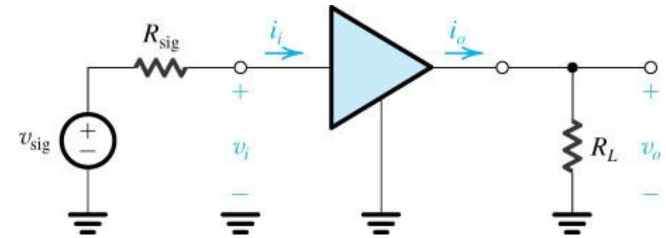
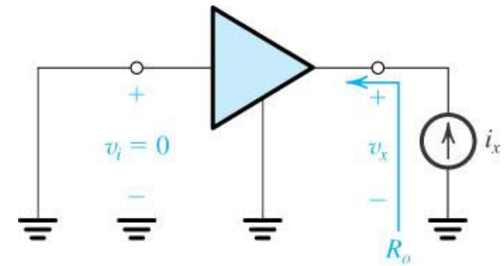
SINGLE STAGE BJT AMPLIFIER

Characterizing BJT Amplifiers – Important Definitions

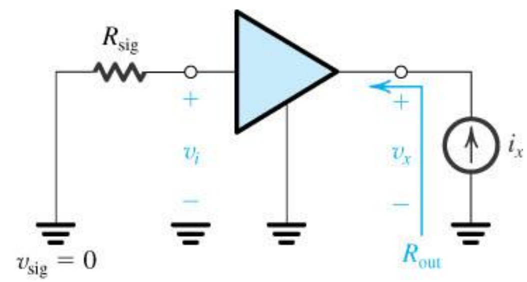
- General Set of Parameters (non unilateral also)
- Parameters of Amplifier proper and those which depend on R_{sig} and R_L
- Input Resistance
  - with no load, R_i
  - Input Resistance, R_{in}
- Voltage Gain
  - Open Circuit Voltage gain, A_{vo}
  - Circuit Voltage Gain, A_v
  - Open Circuit overall Voltage Gain, G_{vo}
  - Overall Voltage Gain, G_v
- Current Gain,
  - Short Circuit Current Gain, A_{is}
  - Circuit Current Gain, A_i
- Short Circuit Transconductance, G_m
- Output Resistance
  - of amplifier proper, R_o
  - Output Resistance, R_{out}
- Interrelationship between pairs of parameters – no such for unilateral amplifiers!!



