Laboratorij za načrtovanje integriranih vezij

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Fakulteta za elektrotehniko

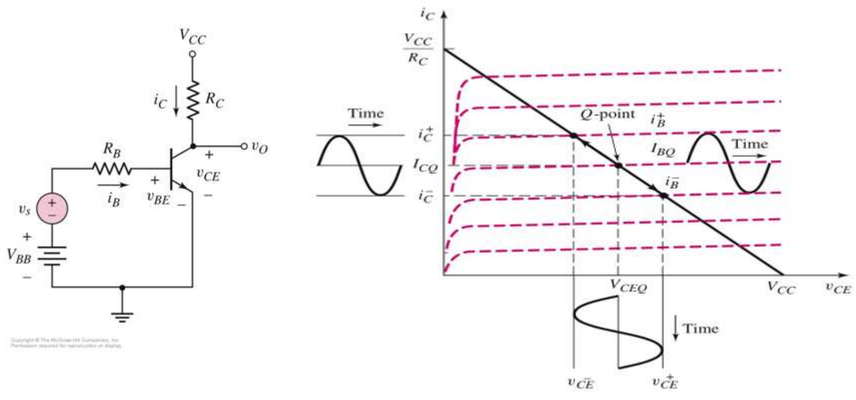
Linearna elektronska vezja

Bipolarni tranzistor: Ojačevalnik

In this chapter, we will:

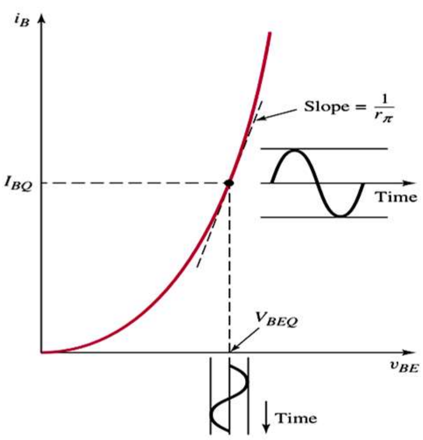
- Investigate a single-transistor circuit that can amplify a small, time-varying input signal
  - Develop small-signal models that are used in the analysis of linear amplifiers
- Discuss and compare the three basic transistor amplifier configurations.
  - Analyze the common-emitter amplifier.
  - Analyze the emitter-follower amplifier.
  - Analyze the common-base amplifier.
- Analyze multitransistor or multistage amplifiers.

Common Emitter with Time-Varying Input

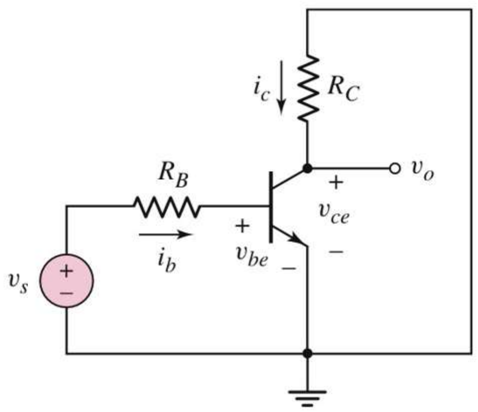


I_B Versus V_{BE} Characteristic

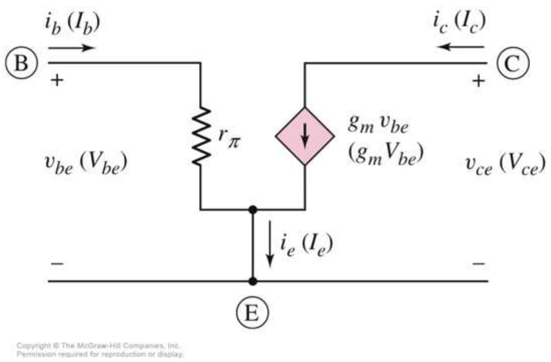
$$i_B \cong I_{BQ}(1+\frac{v_{be}}{V_T}) = I_B + i_b$$



