ECE 321C
Electronic Circuits

Lec. 5: BJT Modeling and re Transistor Model (Hybrid Equivalent Model) (2)

Instructor

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Agenda

- The Hybrid Equivalent Model
- Approximate h-model

The Hybrid Equivalent Model

The Hybrid Equivalent Model

- Main Difference between r_e and H model is that:
  - ➢ The r_e model has the advantage that the parameters are defined by the actual operating conditions
  - ➢ The parameters of the hybrid equivalent circuit are defined in general terms for any operating conditions.

		Min.	Max.	
Input impedance (I_C = 1 mA dc, V_{CE} = 10 V dc, f = 1 kHz)	h_{ie}	0.5	7.5	kΩ
Voltage feedback ratio (I_C = 1 mA dc, V_{CE} = 10 V dc, f = 1 kHz)	h_{re}	0.1	8.0	$\times 10^{-4}$
Small-signal current gain (I_C = 1 mA dc, V_{CE} = 10 V dc, f = 1 kHz)	h_{fe}	20	250	—
Output admittance (I_C = 1 mA dc, V_{CE} = 10 V dc, f = 1 kHz)	h_{oe}	1.0	30	1 µS

FIG. 5.92

Hybrid parameters for the 2N4400 transistor.

The Hybrid Equivalent Model

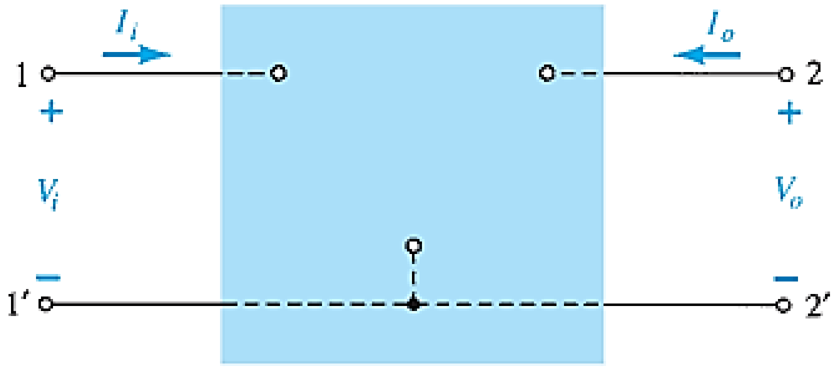


FIG. 5.93
Two-port system.

$$V_i = h_{11}I_i + h_{12}V_o$$

$$I_o = h_{21}I_i + h_{22}V_o$$

$$h_{11} = \left.\frac{V_i}{I_i}\right|_{V_o=0}$$ ohms → short-circuit input-impedance parameter

$$h_{12} = \left.\frac{V_i}{V_o}\right|_{I_i=0}$$ unitless → open-circuit reverse transfer voltage ratio parameter

$$h_{21} = \left.\frac{I_o}{I_i}\right|_{V_o=0}$$ unitless → short-circuit forward transfer current ratio parameter

$$h_{22} = \left.\frac{I_o}{V_o}\right|_{I_i=0}$$ siemens → open-circuit output admittance parameter

Transistor Hybrid Equivalent Circuit

- Hybrid Equivalent Circuit:

$$V_i = h_{11}I_i + h_{12}V_o$$

$$I_o = h_{21}I_i + h_{22}V_o$$

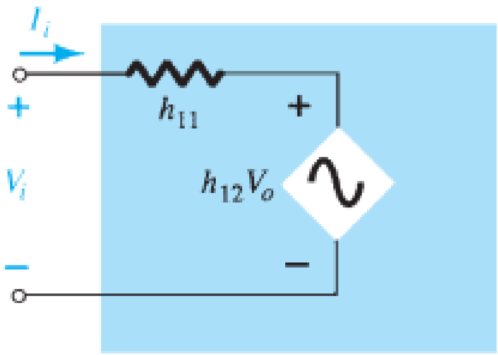


FIG. 5.94
Hybrid input equivalent circuit.

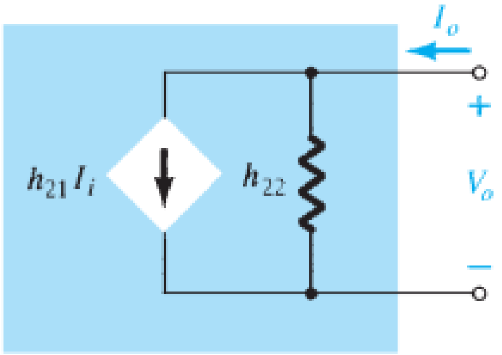


FIG. 5.95
Hybrid output equivalent circuit.