R_i ; R_{in} ; A_{vo} ; A_v ; A_i ; G_m; G_{vo}; G_v

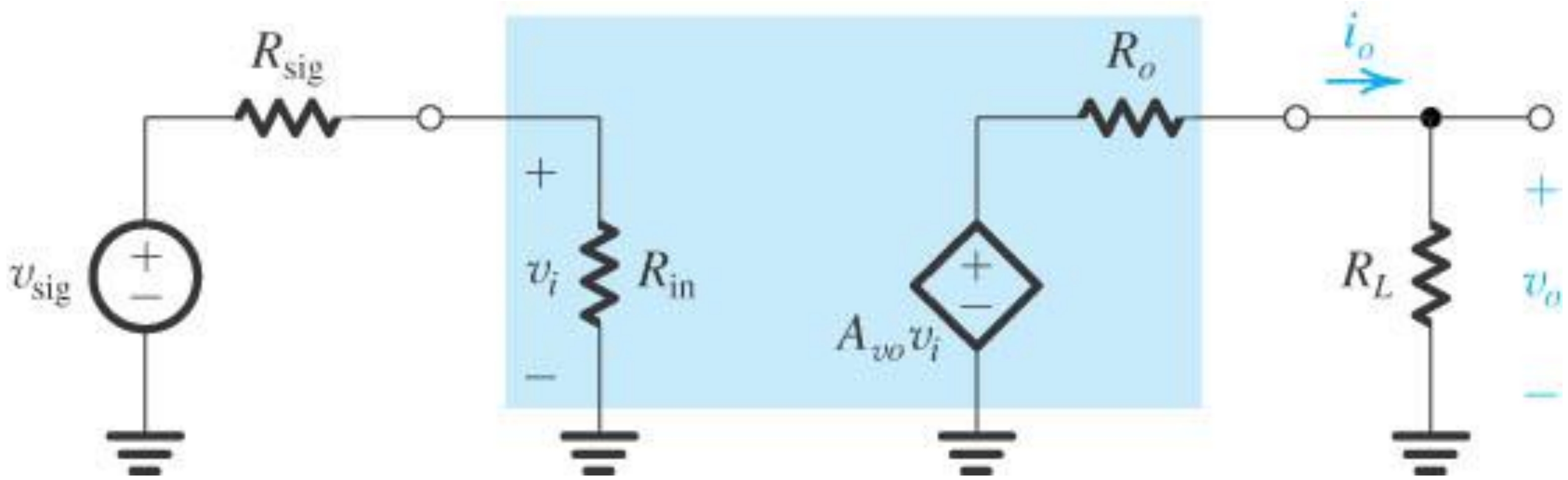


Definition of R_o



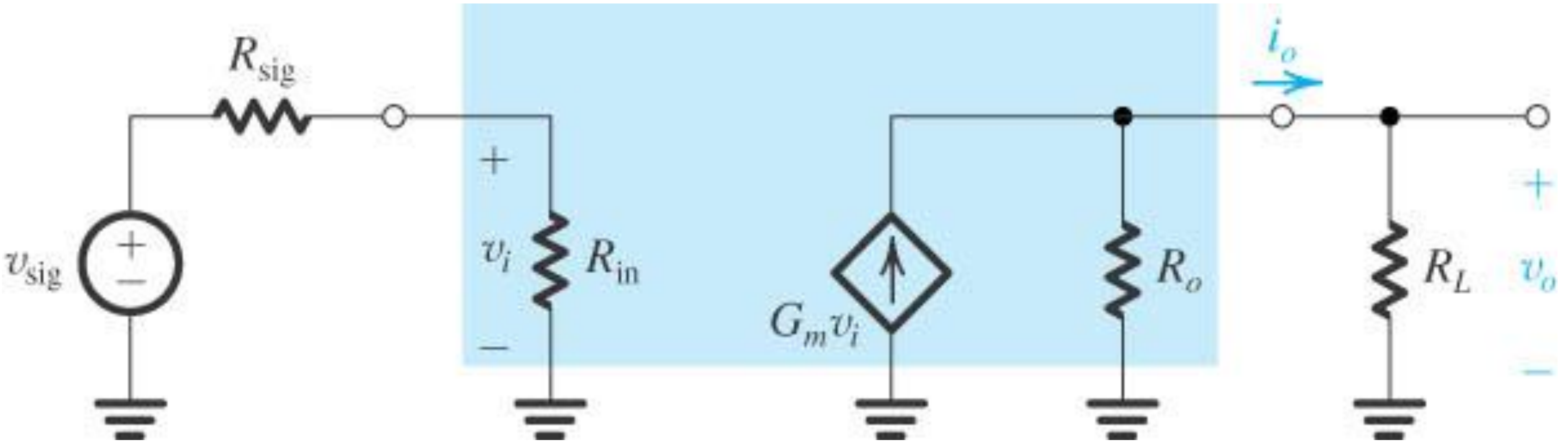
Definition of R_{out}

Characterizing BJT Amplifiers – Important Definitions (contd.)

