ECE 321C
Electronic Circuits

Lec. 6: BJT Modeling and re Transistor Model (Hybrid Equivalent Model) (3)

Instructor

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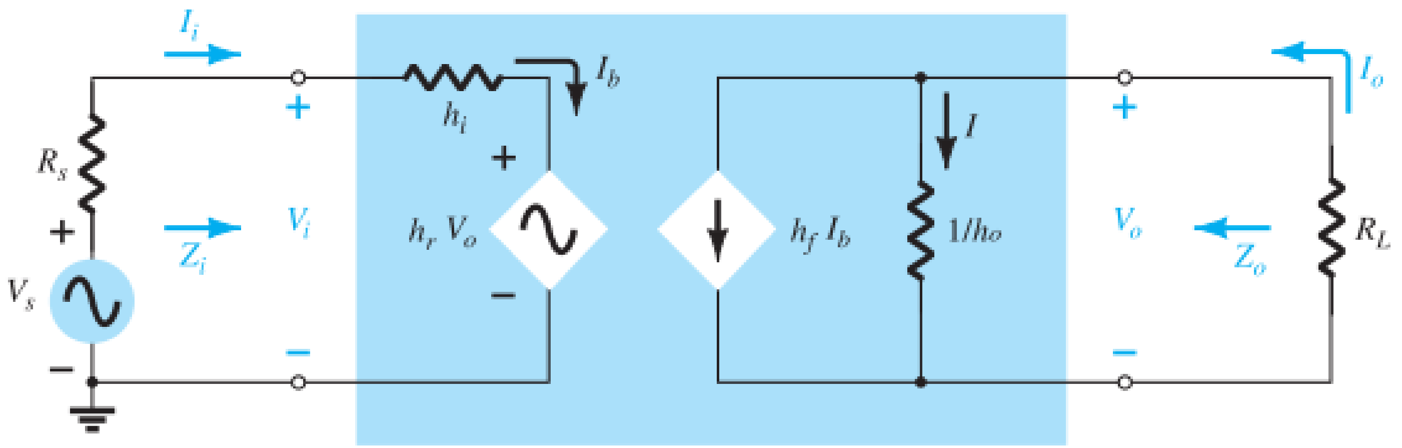
Agenda

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

Complete Hybrid Model

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, $A_v = V_o/V_i$

$$V_i = I_i h_i + h_r V_o$$

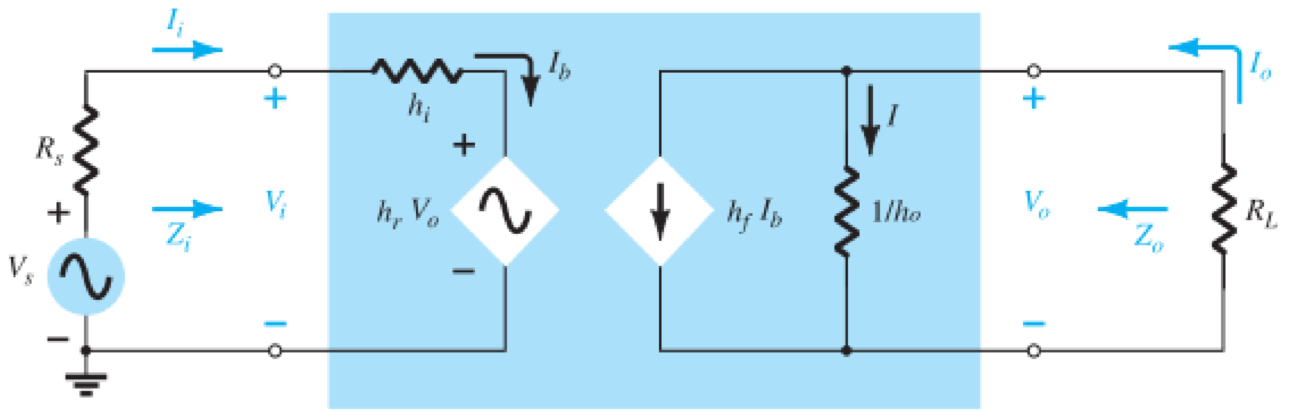
$$I_i = (1 + h_o R_L) I_o / h_f$$

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, $Z_i = V_i/I_i$

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

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

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

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

Output Impedance, $Z_o = V_o/I_o$

$$V_s = 0$$

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

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

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

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.