- For Transistor:

$h_{11} \rightarrow$ input resistance $\rightarrow h_i$

$h_{12} \rightarrow$ reverse transfer voltage ratio $\rightarrow h_r$

$h_{21} \rightarrow$ forward transfer current ratio $\rightarrow h_f$

$h_{22} \rightarrow$ output conductance $\rightarrow h_o$

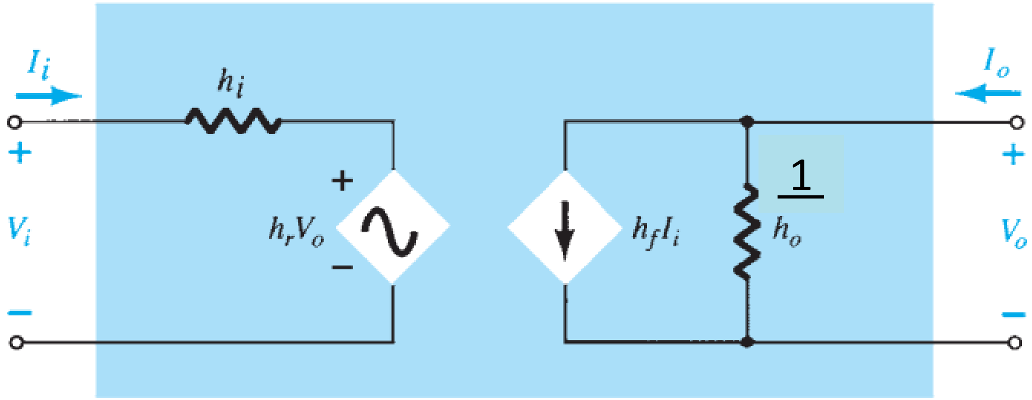


FIG. 5.96
Complete hybrid equivalent circuit.

Transistor Hybrid Equivalent Circuit (CE)