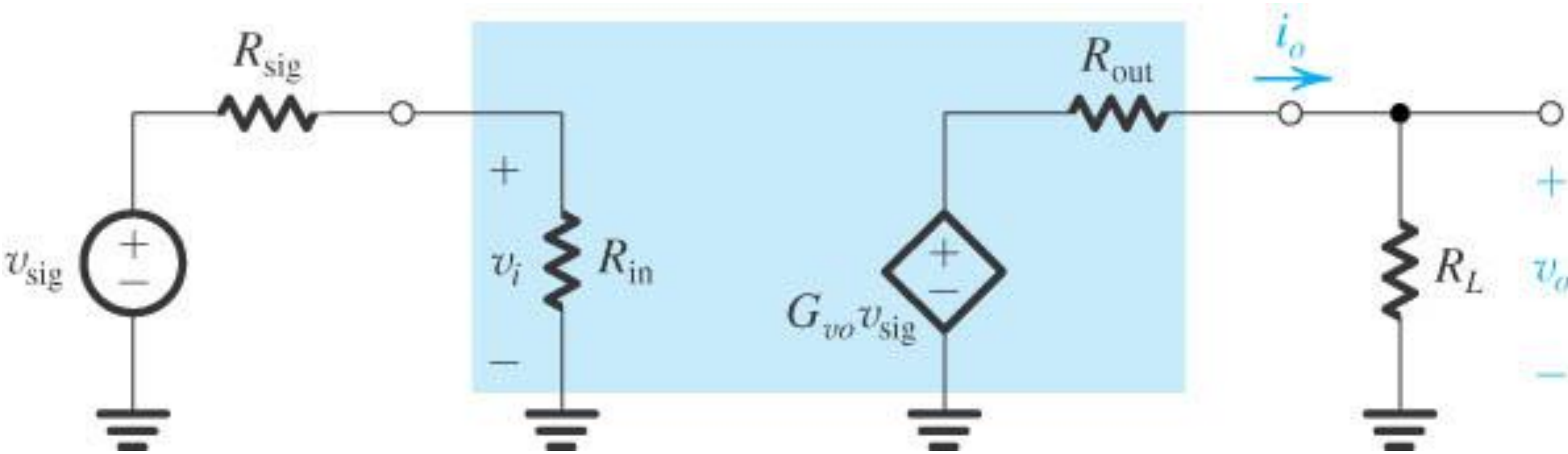


$$\frac{v_i}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} \qquad A_v = A_{vo}\frac{R_L}{R_L + R_o}$$

- When evaluating A_v from A_{vo} , R_o is to be employed – because, A_v is based on feeding the amplifier with an ideal voltage signal v_i



R_{sig}
i_o
v_{sig}
v_i
R_{in}
$G_m v_i$
R_o
R_L
v_o



R_{sig}
i_o
R_{out}
v_{sig}
v_i
R_{in}
$G_{vo} v_{sig}$
R_L
v_o

$$A_{vo} = G_m R_o$$

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_{vo} \frac{R_L}{R_L + R_o}$$