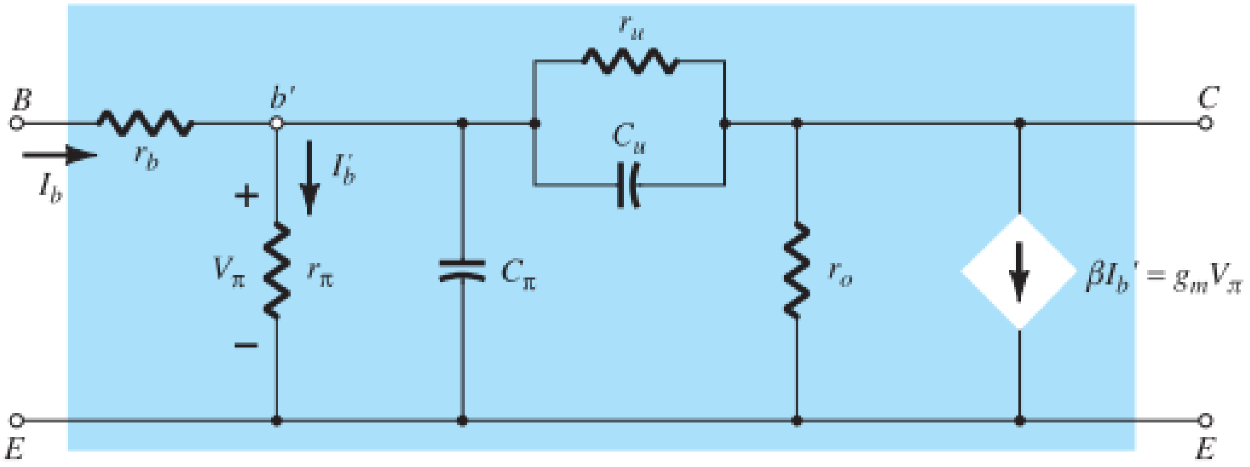


FIG. 5.123

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)

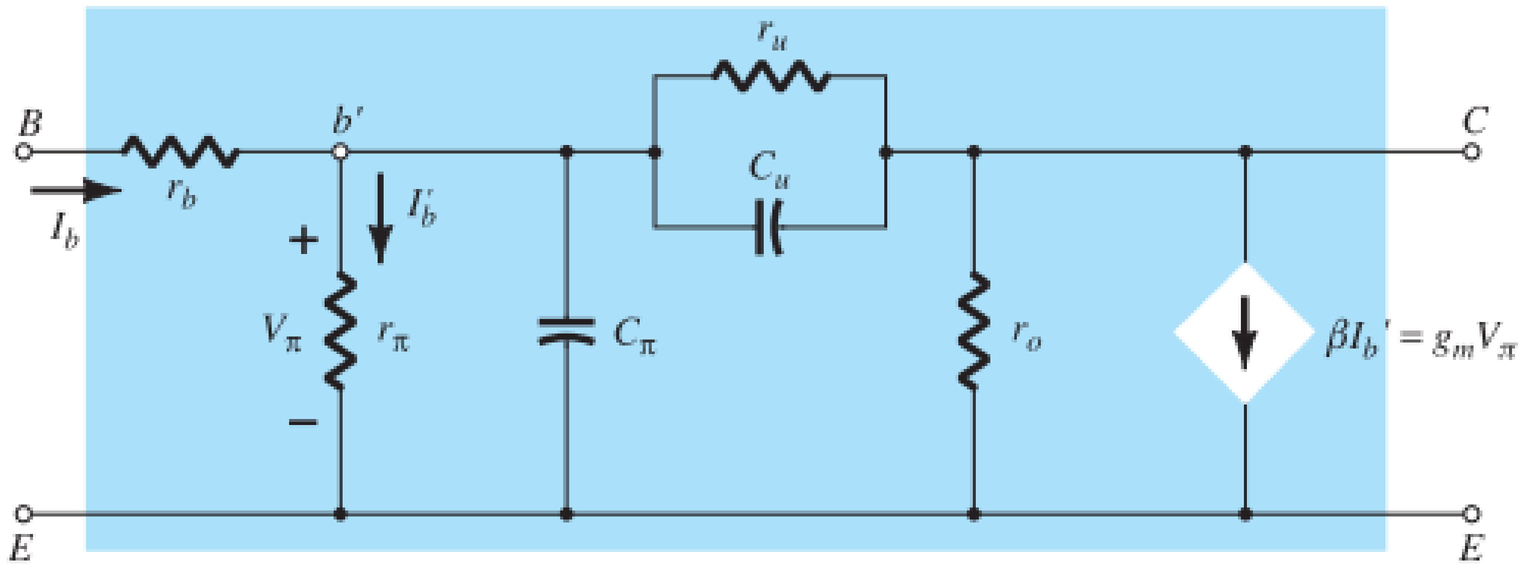


FIG. 5.123

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)