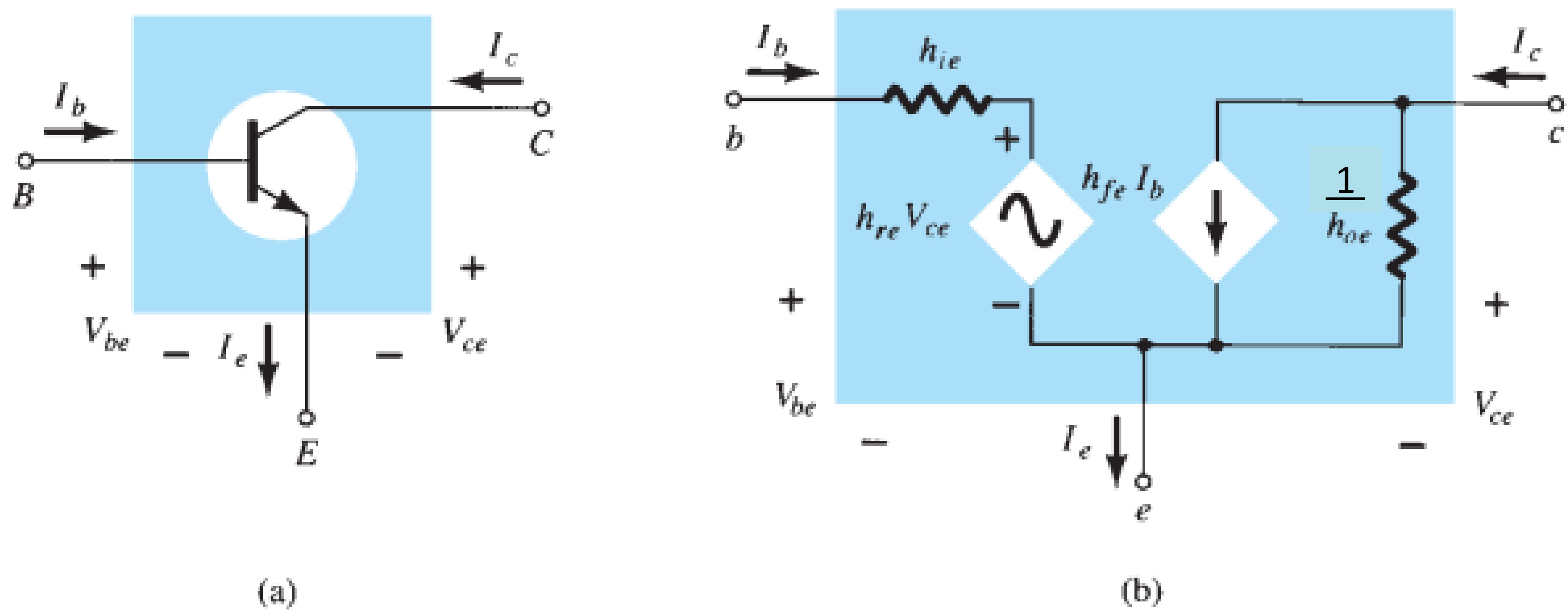


FIG. 5.97

Common-emitter configuration: (a) graphical symbol; (b) hybrid equivalent circuit.

Transistor Hybrid Equivalent Circuit (CB)

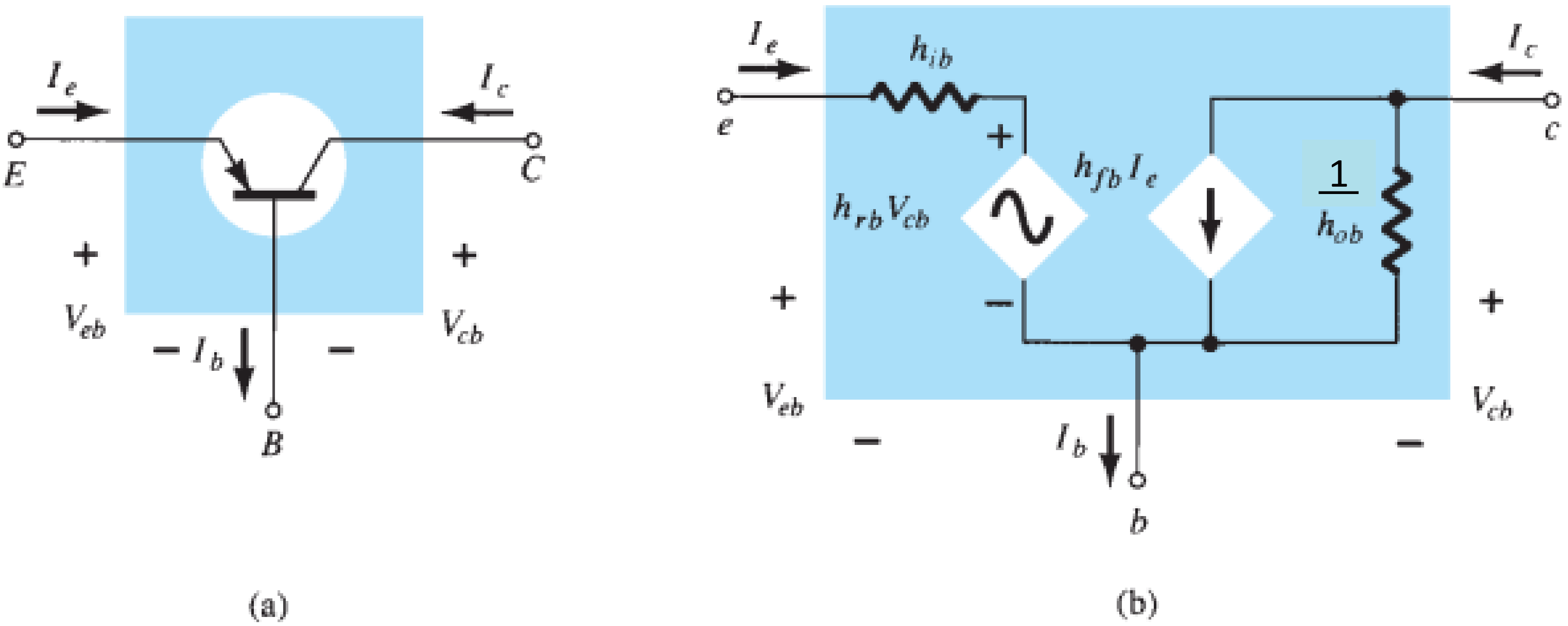


FIG. 5.98

Common-base configuration: (a) graphical symbol; (b) hybrid equivalent circuit.