$$G_{vo} = \frac{R_i}{R_i + R_{sig}} A_{vo}$$

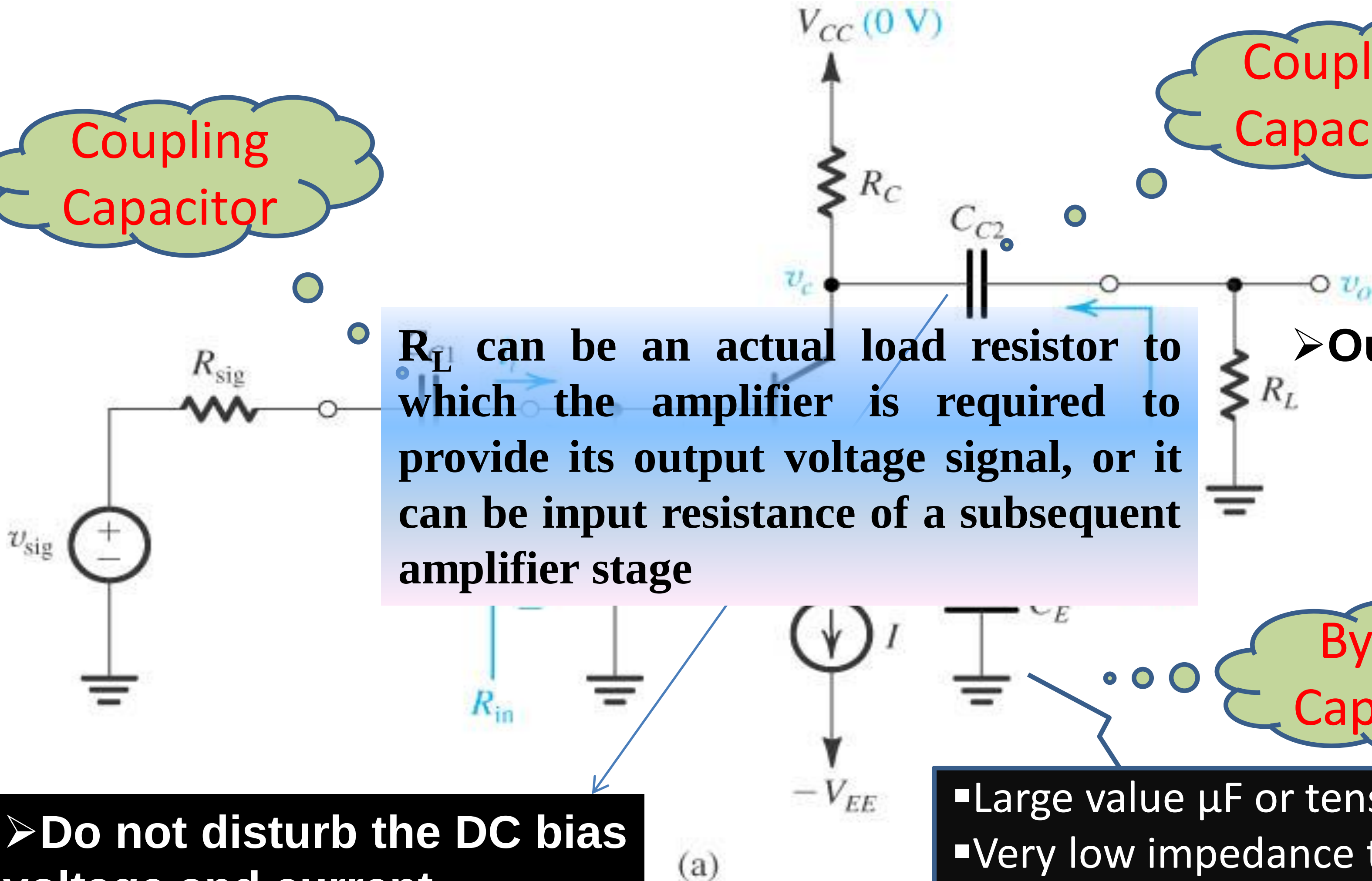
$$G_v = G_{vo} \frac{R_L}{R_L + R_{out}}$$

- When evealuating the overall gain G_v from its open circuit value G_{vo}, R_{out} is to be used-because G_v is defined based on feeding the signal from v_{sig}