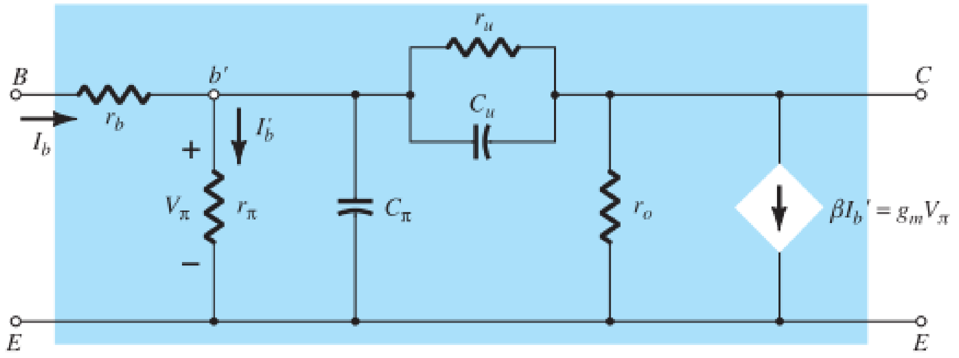


FIG. 5.123

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)

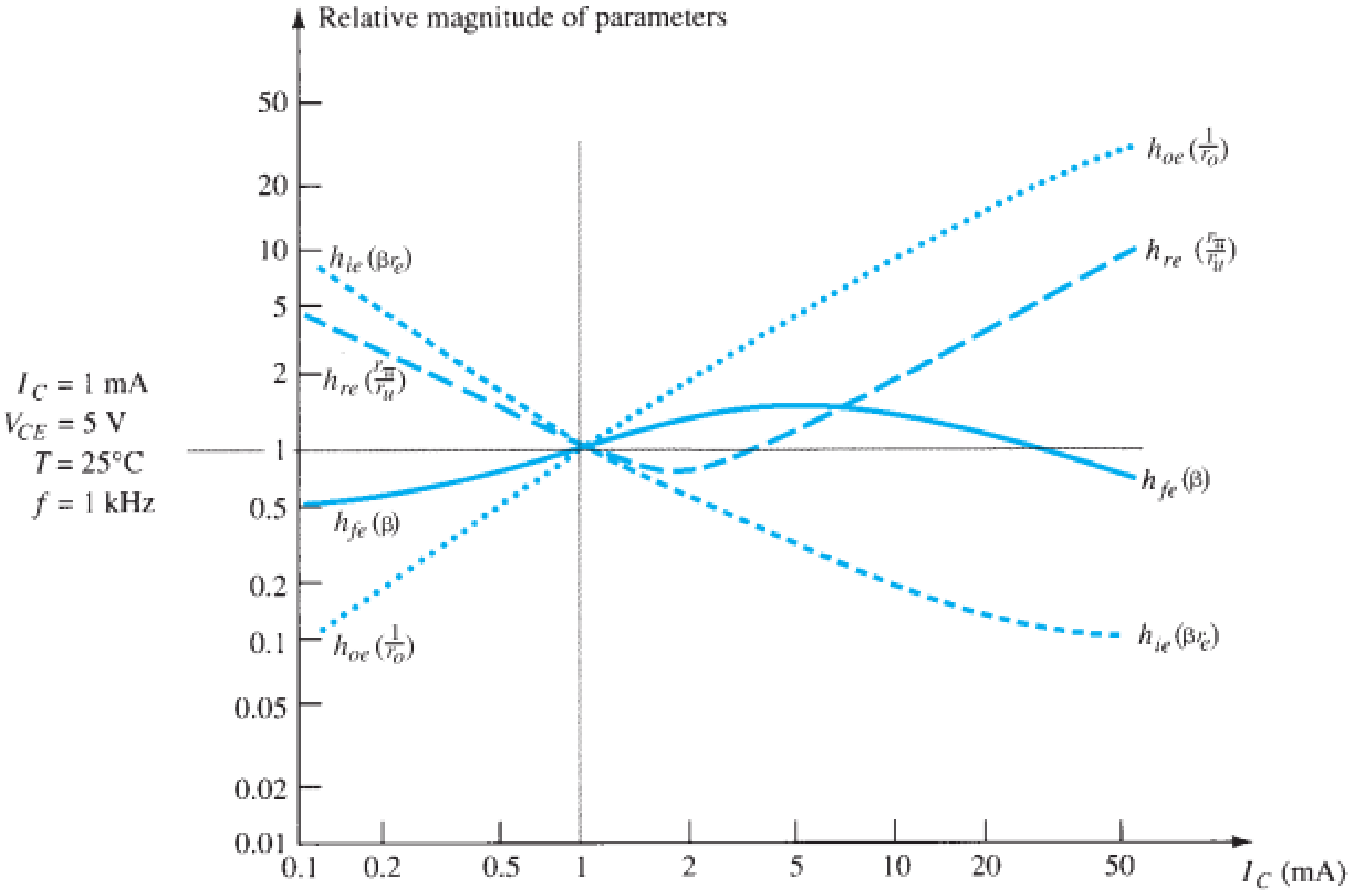


FIG. 5.124
Hybrid parameter variations with collector current.

- 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)