Hybrid Approximation

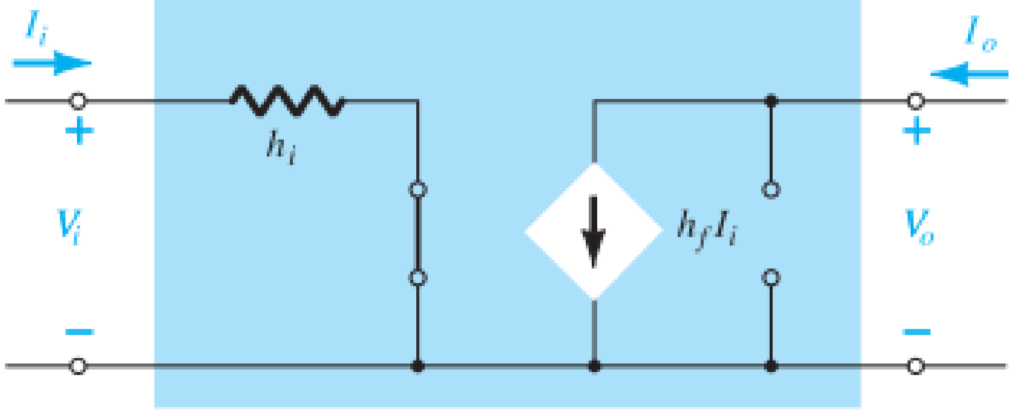


FIG. 5.99
Effect of removing h_{re} and h_{oe} from the hybird equivalent circuit.

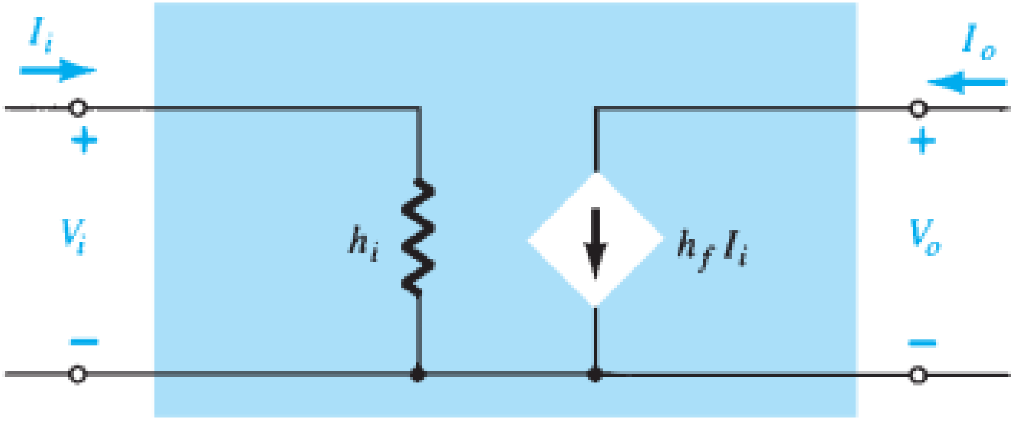


FIG. 5.100
Approximate hybrid equivalent model.