The CE Amplifier

Coupling Capacitor

Coupling Capacitor



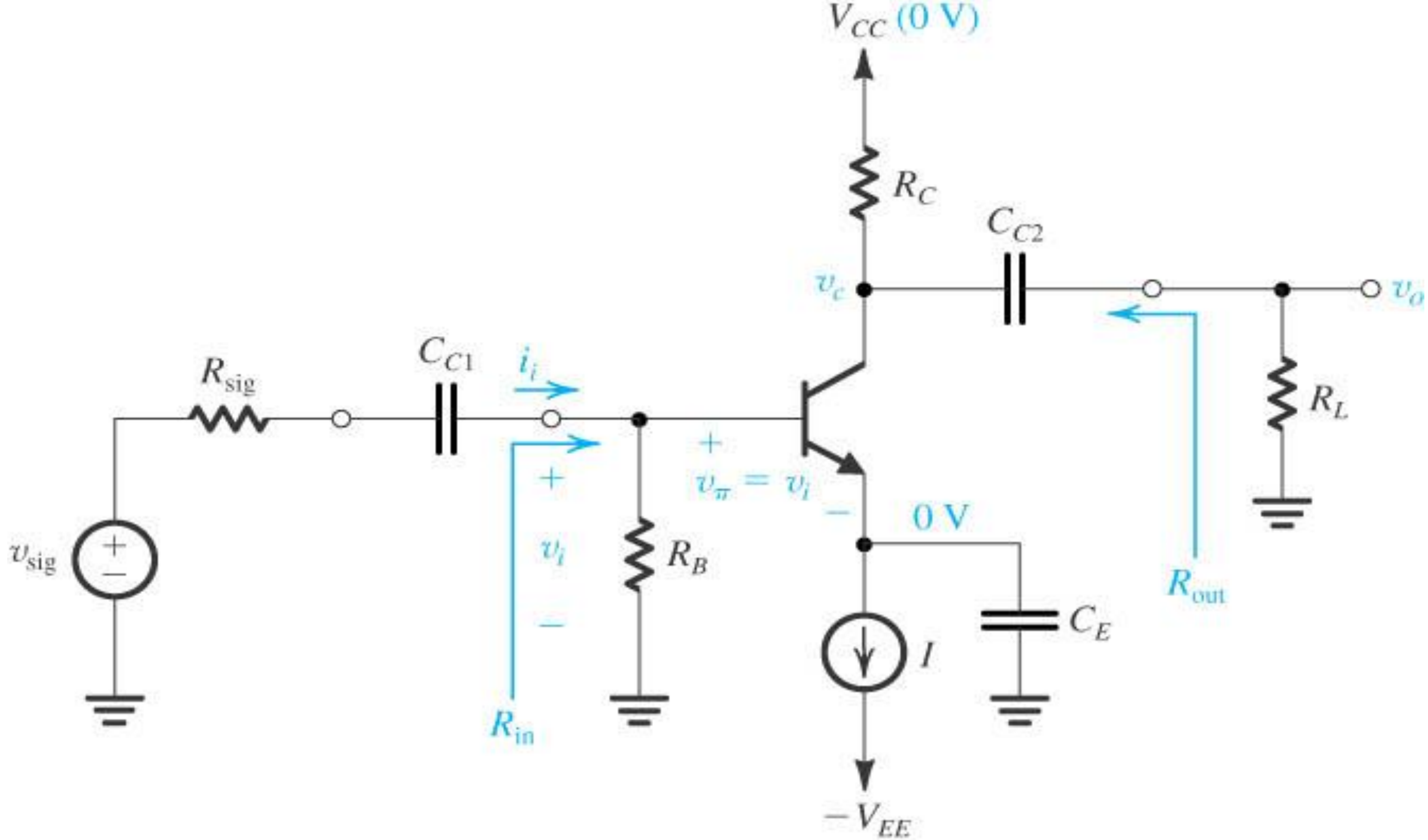
R_L can be an actual load resistor to which the amplifier is required to provide its output voltage signal, or it can be input resistance of a subsequent amplifier stage

➢**Output** $v_o = v_c$

By Pass Capacitor

- ➢Do not disturb the DC bias voltage and current
- ➢Perfect short circuit at all signal frequencies of interest while blocking dc