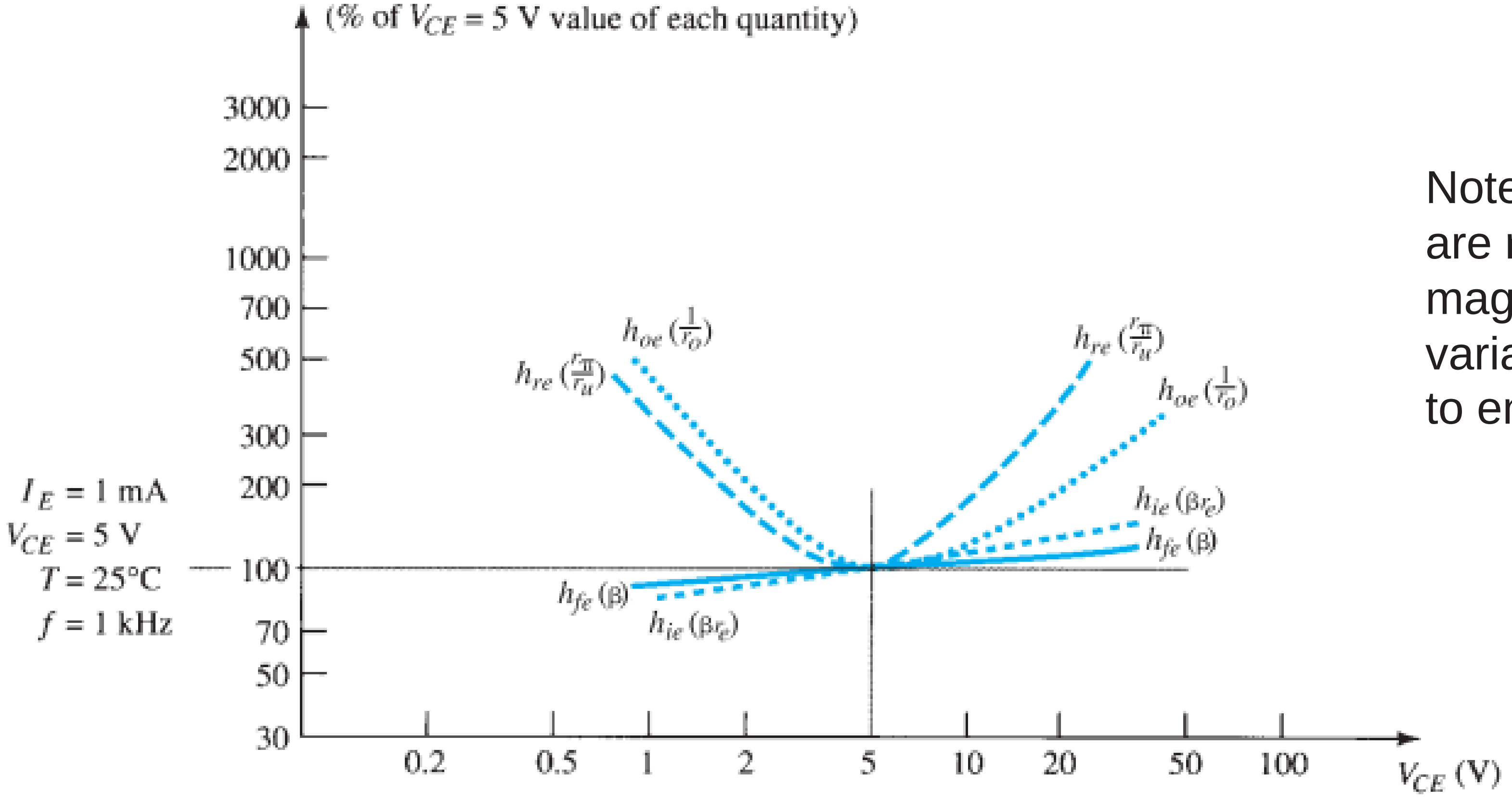


FIG. 5.125

Hybrid parameter variations with collector–emitter potential.

Note that *hfe* and *hie* are relatively steady in magnitude with variations in collector-to emitter voltage

Variations of Transistor Parameters (3 of 3)

