

Chapter 8 - Problems

8.2) Assuming V_{in} is constant during the 1.5 ns of transition, the p-channel transistor turns off when:

$$\bar{\Phi} = V_{in} - 0.9V \Rightarrow \phi = 0.9 - V_{in}$$

The n-channel transistor turns off when:

$$\Phi = V_{in} + 0.8V$$

The difference between the ϕ voltages for the two cases is:

$$\Delta\phi = 0.1 - 2V_{in}$$

$|\Delta\phi|$ is maximized at $V_{in} = -1$ for which $|\Delta\phi|_{\max} = 2.1V$

$$\Rightarrow \Delta t_{\max} = \frac{2.1V}{5V} \times 1.5 \text{ ns} = \underline{\underline{0.63 \text{ ns}}}$$

8.3) Case I) the hold pedestal is only due to the sampling switch turning off. Using (8.3), the hold pedestal is:

$$\text{is : } \underline{\underline{\Delta V' = -13 \text{ mV}}}$$

Case II) the hold pedestal due to Q_2 turning on is twice as much as the hold pedestal due to Q_1 turning off and in the opposite direction. The final hold pedestal is: $\Delta V' = 26 \text{ mV} - 13 \text{ mV} = \underline{\underline{13 \text{ mV}}}$

The result is the same hold pedestal with the opposite sign.

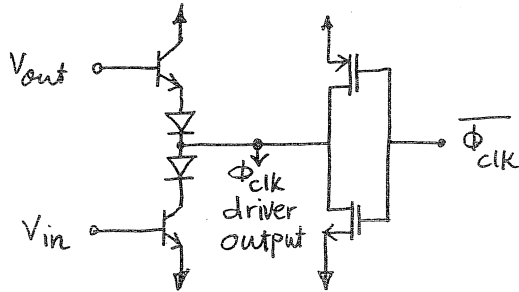
8.4) The gain of the second opamp at 5 MHz is $\frac{100 \text{ MHz}}{5 \text{ MHz}} = 20$.

Therefore, with a 2V p-p signal at the output, the drain of

Q1 can change from $\frac{-1V}{20}$ to $\frac{+1V}{20}$ (a total of 0.1V).

The sampling-time uncertainty is: $\frac{0.1}{5} \times 1.5 \text{ ns} = \underline{0.03 \text{ ns}}$

8.5)



8.6) During the sample mode:

$$\frac{V_o}{A} = V_{os} - V_o \Rightarrow V_o = \frac{A}{A+1} V_{os}$$

where V_{os} is the input offset voltage of the opamp.

During the sample mode, the voltage across C_H is $V_{in} - \frac{A}{A+1} V_{os}$

During the hold mode:

$$V_o = V_{in} - \frac{A}{A+1} V_{os} - \frac{V_o}{A} + V_{os}$$

$$\Rightarrow \underline{V_o = \frac{A}{A+1} V_{in} + \frac{A}{(A+1)^2} V_{os}}$$

8.7) Let's denote the end of Φ_1 by nT . The output voltage at the end of Φ_2 is equal to the output voltage (cont)

8.7) (cont.) at the end of ϕ_1 of the next period.

$$\text{Therefore: } V_o[nT] = \frac{C_2 V_o[nT-T] + C_1 V_{in}[nT-T]}{C_1 + C_2}$$

$$\text{Or, equivalently: } (C_1 + C_2) V_o[z] = C_2 z^{-1} V_o[z] + C_1 z^{-1} V_{in}[z]$$

$$\Rightarrow \frac{V_o(z)}{V_{in}(z)} = \frac{z^{-1}}{1 + \frac{C_2}{C_1} (1 - z^{-1})}$$

$$\text{Substituting } z = e^{j\omega T} \approx 1 + j\omega T :$$

$$\frac{V_o(e^{j\omega T})}{V_{in}(e^{j\omega T})} = \frac{1 - j\omega T}{1 + j\omega \frac{C_2}{C_1} T} \Rightarrow \underline{f_{3dB} = \frac{1}{2\pi} \frac{C_1}{C_2} f_{clk}}$$

8.8)

	V_{in}	V_1	V_2	V_3	V_{out}
track	1*	1.7	0.3	1	1
hold	(-1.1, 3.1)	-0.4	2.4	1	1
track	-1	-0.3	-1.7	-1	-1
hold	(-3.1, 1.1)	-2.4	0.4	-1	-1

* All numbers are in Volts.