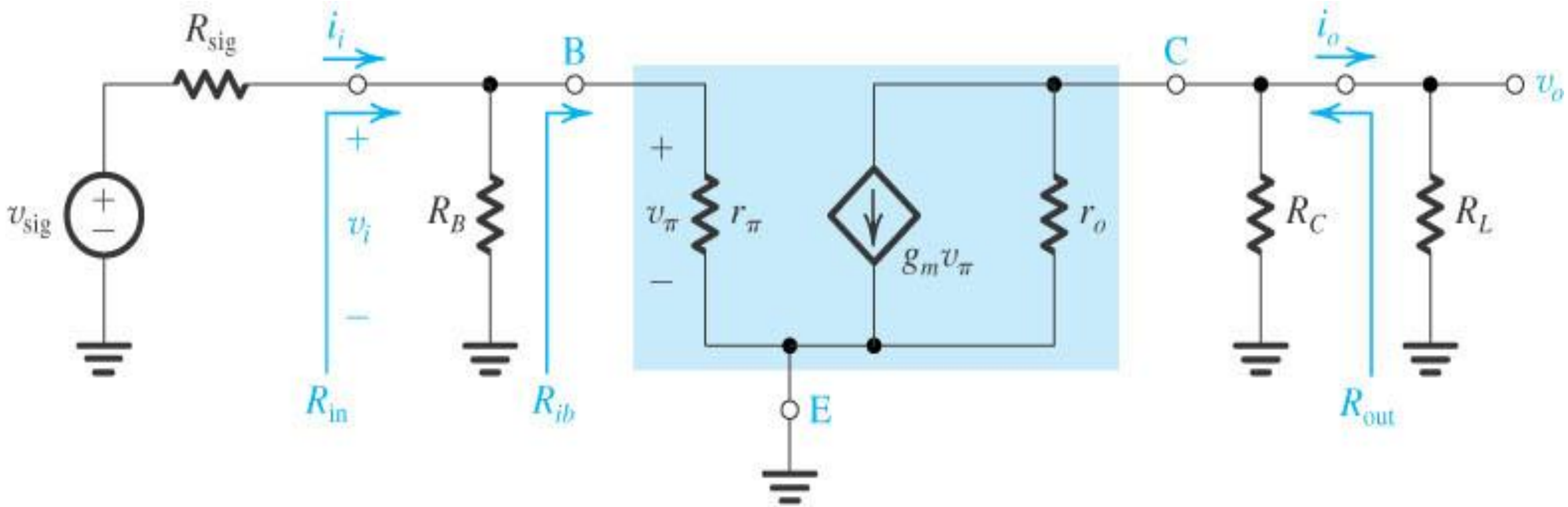
- Large value µF or tens µF
- Very low impedance to ground
- Emitter signal current passes through CE, thus bypassing the current source , hence it is bypass capacitor



V_{CC} (0 V)
R_C
C_{C2}
v_c
v_o
R_{sig}
C_{C1}
i_i
+
$v_\pi = v_i$
−
0 V
v_{sig}
+
v_i
−
R_B
R_L
R_{out}
C_E
I
R_{in}
$-V_{EE}$

(a)

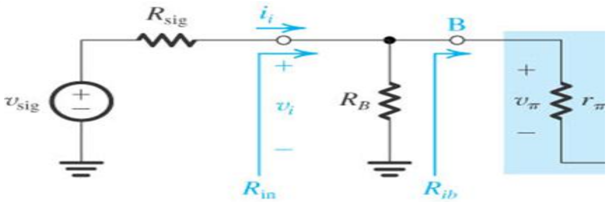
Let us determine Input resistance , voltage gain and output resistance by replacing the BJT with its hybrid π small signal model.



(b)

- Unilateral
- $R_{in}=R_i$ and $R_{out}=R_o$

At the amplifier input we have



$$R_{in} \equiv \frac{v_i}{i_i} = R_B \parallel R_{ib}$$

where R_{ib} is the input resistance looking into the base. Since the emitter is grounded,

$$R_{ib} = r_\pi$$

Normally, we select $R_B \gg r_\pi$, with the result that

$$R_{in} \cong r_\pi$$

The fraction of source signal v_{sig} that appears across the input terminals of the amplifier proper can be found from

$$v_i = v_{sig}\frac{R_{in}}{R_{in} + R_{sig}} = v_{sig}\frac{(R_B \parallel r_\pi)}{(R_B \parallel r_\pi) + R_{sig}}$$

which for $R_B \gg r_\pi$ becomes

$$v_i \cong v_{sig} \frac{r_\pi}{r_\pi + R_{sig}}$$

we note that

$$v_\pi = v_i$$

At the output of the amplifier we have

$$v_o = -g_m v_\pi (r_o \parallel R_C \parallel R_L)$$

Replacing v_π by v_i we can write for the voltage gain of the amplifier proper; that is, the voltage gain from base to collector,

