ECE 312
Electronic Circuits (A)

Lec. 11: BJT Modeling and re Transistor Model (Hybrid Equivalent Model) (3)

Instructor

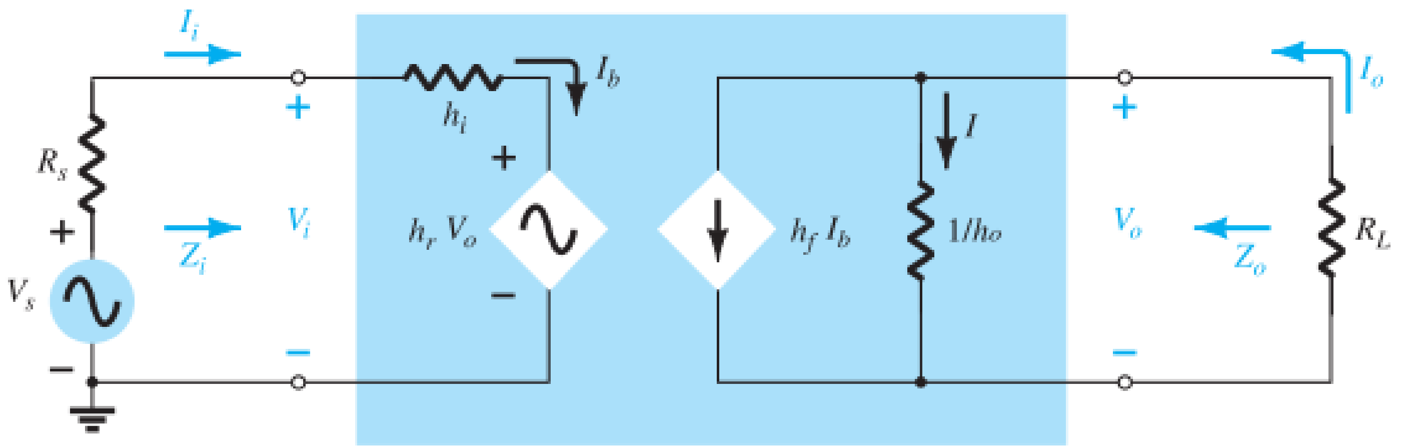
Dr. Maher Abdelrasoul

http://www.bu.edu.eg/staff/mahersalem3

Agenda

- Complete h-model
- Hybrid π Model
- Variations of Transistor Parameters
- Troubleshooting and Practical Applications