Hybrid vs. r_e model

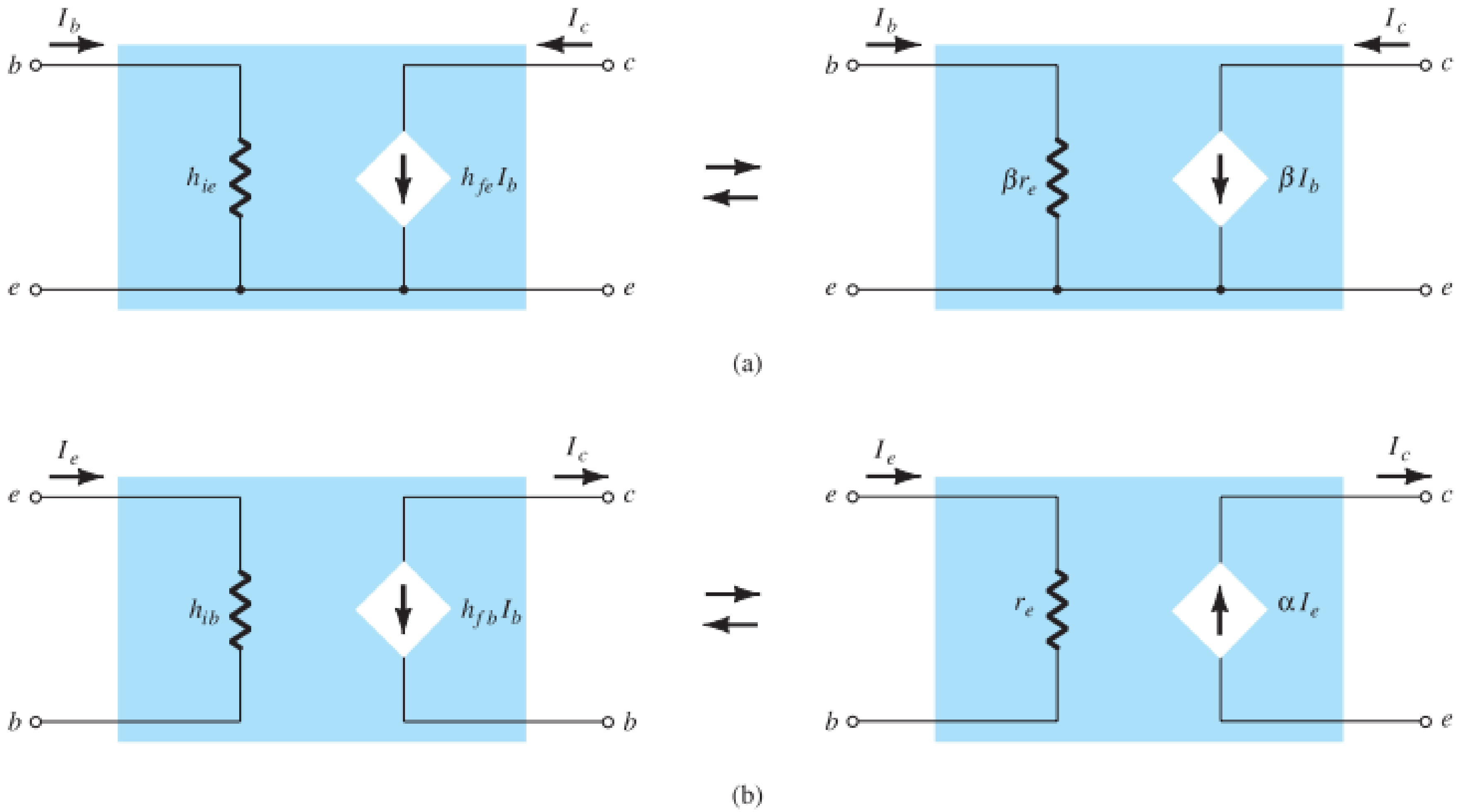


FIG. 5.101

Hybrid versus r_e model: (a) common-emitter configuration; (b) common-base configuration.

$$h_{ie} = \beta r_e$$

$$h_{fe} = \beta_{ac}$$

$$h_{ib} = r_e$$

$$h_{fb} = -\alpha \cong -1$$

Hybrid vs. r_e model (Example)

EXAMPLE 5.19 Given $I_E = 2.5$ mA, $h_{fe} = 140$, $h_{oe} = 20\ \mu S$ (μmho), and $h_{ob} = 0.5\ \mu S$, determine:

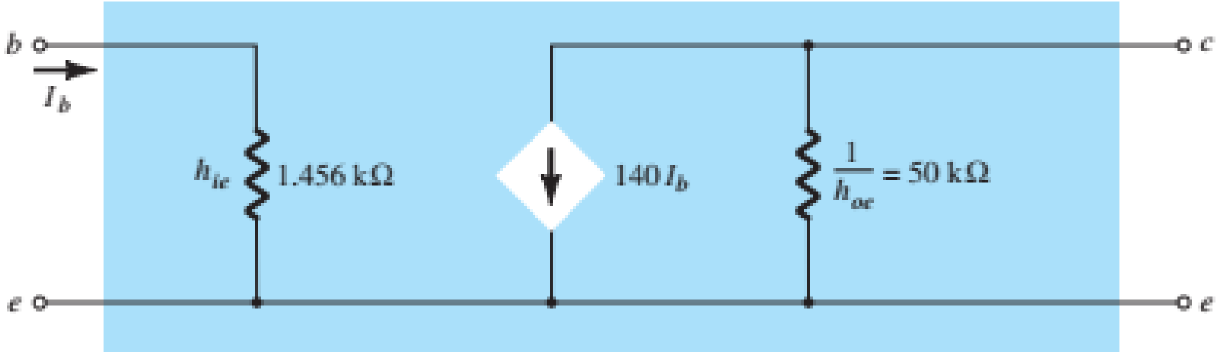
a. The common-emitter hybrid equivalent circuit.
b. The common-base r_e model.

