Voltage Gain: $A_v = \dfrac{v_o}{v_i}$ Current Gain: $A_i = \dfrac{i_o}{i_i}$ Power Gain: $G = A_v A_i$

Decibel: $A_{v\text{dB}} = 20\log(|A_v|)$ $A_{i\text{dB}} = 20\log(|A_i|)$ $G_{\text{dB}} = 10\log(|G|)$

Energy Conservation: $P_i + P_s = P_o + P_d \longrightarrow \begin{cases} P_i & = \text{Power from Source} \\ P_s & = \text{Power from DC Supplies} \\ P_o & = \text{Output Power at Load} \\ P_d & = \text{Power Dissipated in the Op-Amp} \end{cases}$

Frequency Dependence:

Capacitor: $Z_c = \dfrac{1}{j\omega C}$ Inductor: $Z_L = j\omega L$

Summing Point Constraint:

- Only applies when the op-amp is in negative feedback
- Assuming ideal op-amp, $V_+ - V_- = 0$ (no current at terminals)
- For non-ideal op-amps: $V_o = A(s)(V_+ - V_-)$

$f_{3\text{dB}} = \dfrac{\omega_{3\text{dB}}}{2\pi}$ $\text{GBW} = |A_v||f_{3\text{dB}}$

Diodes:

- In Forward Bias (FB): Permit current flow, have a positive voltage drop
- In Reverse Bias (RB): No current flow (open circuit)
  - Constant Voltage Drop (CVD): Diodes have same forward-bias drop ($\approx .7$[V])
- Assume bias mode for each diode in diagram, calculate values to verify assumptions
- CVD + resistance model: $r_d = \frac{nV_T}{I_{DQ}}$ (approximated around quiescent point, Q)

$I_D = I_s e^{\frac{V_D}{nV_T}} + 1$ Room Temp: $V_T \approx 26[\text{mV}]$ $1 < n < 2$ $10^{-6} < I_s 10^{-18}[\text{A}]$

Temp Dependence: constant $I \rightarrow V$ drop decreases ≈ 2[mV] per 1[°C] temperature increase

Zener Diodes: $V_D = -V_{zo} - I_z r_z$ in breakdown, with $I_z = -I_D > 0$

Transformers: step voltages according to turns ratio $(N_p : N_s)$ or $(n : 1)$, with $V_s = V_p/n$

BJT Regions

EBJ	CBJ	Mode
FB	RB	Active
FB	FB	Saturation
RB	RB	Cutoff

Note: When designing an amplifier confirm that the BJT is in the active region

BJT Formulas

$$I_E = I_C + I_B$$

$$I_E = I_{ES}\left[e^{\frac{V_{BE}}{V_T}} - 1\right]$$

Active Region Only:

$$I_C = \alpha I_E$$
$$I_B = (1-\alpha) I_E$$
$$I_C = \beta I_B$$
$$I_S = \alpha I_{ES}$$

For BJTs: $\beta = \dfrac{\alpha}{1-\alpha}$ $\alpha = \dfrac{\beta}{1+\beta}$ Typically: $\alpha \approx 1$, and $I_C \approx I_E$ but $I_C < I_E$