Complete h-model



Current Gain, $A_i = I_o/I_i$

$$I_o = h_f I_b + I = h_f I_i + \frac{V_o}{1/h_o} = h_f I_i + h_o V_o$$

Substituting $V_o = -I_o R_L$ gives

$$I_o = h_f I_i - h_o R_L I_o$$

Rewriting the equation above, we have

$$I_o + h_o R_L I_o = h_f I_i$$

and

$$I_o(1 + h_o R_L) = h_f I_i$$

so that

$$A_i = \frac{I_o}{I_i} = \frac{h_f}{1 + h_o R_L}$$

Voltage Gain, $A_v = V_o/V_i$

$$V_i = I_i h_i + h_r V_o$$

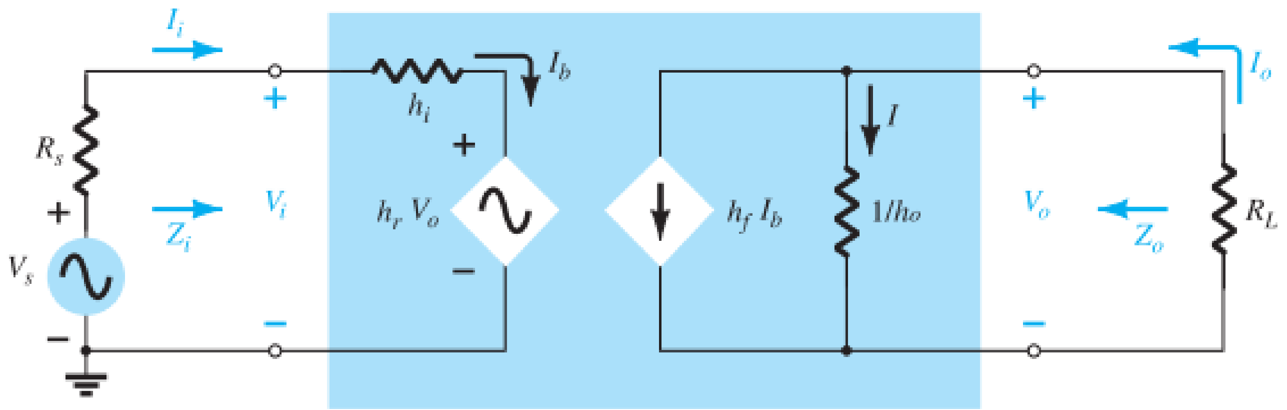
$$I_i = (1 + h_o R_L) I_o / h_f$$

and $I_o = -V_o/R_L$

$$V_i = \frac{-(1 + h_o R_L) h_i}{h_f R_L} V_o + h_r V_o$$

$$A_v = \frac{V_o}{V_i} = \frac{-h_f R_L}{h_i + (h_i h_o - h_f h_r) R_L}$$

Complete h-model



Input Impedance, $Z_i = V_i/I_i$

$$V_i = h_i I_i + h_r V_o$$
$$V_o = -I_o R_L$$
$$V_i = h_i I_i - h_r R_L I_o$$
$$A_i = \frac{I_o}{I_i}$$
$$I_o = A_i I_i$$
$$V_i = h_i I_i - h_r R_L A_i I_i$$

$$A_i = \frac{h_f}{1 + h_o R_L}$$

$$Z_i = \frac{V_i}{I_i} = h_i - h_r R_L A_i$$

$$\boxed{Z_i = \frac{V_i}{I_i} = h_i - \frac{h_f h_r R_L}{1 + h_o R_L}}$$

Output Impedance, $Z_o = V_o/I_o$

$$V_s = 0$$

$$I_i = -\frac{h_r V_o}{R_s + h_i}$$

$$I_o = h_f I_i + h_o V_o$$
$$= -\frac{h_f h_r V_o}{R_s + h_i} + h_o V_o$$

$$\boxed{Z_o = \frac{V_o}{I_o} = \frac{1}{h_o - [h_f h_r/(h_i + R_s)]}}$$

Hybrid π Model

Hybrid π Model (1 of 3)

It includes parameters that do not appear in the other two models primarily to provide a more accurate model for high-frequency effects.

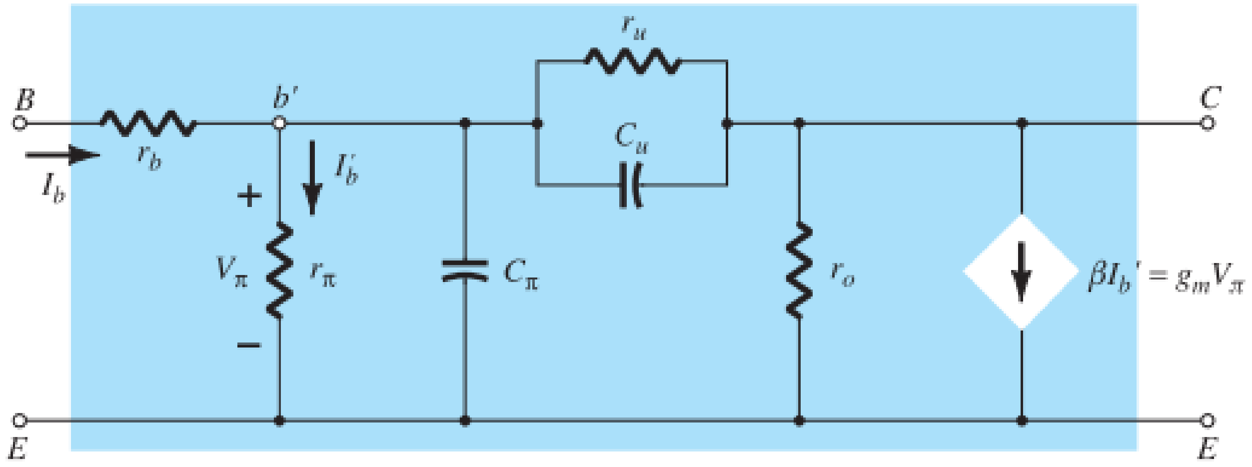


FIG. 5.123

Giacoletto (or hybrid π) high-frequency transistor small-signal ac equivalent circuit.