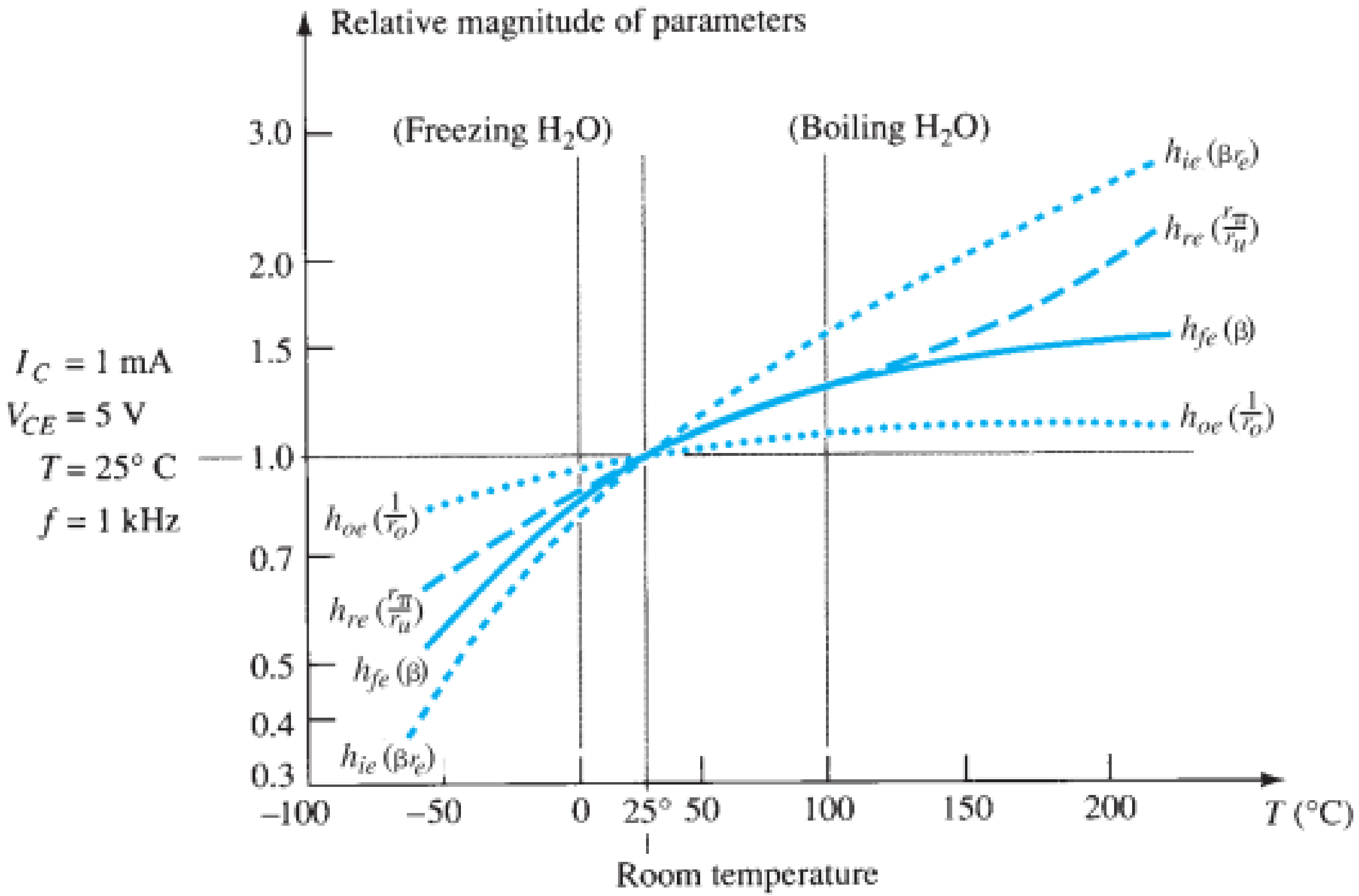


FIG. 5.126

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.

