BJT’s

NPN Bipolar Junction Transistor

PNP Bipolar Junction Transistor
BJT Operating Point

- Three regions of operation:
- Cutoff
- Saturation
- Forward Active
  - \( V_T = kT/q \)
  - \( I_C = \beta I_B \)
  - \( I_E = I_C + I_B \)
  - \( I_e = g_m R \)
BJT Incremental Model
Gain Calculation

\[ A_v = -G_M R_{out} \]

\( G_M \) = Small signal transconductance, ratio of \( i_{out} \) to \( v_{in} \)

\( R_{OUT} \) = Equivalent incremental output resistance

\( R_{IN} \) = Equivalent incremental input resistance
Common Amplifier Topologies

1. Diode-tied Transistor
   a. What is overdrive voltage here?
   b. Is this always in saturation?

2. Common Emitter/Collector/Gate
   a. Purpose of each topology?
   b. Equations

3. Common Emitter with Degeneration

4. Common Collector with Modulation

5. Cascode
Terminal Impedances of BJT’s

\[ R_C = r_o \]

\[ R_B = R_{\pi} \]

\[ R_E = R_{\pi}/(1+1) \]

Diode-Tied = \( R_{\pi}/(1+1) \)
Common Emitter/Collector/Base

\[ R_{OUT} = R_c \parallel r_o \]
\[ R_{IN} = R_{\pi} + R_B \]
\[ G_m = \frac{1}{(R_{\pi} + R_B)} \]

\[ R_{OUT} = \frac{((R_{\pi} + R_B)/(\pi + 1))}{R_E} \]
\[ R_{IN} = R_B + R_{\pi} + ((\pi + 1))R_E \]
\[ G_m = - \frac{(\pi + 1)}{(R_{\pi} + R_B)} \]

\[ R_{OUT} = R_c \parallel r_o \]
\[ R_{IN} = (R_{\pi} + R_B)/(\pi + 1) \]
\[ G_m = \frac{1}{(R_{\pi} + R_B)} \]
Degeneration

When a resistance is “viewed” through the collector, it appears bigger by a factor related to the transconductance.

\[ G_m = \frac{1}{\left(\left(\frac{R_B + R_{\pi}}{R}\right) + \left(\frac{+1}{R}\right)\right)R_E} \]

\[ R_{IN} = R_B + R_{\pi} + \left(\frac{+1}{R}\right)R_E \]
Modulation

Resistances seen through the Emitter seem smaller.

\[
G_m = -\frac{\Box + 1}{R_B + R_x}
\]

\[
R_{IN} = R_B + R_x + ((\Box + 1))R_E
\]
Cascode

\[ \text{vout} \]
Bode Plots

Magnitude

Pole: Roll down by 20 db/dec, 6 db/oct

Zero: Roll up by 20 db/dec, 6 db/oct

Phase: \(\text{arctan}(\omega/\omega_p)\)

Usually -90° for poles, +90° for zeros

\[\omega_{ugf} = 20\log|A_n| \cdot \omega_{pn}\] where \(n\) is the pole located before unity gain frequency