$$r_\pi = \beta r_e$$

$$r_o = \frac{1}{h_{oe}}$$

$$g_m = \frac{1}{r_e}$$

$$\frac{r_\pi}{r_\pi + r_u} \cong \frac{r_\pi}{r_u} \cong h_{re}$$

Hybrid π Model (2 of 3)

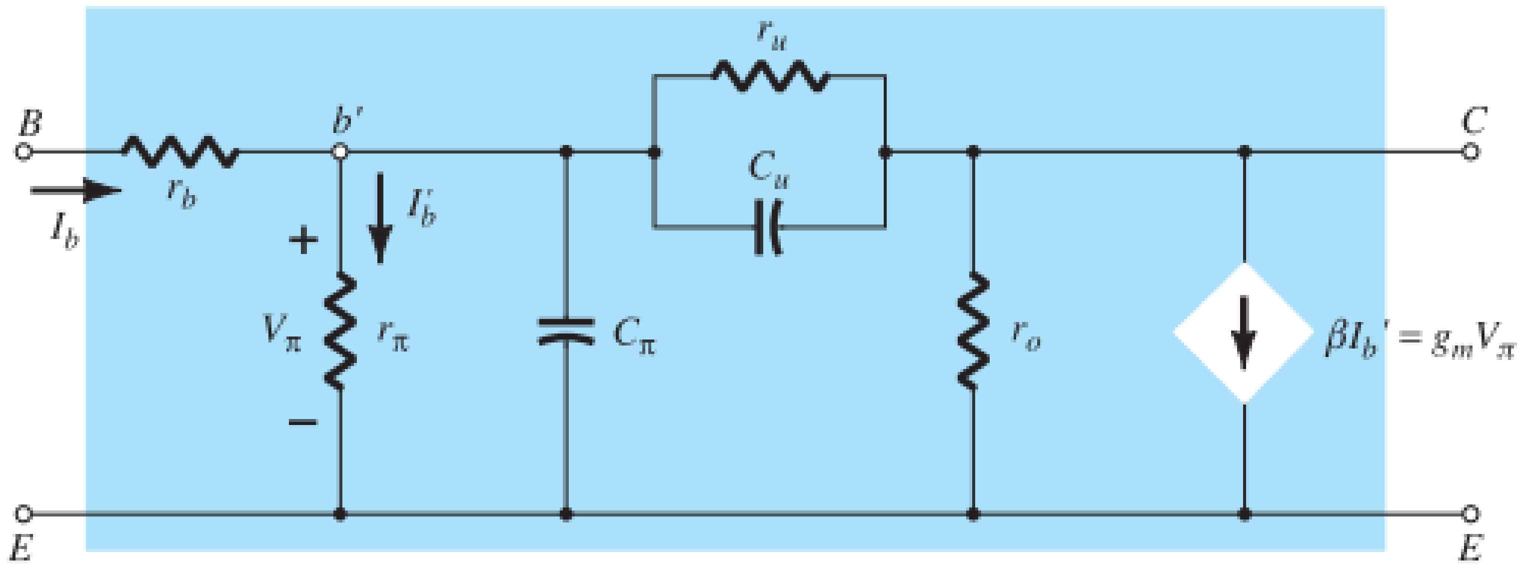


FIG. 5.123

Giacoletto (or hybrid π) high-frequency transistor small-signal ac equivalent circuit.

- The resistance r_π (using the symbol π to agree with the hybrid π terminology) is simply βr_e as introduced for the common-emitter r_e model.
- The output resistance r_o is the output resistance normally appearing across an applied load.

Hybrid π Model (3 of 3)

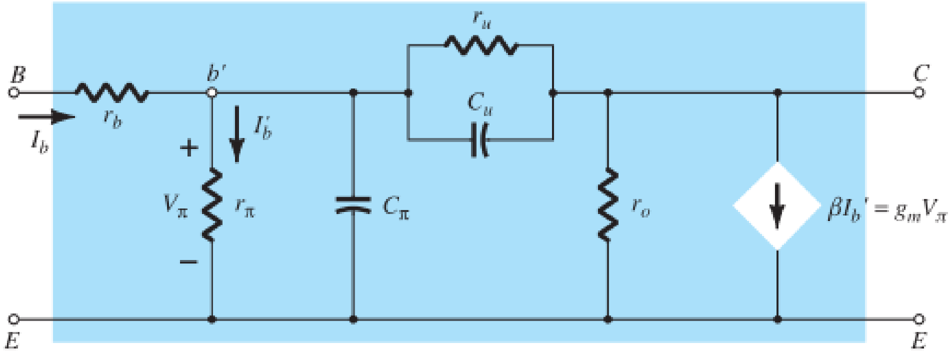


FIG. 5.123

Giacoletto (or hybrid π) high-frequency transistor small-signal ac equivalent circuit.