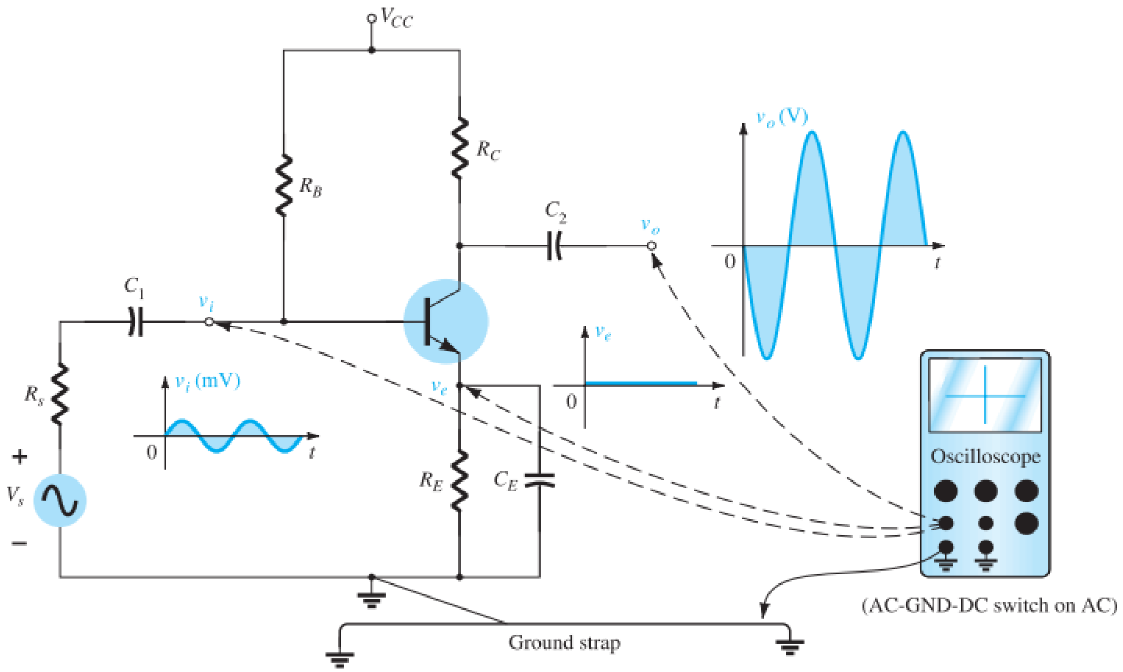


FIG. 5.128

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

PRACTICAL APPLICATIONS

- Audio Mixer