ac Equivalent Circuit for Common Emitter



Small-Signal Hybrid π Model for npn BJT

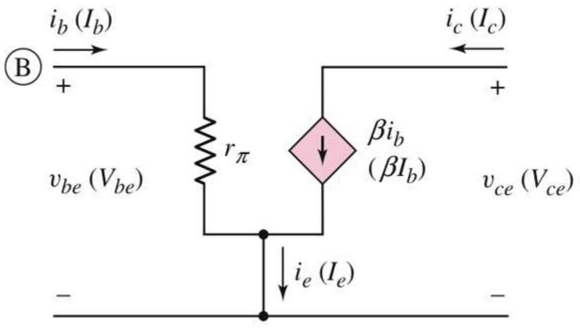


$$g_m = \frac{I_{CQ}}{V_T}$$

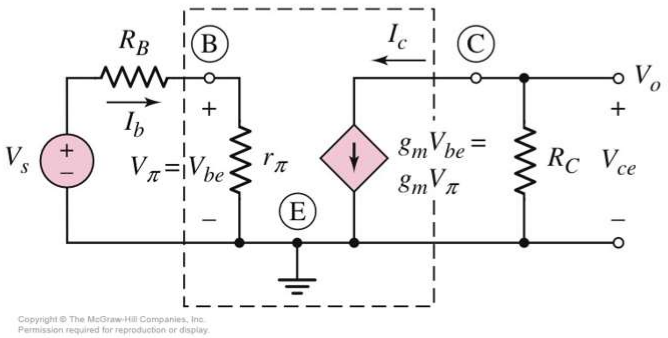
$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$g_m r_\pi = \beta$$

S-S EC Using Common-Emitter Current Gain



S-S EC for npn Common Emitter circuit

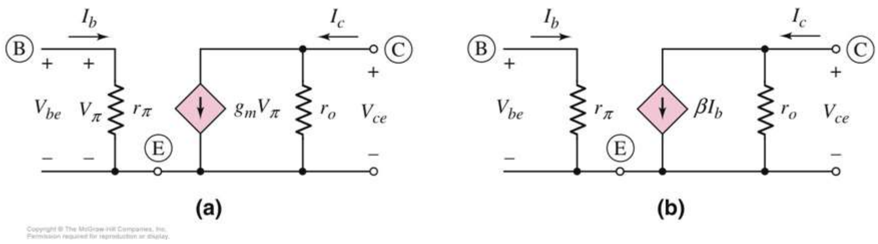


$$A_v = -(g_m R_C)(\frac{r_\pi}{r_\pi + R_B})$$

Problem Solving Techniques

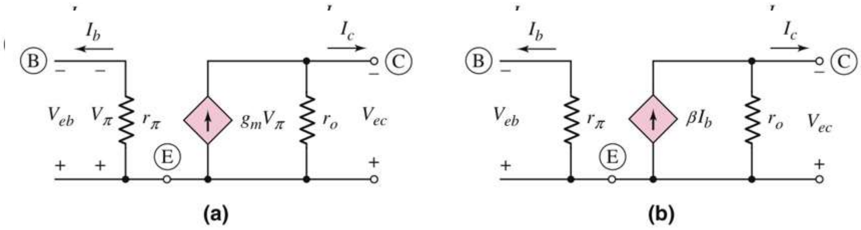
1. Analyze circuit with only the dc sources to find quiescent solution.
   - Transistor must be biased in active region for linear amplifier.
2. Replace elements with small-signal model.
3. Analyze small-signal equivalent circuit, setting dc sources to zero, to produce the circuit to the time-varying input signals only.