- The resistance r_u (the subscript u refers to the *union* it provides between collector and base terminals) is a very large resistance and provides a feedback path from output to input circuits in the equivalent model.
- All the capacitors are stray parasitic capacitors between the various junctions of the device.
- The controlled source can be a voltage-controlled current source (VCCS) or a current-controlled current source (CCCS), depending on the parameters employed.

$$\beta I_b' = \frac{1}{r_e} \cdot r_e \beta I_b' = g_m I_b' \beta r_e = g_m (I_b' r_\pi) = g_m V_\pi$$

Variations of Transistor Parameters

Variations of Transistor Parameters (1 of 3)

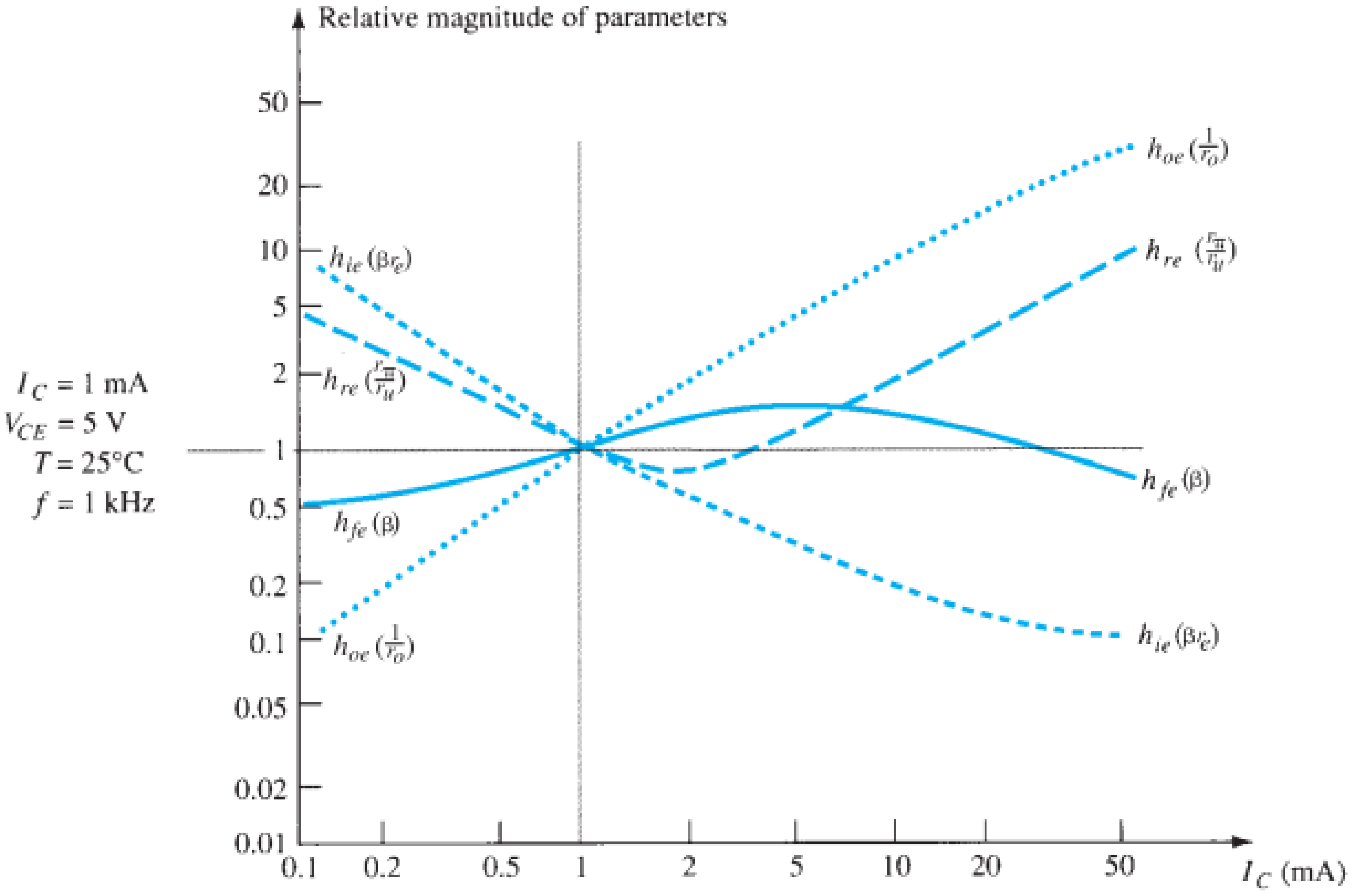


FIG. 5.124

Hybrid parameter variations with collector current.

- The parameter $h_{fe}(\beta)$ varies the least of all the parameters of a transistor equivalent circuit when plotted against variations in collector current.

Variations of Transistor Parameters (2 of 3)