Solution:

a. $r_e = \frac{26\text{ mV}}{I_E} = \frac{26\text{ mV}}{2.5\text{ mA}} = \mathbf{10.4\ \Omega}$

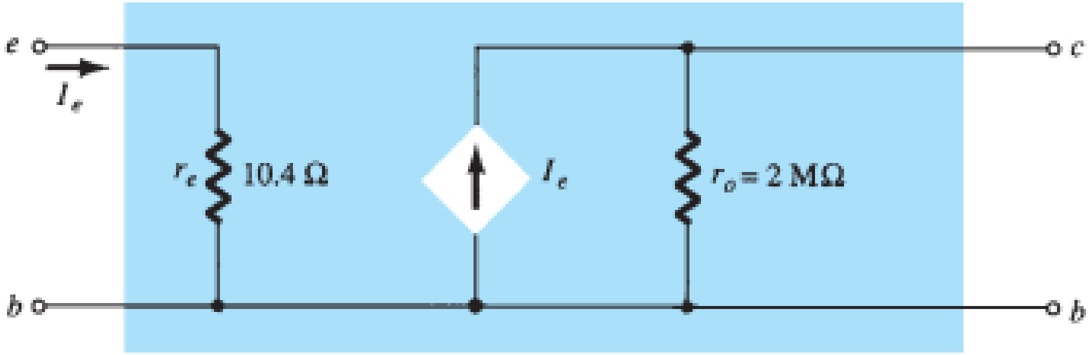
$h_{ie} = \beta r_e = (140)(10.4\ \Omega) = \mathbf{1.456\ k\Omega}$

$r_o = \frac{1}{h_{oe}} = \frac{1}{20\ \mu S} = \mathbf{50\ k\Omega}$



b. $r_e = \mathbf{10.4\ \Omega}$

$\alpha \cong 1, \qquad r_o = \frac{1}{h_{ob}} = \frac{1}{0.5\ \mu S} = \mathbf{2\ M\Omega}$



Approximate & Complete h-model

Approximate h-model

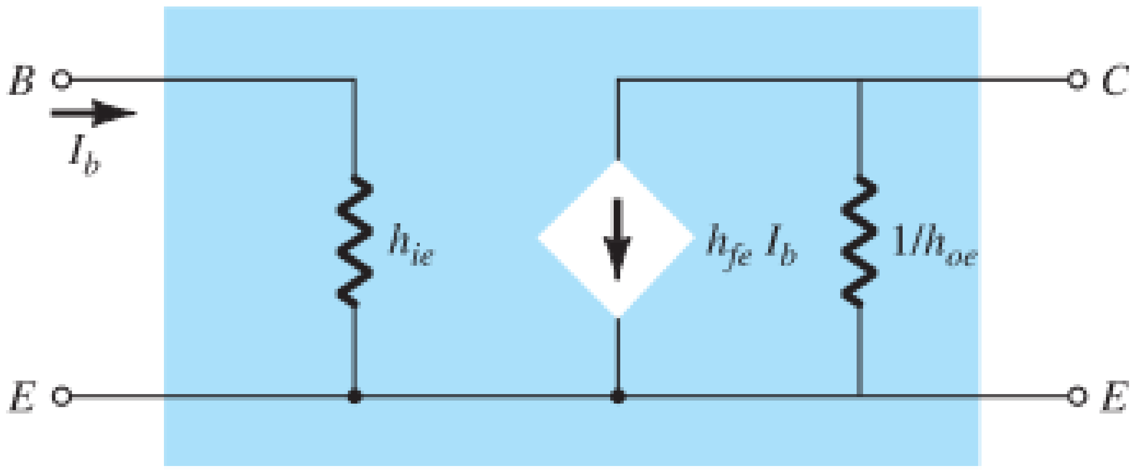


FIG. 5.104
Approximate common-emitter hybrid equivalent circuit.