Hybrid π Model for npn with Early Effect

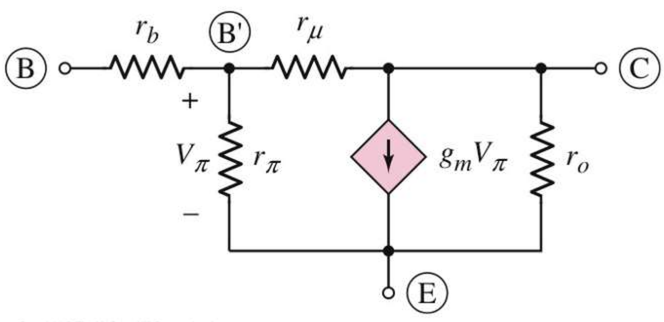


$$r_o = \frac{V_A}{I_{CQ}}$$

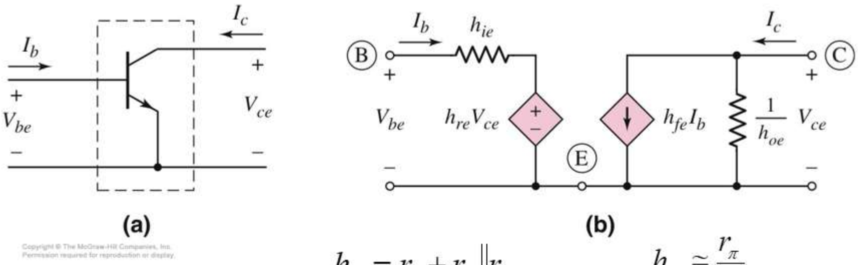
Hybrid π Model for pnp with Early Effect



Expanded Hybrid π Model for npn



h-Parameter Model for npn



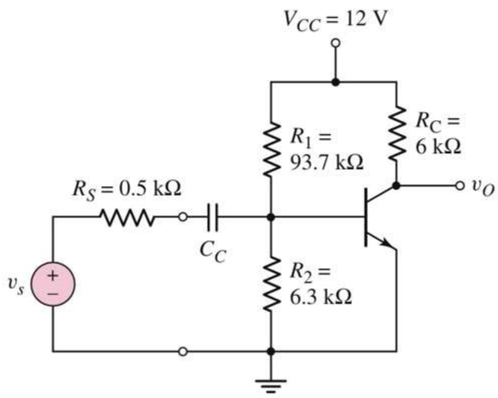
$$h_{ie} = r_b + r_\pi \| r_\mu$$

$$h_{fe} = \beta$$

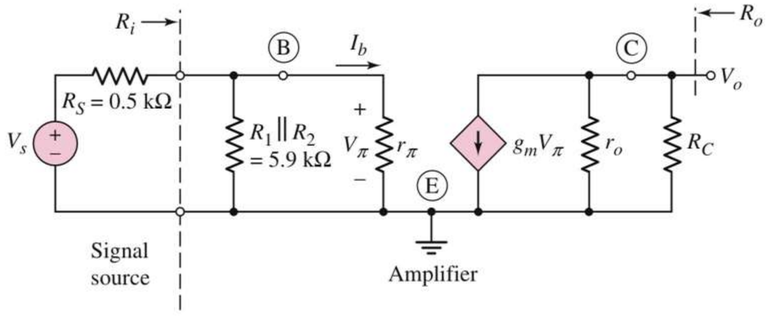
$$h_{re} \cong \frac{r_\pi}{r_\mu}$$

$$h_{oe} = \frac{1+\beta}{r_\mu} + \frac{1}{r_o}$$

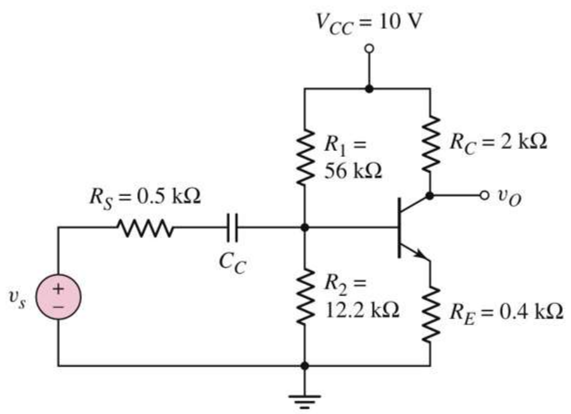
C-E with Voltage-Divider Bias and a Coupling Capacitor