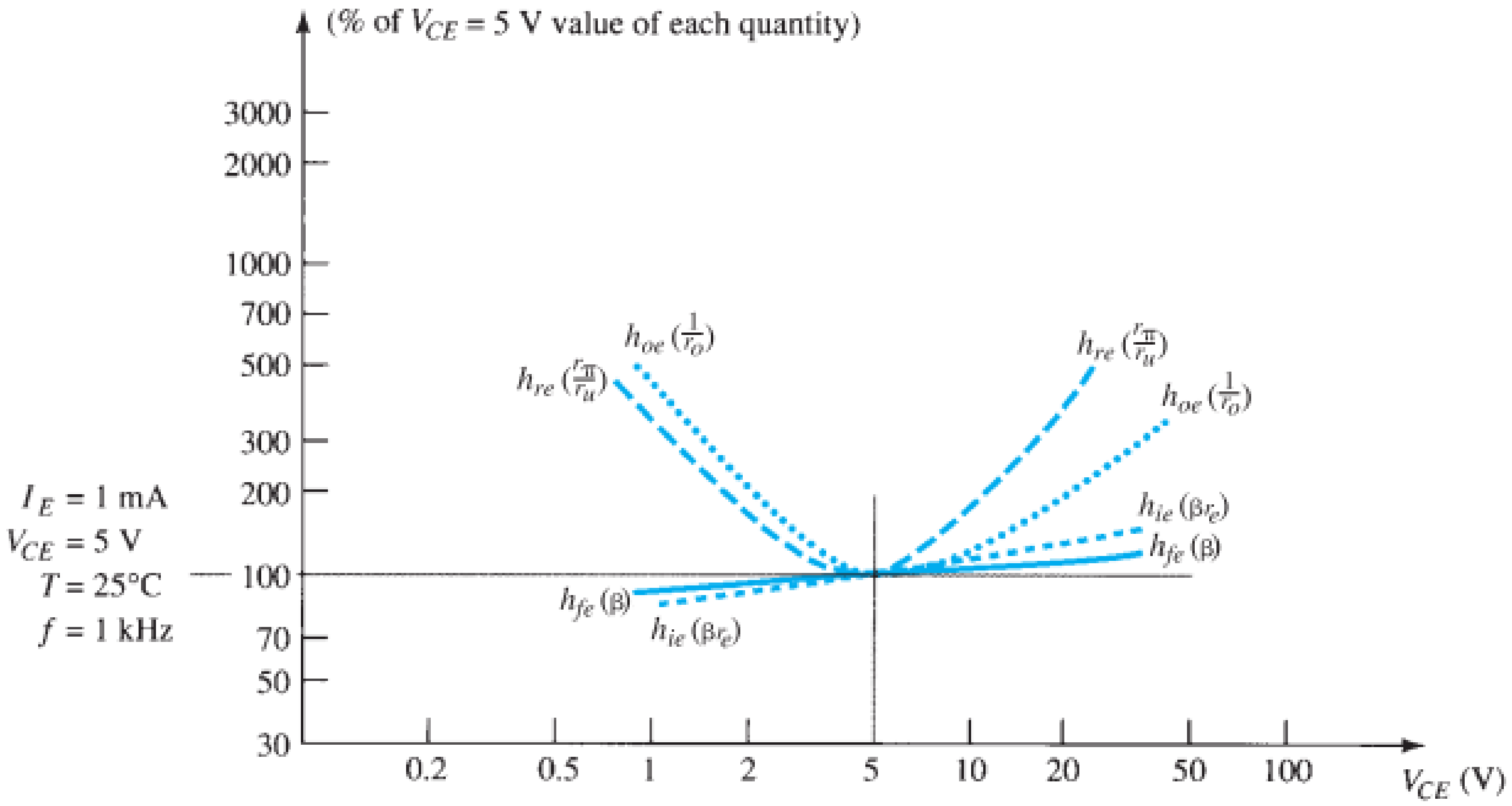


FIG. 5.125

Hybrid parameter variations with collector–emitter potential.