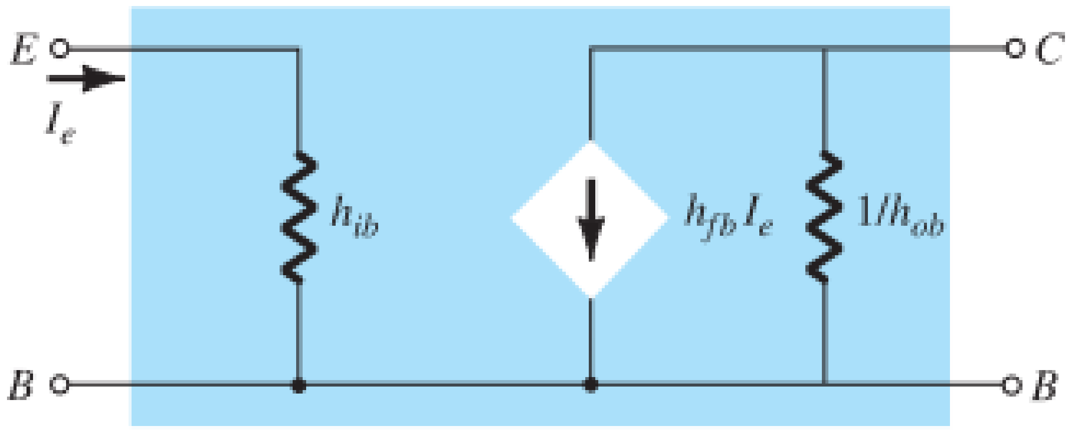
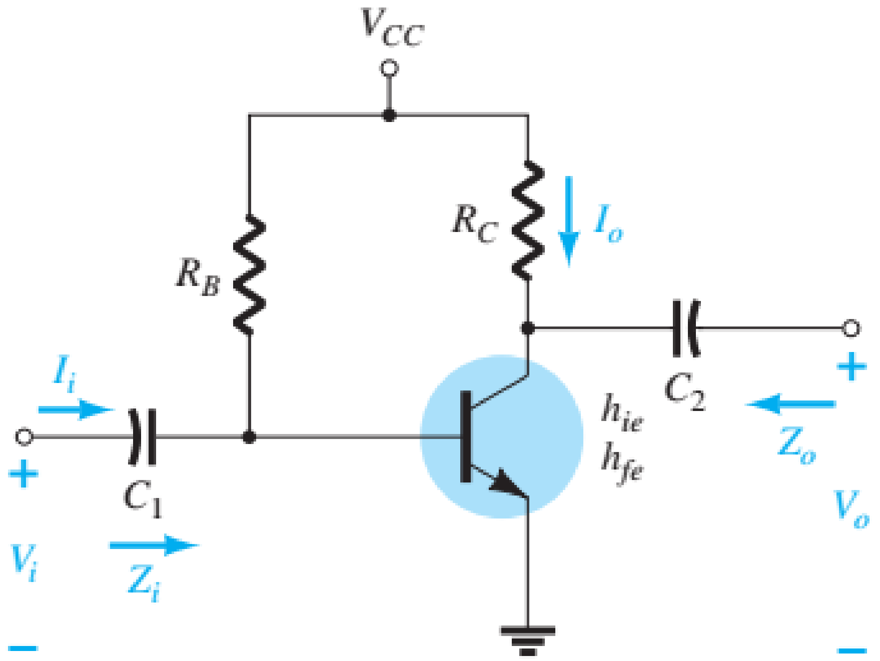
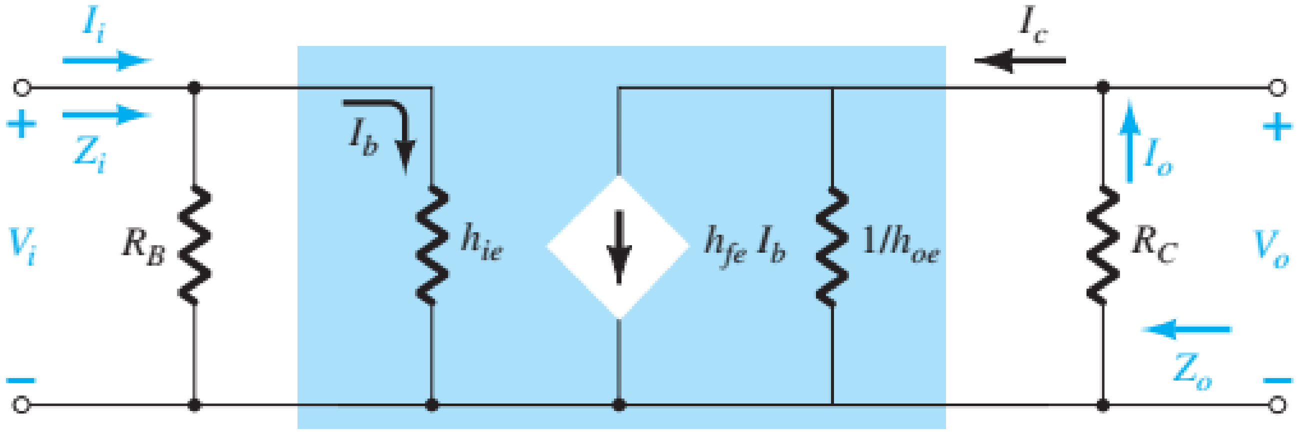