$$A_v = -g_m (r_o \parallel R_C \parallel R_L)$$

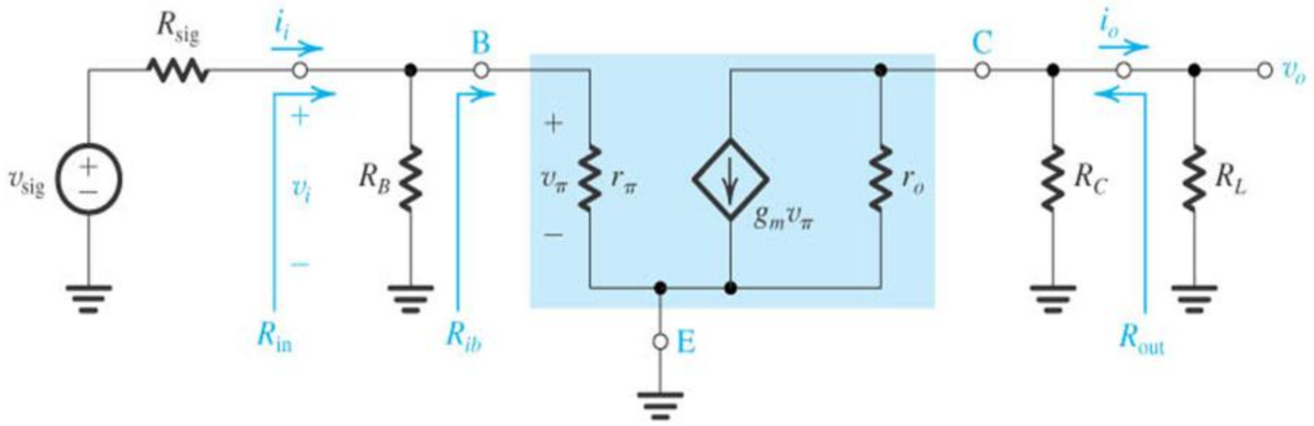
The open-circuit voltage gain

A_{vo} can be obtained by setting $R_L = \infty$

$$A_{vo} = -g_m(r_o \parallel R_C)$$

since typically $r_o \gg R_C$, resulting in

$$A_{vo} \cong -g_m R_C$$



The output resistance R_{out} can be found from the equivalent circuit by look ing back into the output terminal while short-circuiting the source v_{sig}.

Since this will result in $v_\pi = 0$, we see that

$$R_{out} = R_C \parallel r_o$$

$$r_o \gg R_C$$

$$R_{\text{out}} \cong R_C$$

unilateral amplifier $R_o = R_{\text{out}}$,

voltage gain A_v corresponding to any particular R_L,

$$A_v = A_{vo}\frac{R_L}{R_L + R_o}$$

The overall voltage gain from source to load, G_v, can be obtained by multiplying (v_i / v_{sig}) by A_v

$$G_v = -\frac{(R_B \parallel r_\pi)}{(R_B \parallel r_\pi) + R_{sig}} g_m (r_o \parallel R_C \parallel R_L)$$

For the case $R_B \gg r_\pi$, this expression simplifies to

$$G_v \cong -\frac{\beta (R_C \parallel R_L \parallel r_o)}{r_\pi + R_{sig}}$$

if $R_{sig} \gg r_{\pi}$, the overall gain will be highly dependent on β.

This is not a desirable property since β varies considerably between units of the same transistor type.

if $R_{sig} \ll r_{\pi}$, we see that the expression for the overall voltage gain reduces to

$$G_v \cong -g_m(R_C \parallel R_L \parallel r_o)$$

which is the gain A_v;

in other words, when R_{sig} is small,

the overall voltage gain is almost

equal to the gain of the CE circuit proper,

which is independent of β.

short-circuit current gain, A_{is}

This can be easily done by referring to the amplifier equivalent circuit

R_L is short circuited, the current through it will be equal to $-g_m v_\pi$,

$$i_{os} = -g_m v_\pi$$

Since v_π is related to i_i by

$$v_\pi = v_i = i_i R_{\text{in}}$$

the short-circuit current gain can be found as

$$A_{is} \equiv \frac{i_{os}}{i_i} = -g_m R_{\text{in}}$$

$$R_{\text{in}} = R_B \parallel r_\pi \qquad R_B \gg r_\pi,$$

$|A_{is}|$ reduces to β, by definition,

the short-circuit current gain of the common-emitter configuration.

In conclusion, the common-emitter configuration can provide large voltage and current gains, but R_{in} is relatively low and R_{out} is relatively high.