Variations of Transistor Parameters (3 of 3)

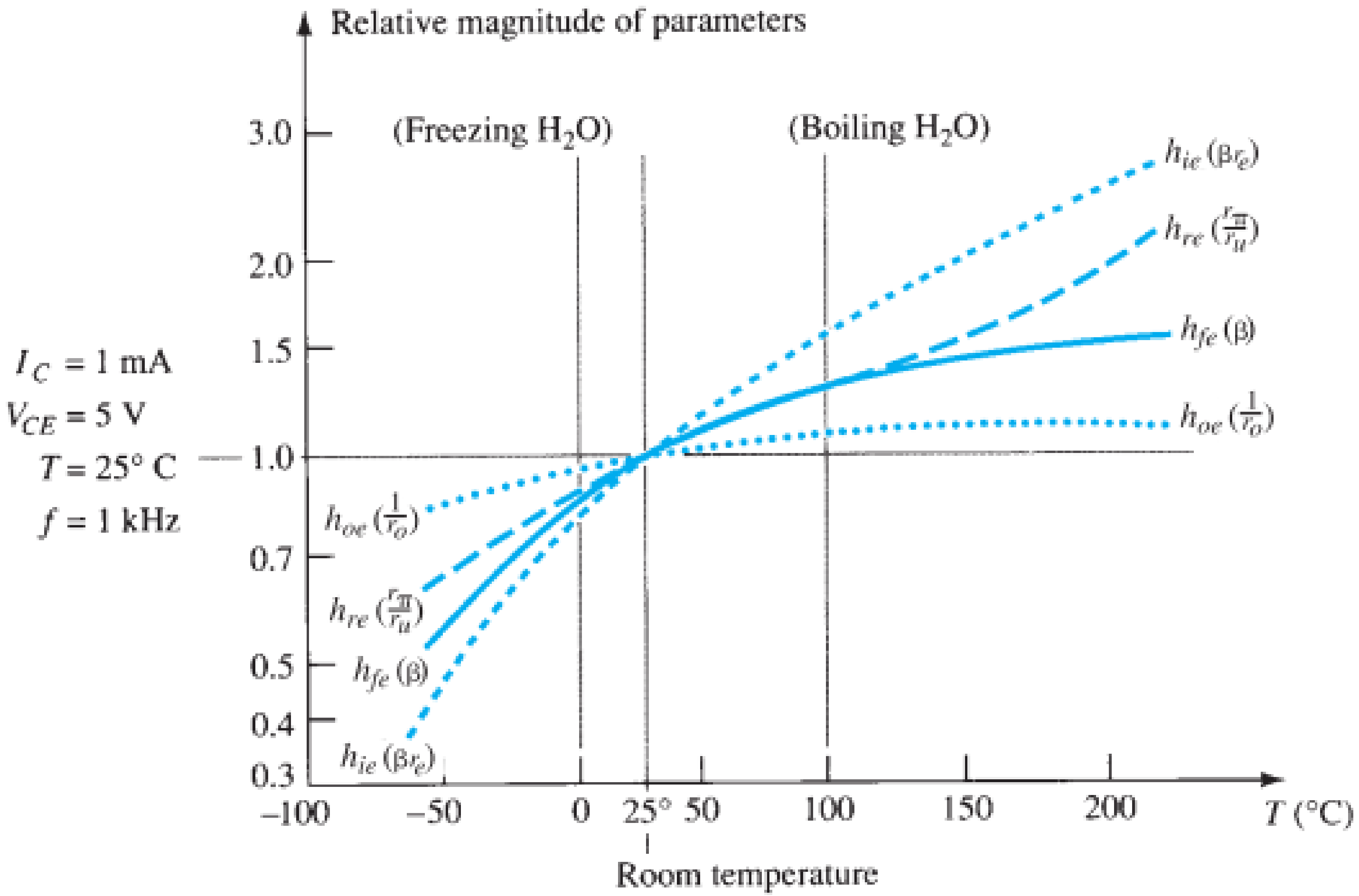


FIG. 5.126

Hybrid parameter variations with temperature.