BJT Models

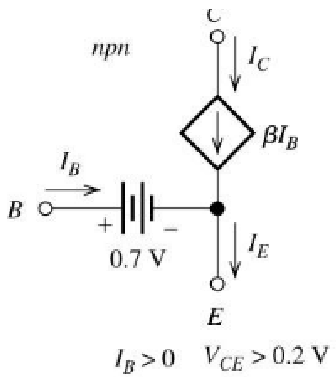

Figure 1: *npn* in Active Mode

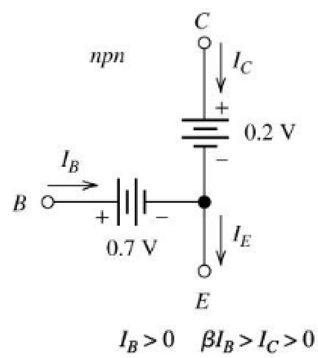

Figure 2: *npn* in Saturation

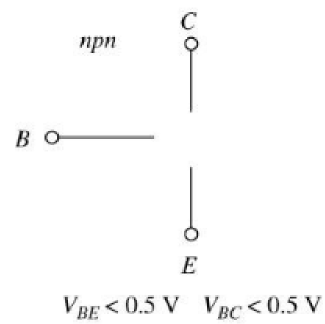

Figure 3: *npn* in Cutoff

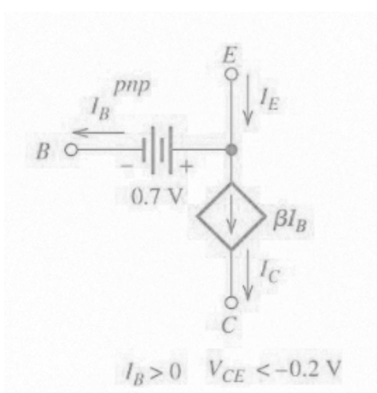

Figure 4: *pnp* in Active Mode

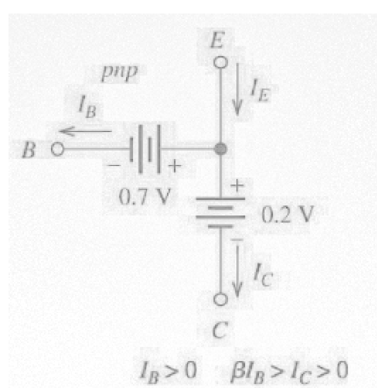

Figure 5: *pnp* in Saturation

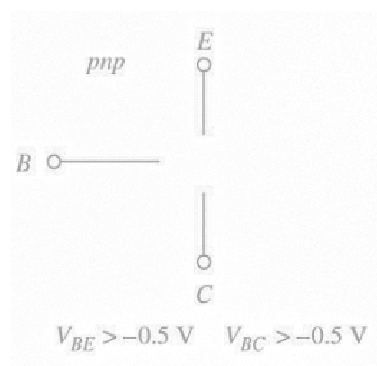

Figure 6: *pnp* in Cutoff

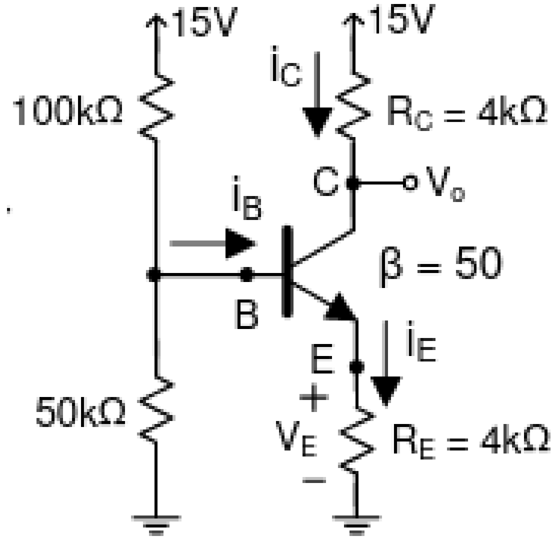

Figure 7: Initial Circuit

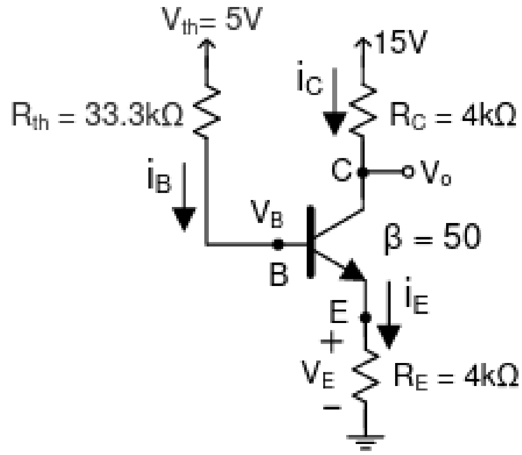

Figure 8: Thévenin Equivalent