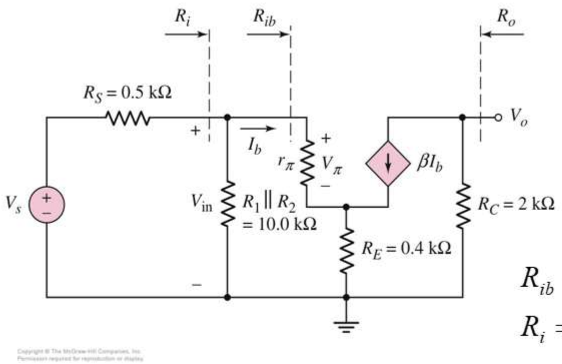
S-S EC – Coupling Capacitor Assumed a Short



npn Common Emitter with Emitter Resistor



S-S EC – Common Emitter with R_E

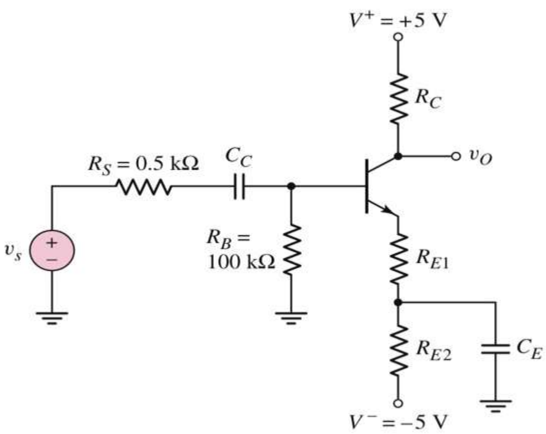


$$R_{ib} = r_\pi + (1+\beta)R_E$$

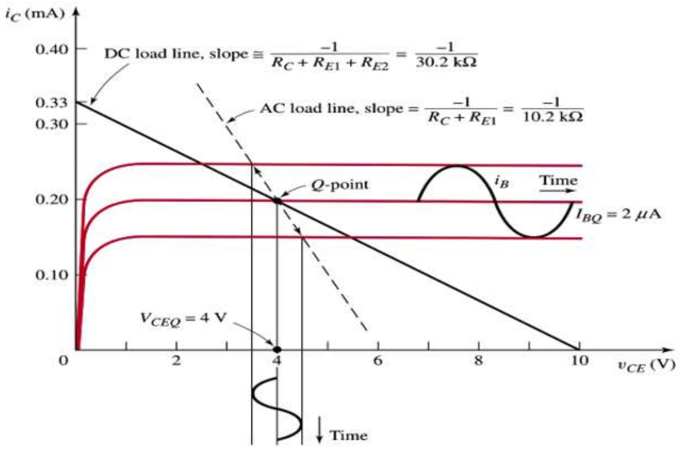
$$R_i = R_1 \| R_2 \| R_{ib}$$

$$A_v = \frac{-\beta R_C}{r_\pi + (1+\beta)R_E}\left(\frac{R_i}{R_i + R_S}\right)$$