- All the parameters of a hybrid transistor equivalent circuit increase with temperature.

Troubleshooting & Practical Applications

Troubleshooting

- In general, if a system is not working properly, first disconnect the ac source and check the dc biasing levels.

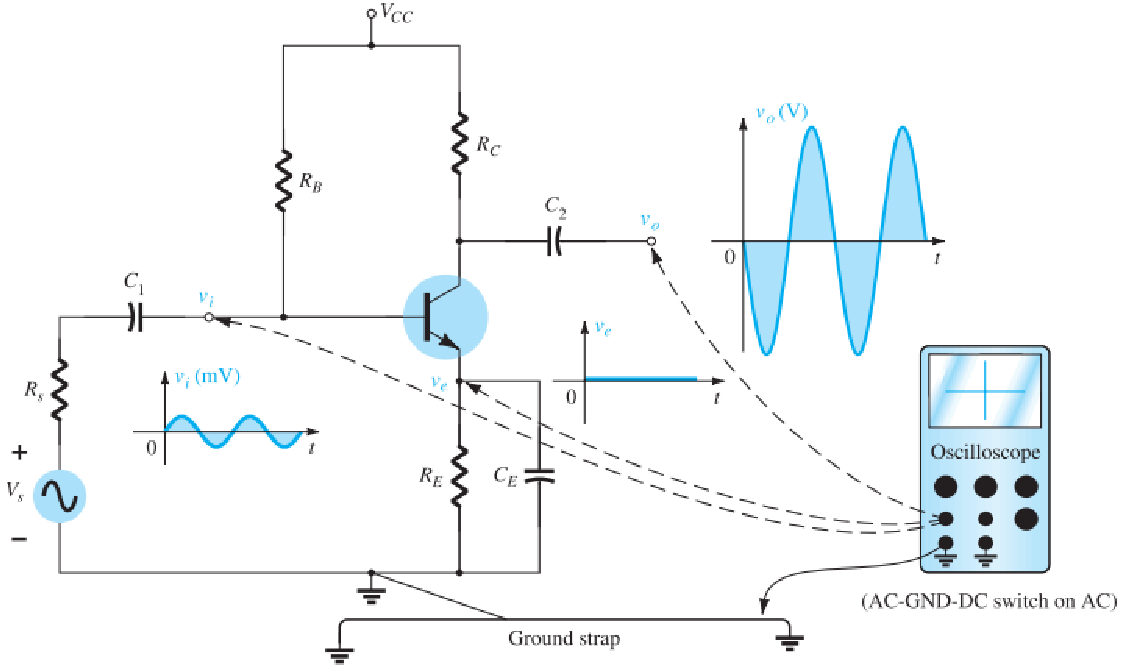


FIG. 5.128
Using the oscilloscope to measure and display various voltages of a BJT amplifier.

