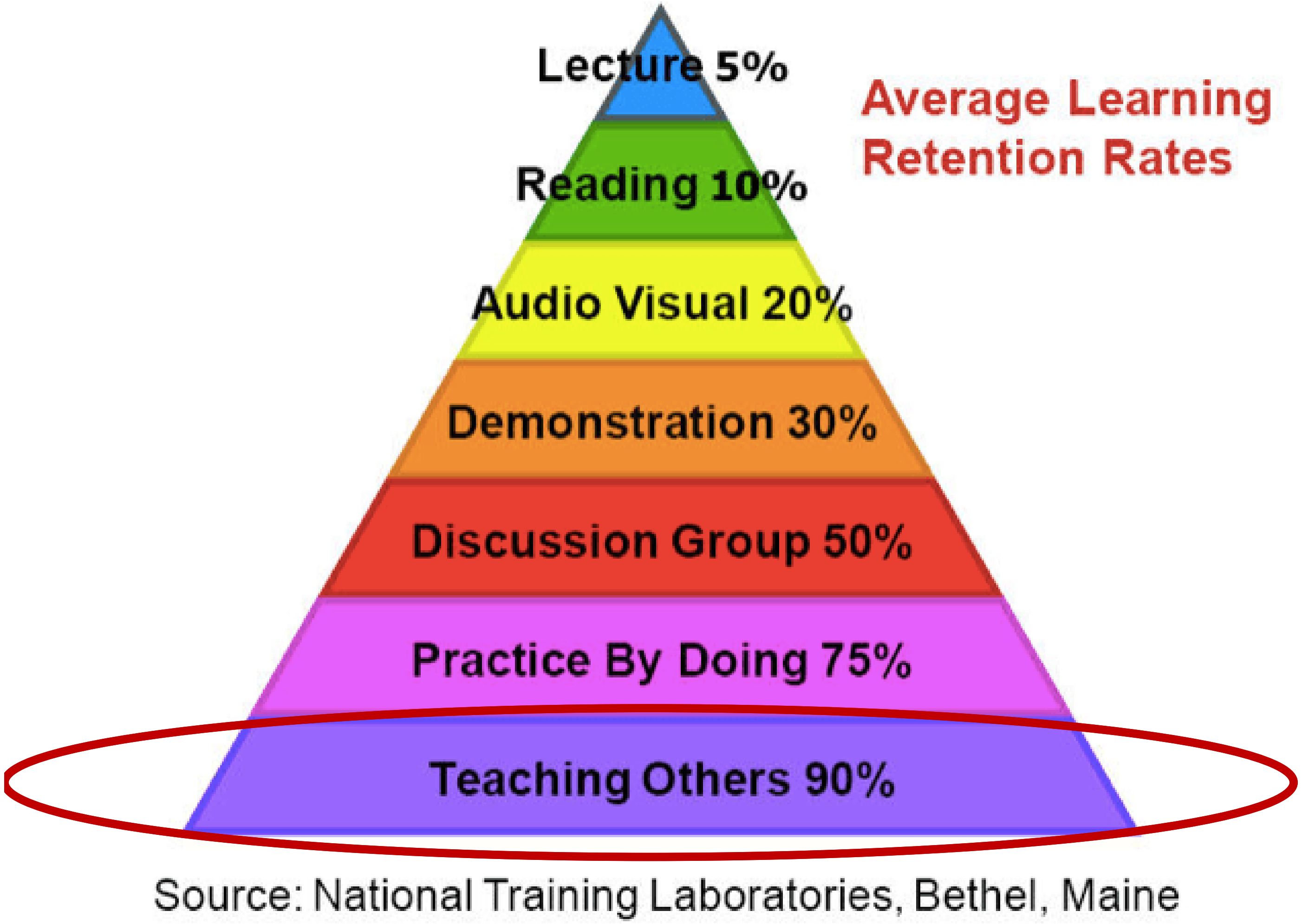
- The worksheet is available on iLearn
- There are several practice questions on Diodes and BJTs
- Try your best to solve them all before the workshop session, if you need help, come along to the workshop and speak to the tutors
- Tutorial workshops are not graded, this is just for practice. It will help you a lot with the assignment and exam!

First Assignment!

- The first assignment is available now.
- An iLearn quiz on the topics of diodes and BJTs
- Final question requires video Submission!
- Submission is due by 11:55pm Friday 25th August

Assignment

WHY A VIDEO EXPLAINER?



- Teaching a topic helps you to retain the learning!
- This also gives you a chance to work on your communication skills