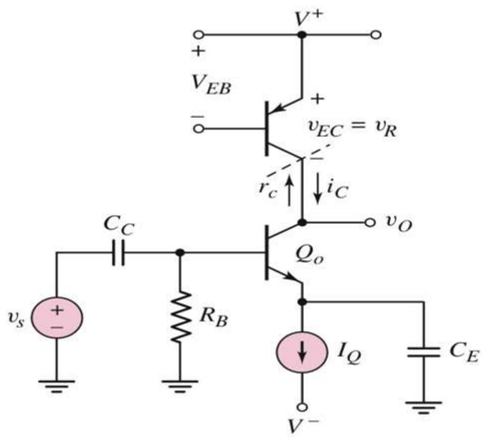
R_E and Emitter Bypass Capacitor



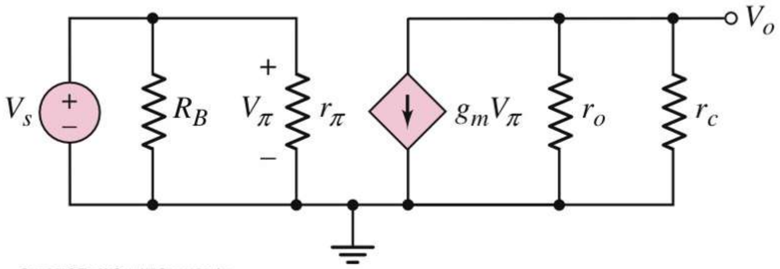
dc AND ac Load Lines: R_E and Emitter Bypass Capacitor