PRACTICAL APPLICATIONS

- Audio Mixer

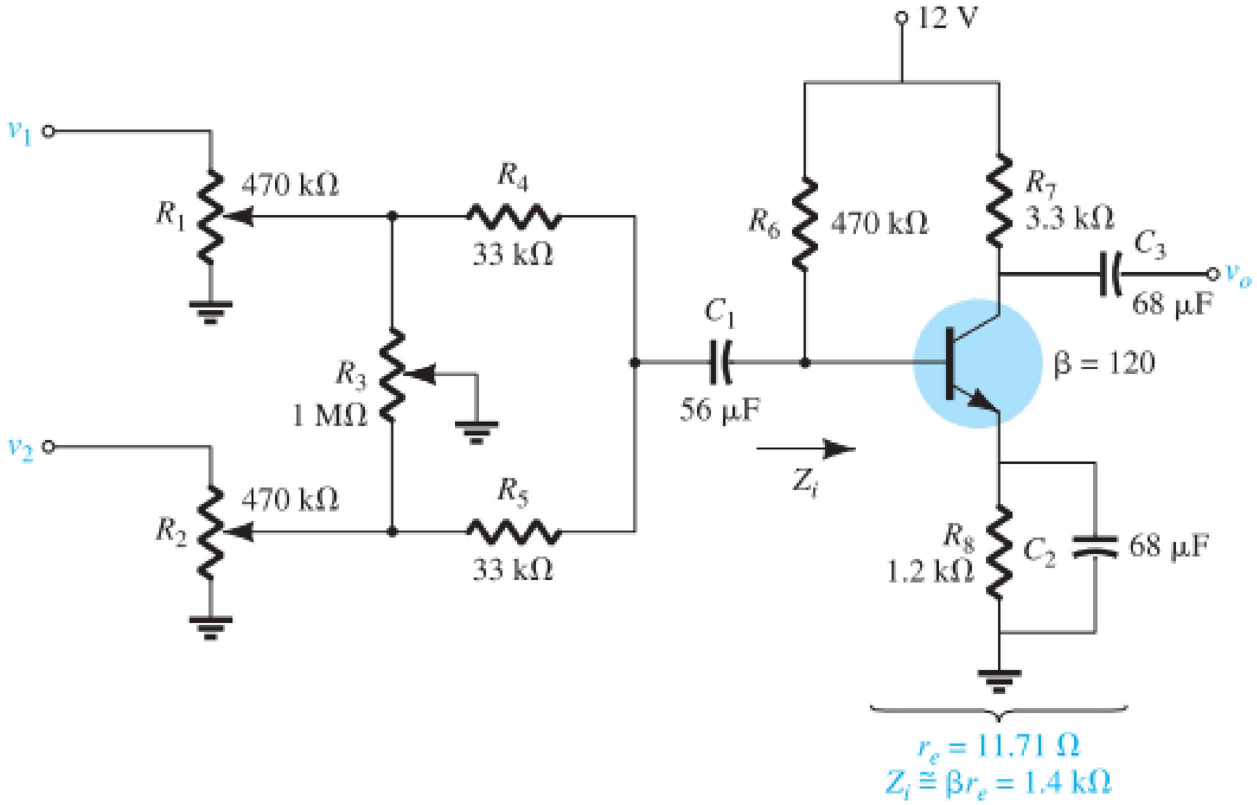


FIG. 5.130
Audio mixer.

- Preamplifier

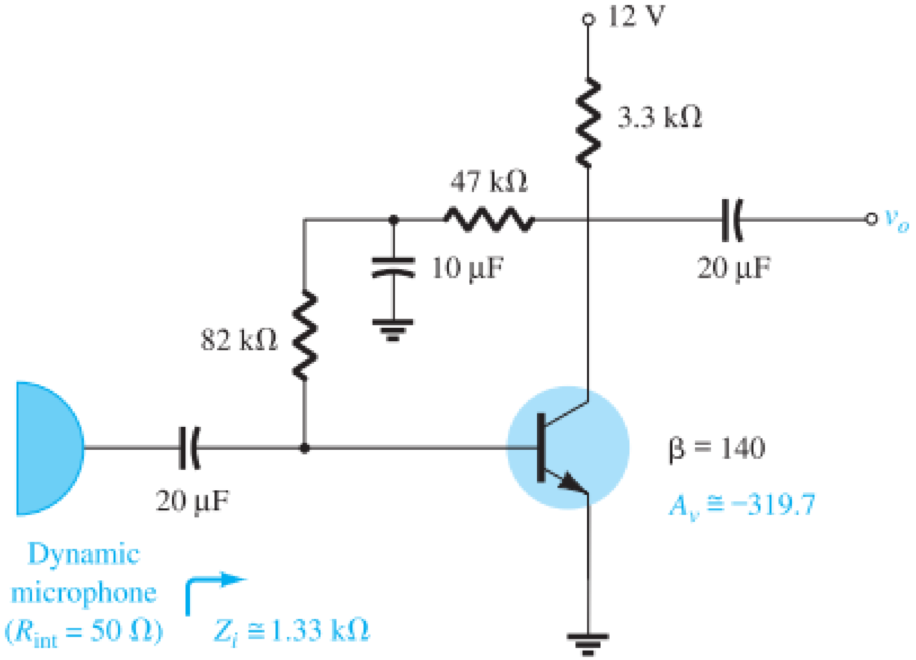


FIG. 5.133
Preamplifier for a dynamic microphone.


Thank You!