FIG. 5.105
Approximate common-base hybrid equivalent circuit.

Approximate h-model (Fixed Bias circuit)





$$Z_i = R_B \| h_{ie}$$

$$Z_o = R_C \| 1/h_{oe}$$

$$R' = 1/h_{oe} \| R_C$$

$$V_o = -I_o R' = -I_C R'$$

$$= -h_{fe} I_b R'$$

$$I_b = \frac{V_i}{h_{ie}}$$

$$V_o = -h_{fe} \frac{V_i}{h_{ie}} R'$$

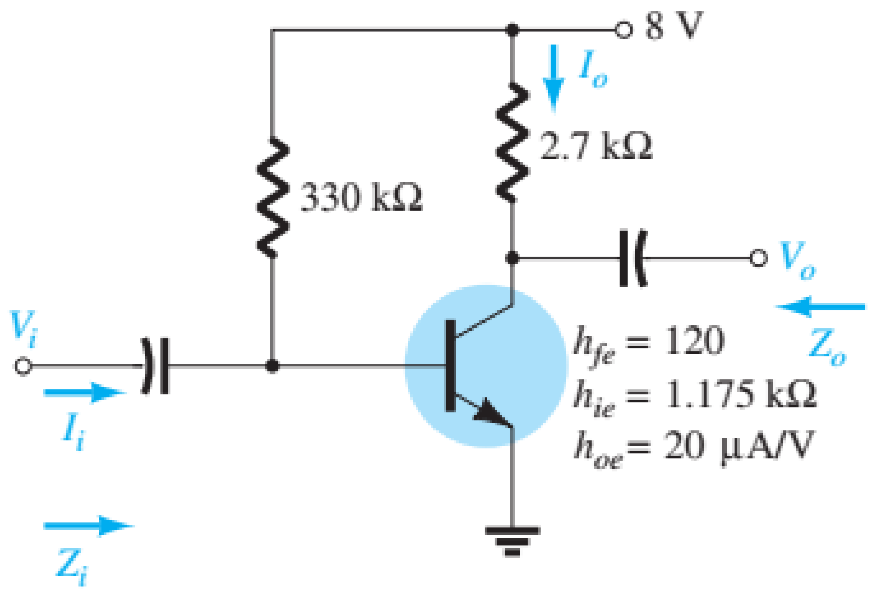
$$A_v = \frac{V_o}{V_i} = -\frac{h_{fe}\ (R_C \| 1/h_{oe})}{h_{ie}}$$

$$A_i = \frac{I_o}{I_i} \cong h_{fe}$$

Approximate h-model (Fixed Bias circuit, Example)

EXAMPLE 5.20 For the network of Fig. 5.108, determine:

a. Z_i.
b. Z_o.
c. A_v.
d. A_i.



Solution:

a. $Z_i = R_B \| h_{ie} = 330\,\text{k}\Omega \| 1.175\,\text{k}\Omega$

$\cong h_{ie} = \mathbf{1.171\,k\Omega}$

b. $r_o = \dfrac{1}{h_{oe}} = \dfrac{1}{20\,\mu\text{A/V}} = 50\,\text{k}\Omega$

$Z_o = \dfrac{1}{h_{oe}} \| R_C = 50\,\text{k}\Omega \| 2.7\,\text{k}\Omega = \mathbf{2.56\,k\Omega} \cong R_C$

c. $A_v = -\dfrac{h_{fe}(R_C \| 1/h_{oe})}{h_{ie}} = -\dfrac{(120)(2.7\,\text{k}\Omega \| 50\,\text{k}\Omega)}{1.171\,\text{k}\Omega} = \mathbf{-262.34}$

d. $A_i \cong h_{fe} = \mathbf{120}$

Check Other Configurations


Thank You!