Current Source Biasing and Nonlinear Load

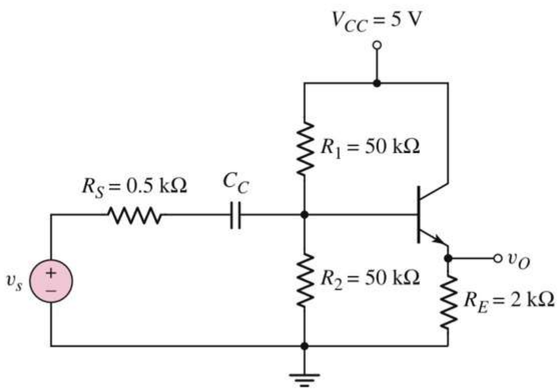


S-S EC with Current Biasing and Nonlinear Load

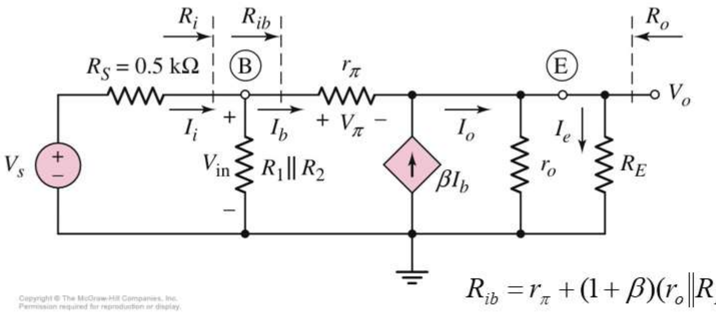


$$A_v = -g_m (r_o \| r_c)$$

Common-Collector or Emitter-Follower Amplifier



S-S EC: Emitter Follower

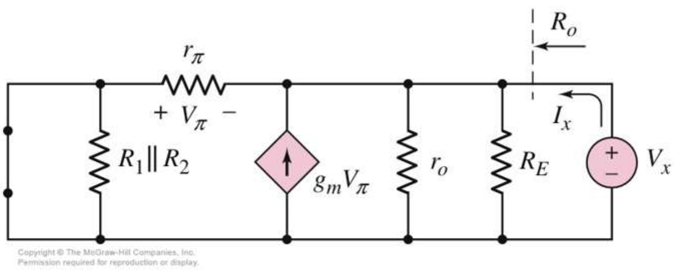


$$R_{ib} = r_\pi + (1+\beta)(r_o \| R_E)$$

$$R_i = R_1 \| R_2 \| R_{ib}$$

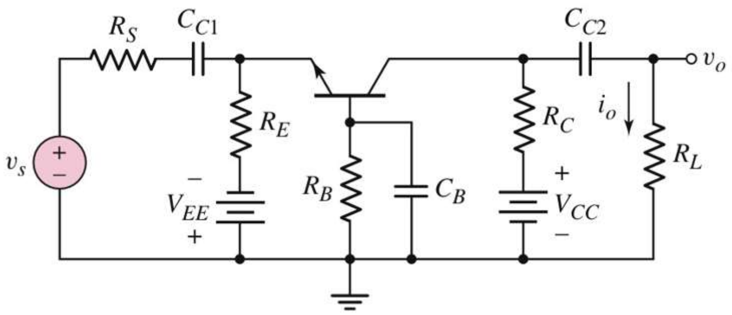
$$A_v = \frac{(1+\beta)(r_o \| R_E)}{r_\pi + (1+\beta)(r_o \| R_E)} \left(\frac{R_i}{R_i + R_S}\right)$$

Output Resistance: Emitter Follower

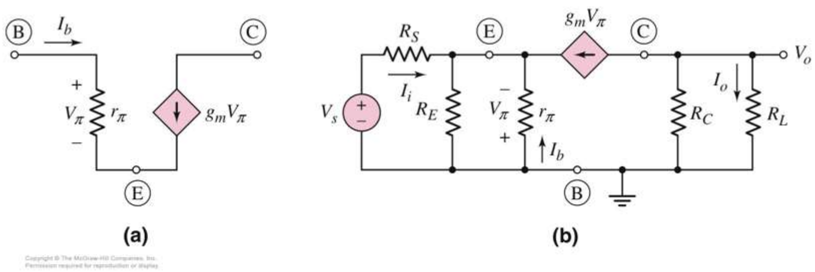


$$R_o = \frac{r_\pi}{1+\beta} \| R_E \| r_o$$

Common-Base Amplifier



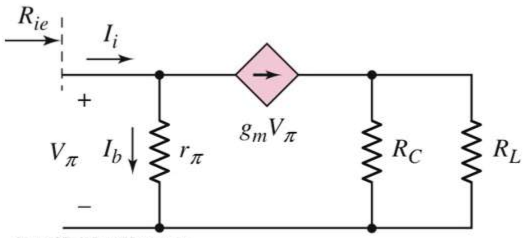
S-S EC: Common Base



$$A_v = g_m (R_C \| R_L)$$

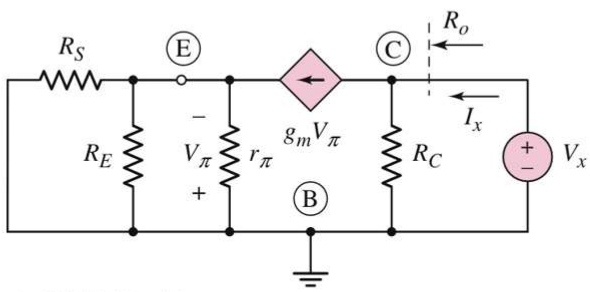
$$A_i = g_m \left(\frac{R_C}{R_C + R_L}\right)\left[\frac{r_\pi}{1+\beta} \| R_E\right]$$

