Design Notes Expt 5

Setting the differential input resistance

$$R_{id} = 2r_{be} = \frac{2\beta_o}{g_m} = \frac{2\beta_o}{40I_C}$$

So bias current, I_O in differential amplifier is

$$I_O = 2I_C = 2\frac{2\beta_o}{40R_{id}}$$

$$I_O = \frac{\beta_o}{10R_{id}}$$

Now to design the Widlar current mirror to bias the diff amp stage.

$$R_E I_O = V_T \ell n\left(\frac{I_{ref}}{I_O}\right) \quad \text{or} \quad I_{ref} = I_O \exp\left(\frac{I_O R_E}{V_T}\right)$$

Don't know R_E or I_{ref}

Try $I_O R_E = V_T$

Then $I_{ref} = I_O \exp(1)$

OR Set $I_{ref} = 10 \times I_O$ then

$$R_E = \frac{V_T}{I_O}\ell n(10)$$

Resistor in other branch of CM is

$$R = \frac{V_{CC} + V_{EE} - 0.6}{I_{ref}}$$

Gains

Gain of differential amplifier

$$A_{Vd} = \frac{1}{V_T}\frac{V_{An}V_{Ap}}{V_{An} + V_{Ap}}$$

Gain of CE stage (assume CC gain is unity)

$$A_{VT} \approx A_{Vd} \times A_{VCE}$$

So $A_{VCE} > \frac{5\times10^5}{A_{Vd}}$

$$A_{VCE} = \frac{1}{V_T}\frac{V_{An}V_{Ap}}{V_{An} + V_{Ap}}$$

Calculation for input resistance of CC coupling stage

$$R_i(CC) = r_{be}(CC) + (1+\beta_o)R_E \,//\, R_L$$

$$R_E \,//\, R_L = \frac{R_E r_{be}(CE)}{R_E + r_{be}(CE)}$$

Set R_i (CC) to be much bigger than the output resistance of the Diff/ amp stage (which acts as the source resistance of the CC stage):

$$R_o^{DA} = \frac{\frac{V_{An}}{I_C} \times \frac{V_{Ap}}{I_C}}{\frac{V_{An}}{I_C} + \frac{V_{Ap}}{I_C}}$$

(need to try a bias current for the common emitter, CE stage)

Then get a quadratic equation for the CC bias current. Use this to calculate the gain of the CC stage

$$A_V = \frac{g_m R_E \,//\, R_L}{1 + g_m R_E \,//\, R_L} = \frac{g_m R_E \,//\, r_{be}(CE)}{1 + g_m R_E \,//\, r_{be}(CE)}$$

Output resistance of op-amp (set by another CC stage)

$$R_o = \frac{r_{be} + R_S}{1+\beta_o} \,//\, R_E, \quad R_o = \left(\frac{r_{be}}{\beta_o} + \frac{R_S}{\beta_o}\right) \,//\, R_E$$ This r_{be} is that of CC $(\beta_o = g_m r_{be})$

$$R_o = \left(\frac{r_{be}}{\beta_o} + \frac{R_S}{\beta_o}\right) \,//\, \frac{V_{EE}}{I_C}$$

The source resistance, R_S is the output resistance of the previous stage (CE) – see equation for the differential amplifier.

Set R_o to meet the specification; rearranging gives a quadratic equation for this CC bias current.