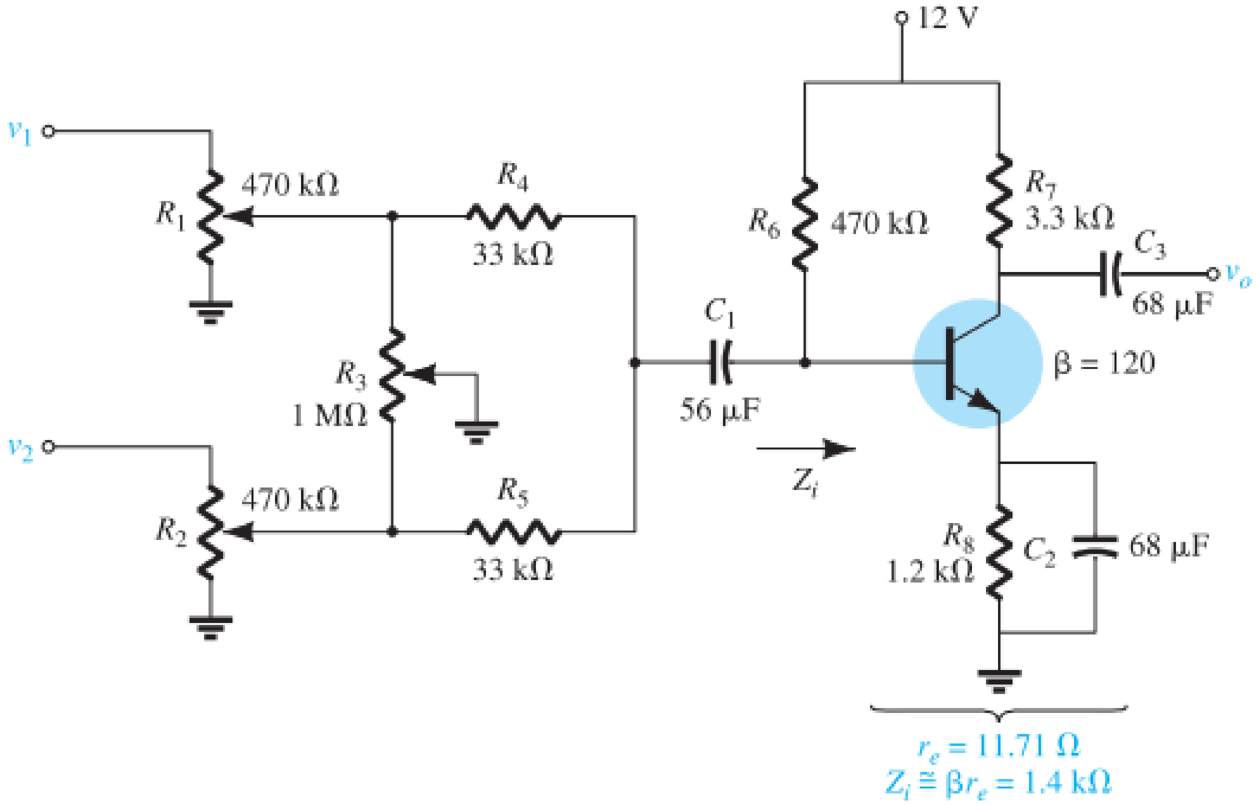


FIG. 5.130
Audio mixer.

- Preamplifier

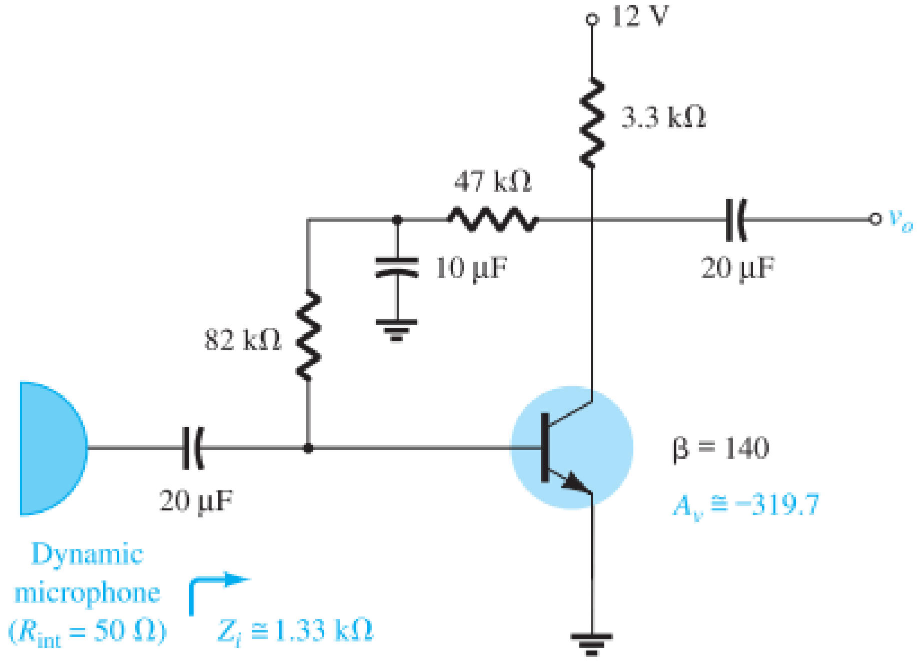


FIG. 5.133
Preamplifier for a dynamic microphone.


Thank You!