Input Resistance: Common Base



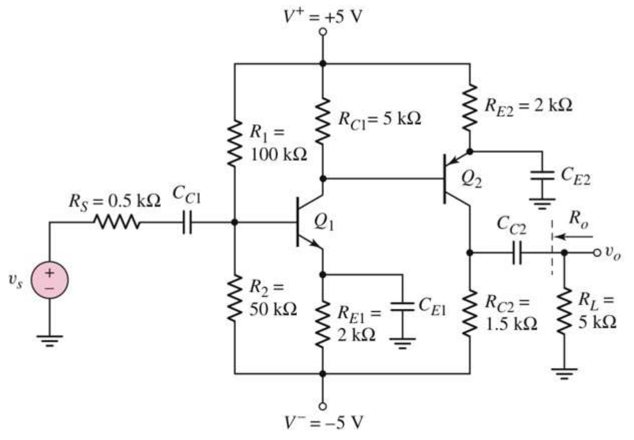
$R_{ie} = r_\pi/(1+\beta)$

Output Resistance: Common Base

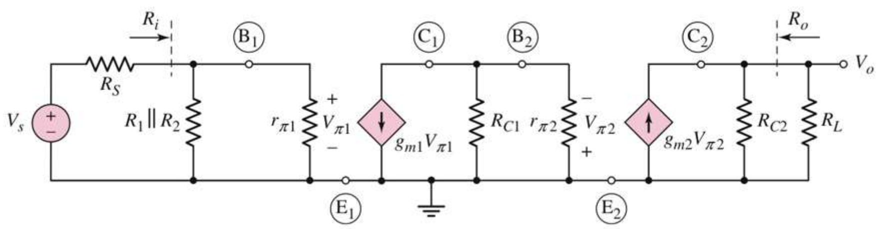


$R_O = R_C$

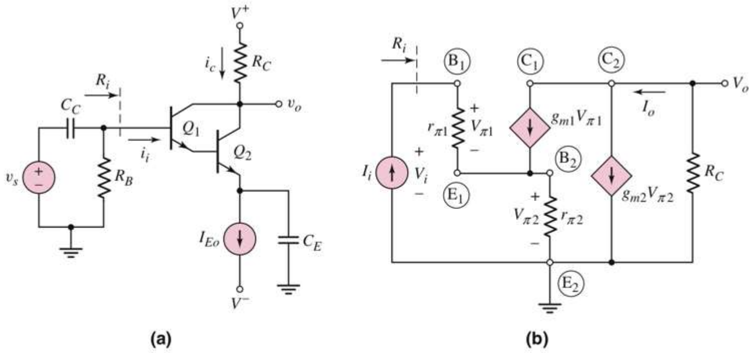
Common Emitter Cascade Amplifier



S-S EC: Cascade Amplifier

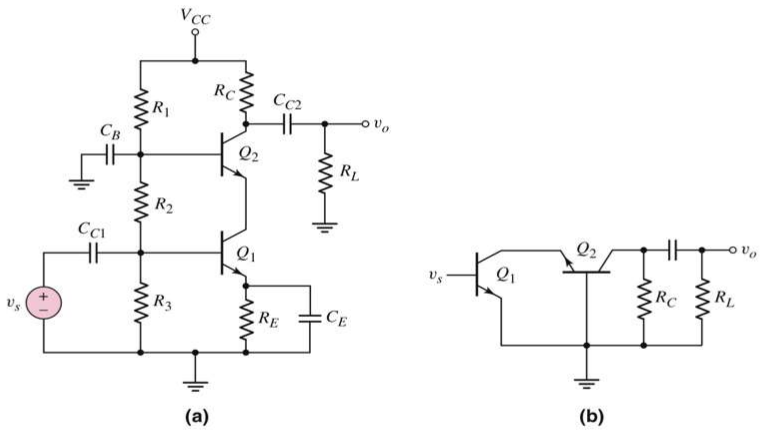


Darlington Pair

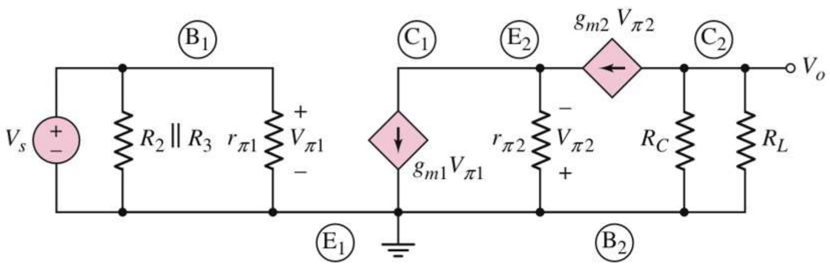


$$A_i \cong \beta_1 \beta_2$$

Cascode Amplifier



S-S EC: Cascode Amplifier



$$A_v \cong -g_{m1}(R_C \| R_L)$$