HW #5 Due Friday

HW #4 Graded handed back

Test 1: Hi: 95/95, Lo 26/95
Avg 70.1/95, MEDIAN 72/95

Mid-term grading petitions due by Friday Feb. 10; write a note explaining why you deserve credit

\[ \beta = 100 \]

\[ I_B = 10 \mu A \quad \rightarrow \quad I_C = \beta I_B = 1 mA \]

\[ I_E = I_C = 1 mA \quad V_E = (1 k\Omega)(1 mA) = 1 V \]

\[ V_B = 1 + 0.7 = 1.7 V \]

\[ I_B = 10 \mu A \quad I_E = (\beta+1) I_B = 101 \times 10 \mu A = 101 mA \]
5V - 3.3I_E1 - 0.7 - 5I_B1 = 0

\[ I_{B1} = \frac{I_E1}{\beta + 1} = \frac{I_E1}{5} \]

\[ A \cdot 3 = 3.3I_E1 + \beta \cdot \frac{I_E1}{5} = 4.3I_E1 \]

\[ I_{E1} = 1 \text{mA} \Rightarrow I_{B1} = \frac{1 \text{mA}}{5} = 0.2 \text{mA} \]

\[ V_O = 5I_{B1} = 1V \]

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**Small-signal analysis**

- small input signals
  - linearize nonlinearity at the dc op. pt
- linear circuit analysis

**Analysis of circuits**

1. Determine the dc operating point (quiescent op. pt) or the bias \( I_{CQ} \)

2. Determine the small-signal parameters of the transistor \( g_m, r_x \)

\[ g_m = \frac{I_C}{V_{bw}}, \quad r_x = \frac{\beta}{g_m} \]
3. Replace transistor with small-signal equivalent circuit and perform a linear circuit analysis with the input signal to determine the output.

Hybrid-π model

T-model

Independent DC sources are set to 0.

Undep DC Voltage Source → Short circ. " " Current " " → Open circ.

Total quantity: e.g. $i_C = I_{CQ} + i_c \leftarrow \text{small-signal current}$

DC op. pt. collector current determined in Step 3

determined in Step 1

Small-signal analysis

$A_V = \frac{v_o}{v_i}$

$v_o = -g_m v_k R_C$

$v_k = \frac{v_k}{v_k + R_\beta}$
\[ V_0 = -g_m \frac{r_k}{r_k + R_B} R_c V_i \]

\[ A_v = \frac{V_0}{V_i} = -g_m \frac{R_c}{r_k + R_B} \]

\[ \frac{I_C}{V_{th}} = \frac{I_s e^{v_{BE}/V_{th}}}{V_{th}} \]

\[ g_m = \frac{\partial I_C}{\partial v_{BE}} \bigg|_{\text{opt. pt.}} = \frac{I_s e^{v_{BE}/V_{th}}}{V_{th}} \left( 1 + \frac{V_{CE}}{V_A} \right) = f(v_{BE}, V_{CE}) \]

\[ \frac{\partial I_C}{\partial V_{CE}} \bigg|_{\text{op. pt.}} = \frac{I_s e^{v_{BE}/V_{th}}}{V_{th}} \left( 1 + \frac{V_{CE}}{V_A} \right) = \frac{I_C}{V_A} = \frac{I_C}{r_0} \]

Complex small-signal circuit:

- \[ I_{CB} = 1 \text{mA} \]
- \[ V_A = 100 \text{V} \]
- \[ V_r = \frac{V_A}{I_{CA}} = 100 \text{k}\Omega \]
- \[ r_0 \text{ large resistance} \]

We will ignore \( r_0 \) for ECE 322.