8.9) Using (8.12): $\Delta V_{BE} = 0.0275 \times \ln 8 = \underline{57.2 \text{ mV}}$

$$\frac{\Delta V_{BE}}{\Delta V_T} = \frac{57.2 \text{ mV}}{320 \text{ }^\circ\text{K}} = \underline{0.178 \frac{\text{mV}}{^\circ\text{K}}}$$

8.10) Using (8.21): $K = \frac{(1.206) + (1.3)(0.0275) - 0.65}{(0.0275) \ln(8)} = \underline{10.35}$

$$8.11) \text{ From (8.18): } K \frac{kT}{q} \ln\left(\frac{J_2}{J_1}\right) = \frac{T}{T_0} V_{CT0} + (m-1) \frac{kT}{q} - \frac{T}{T_0} V_{BE0-2}$$

Substituting this into the last term of (8.16), we have:

$$V_{ref} = V_{CT0} + \frac{T}{T_0} (V_{BE0-2} - V_{CT0}) + (m-1) \frac{kT}{q} \ln\left(\frac{T_0}{T}\right) + \frac{T}{T_0} V_{CT0} + (m-1) \frac{kT}{q} - \frac{T}{T_0} V_{BE0-2}$$

$$\therefore V_{ref} = \underbrace{V_{CT0} + (m-1) \frac{kT}{q} (1 + \ln \frac{T_0}{T})}$$

which proves (8.22).

$$\begin{aligned} \text{Also: } \frac{\partial V_{ref}}{\partial T} &= (m-1) \frac{k}{q} (1 + \ln \frac{T_0}{T}) + (m-1) \frac{kT}{q} \left(-\frac{1}{T}\right) \\ &= \underbrace{(m-1) \frac{k}{q} \ln \frac{T_0}{T}} \end{aligned}$$

which proves (8.23).

8.12) Using (8.34), we have:

$$V_{ref-0} = \left(1 + \frac{R_4}{R_5}\right) 1.24 \text{ V} = 2.5 \text{ V} \Rightarrow \underbrace{\frac{R_4}{R_5} = 1}$$

$$\text{Using (8.32): } \underbrace{\frac{R_1}{R_2} = 5.5}$$

Assuming $\underline{R_2 = 1 \text{ k}\Omega}$ & $\underline{R_5 = 10 \text{ k}\Omega}$ results in:

$$\underline{R_1 = 5.5 \text{ k}\Omega} \quad \& \quad \underline{R_4 = 10 \text{ k}\Omega}$$

$$\text{Also, } R_3 = \frac{R_2}{R_1} R_4 \parallel R_5 = \frac{1}{5.5} (10 \text{ k}) = \underline{900 \Omega}$$

$$8.13) \quad V_{BE1} - V_{BE2} = R_2 I_2 \quad \& \quad R_3 I_2 = R_1 I_1$$

$$V_{ref} = V_{BE1} + R_1 I_1 = V_{BE1} + R_3 I_2 = V_{BE1} + R_3 \frac{1}{R_2} (V_{BE1} - V_{BE2})$$

$$\begin{aligned} \Rightarrow V_{ref} &= V_{BE1} + \frac{R_3}{R_2} \frac{kT}{q} \ln \frac{I_1}{I_2} \\ &= \underbrace{V_{BE1} + \frac{R_3}{R_2} \frac{kT}{q} \ln \left(\frac{R_3}{R_1} \right)} \end{aligned}$$

which proves (8.41) for the circuit of Fig. 8.27(b).

8.14) Using (8.61):

$$\text{For a gain of } 0.5, \quad \frac{I_2}{I_1} = 0.5 \Rightarrow I_1 = 2I_2 = \underline{400\mu A}$$

$$\text{" " " " } 4, \quad \frac{I_2}{I_1} = 4 \Rightarrow I_1 = \frac{I_2}{4} = \underline{50\mu A}$$

Therefore, the extreme values of I_1 are $50\mu A$ & $400\mu A$.

The peak value of i_{o1} is limited to $I_1 - 20\mu A$.

since $I_1(\min) = 50\mu A$, i_{o1} is limited to $30\mu A$.

$$8.15) \quad \text{From (8.68): } i_o = \frac{i_1 i_2}{I_1}$$

$$\Rightarrow \ln i_o = \ln i_1 + \ln i_2 - \ln I_1$$

$$\Rightarrow \frac{\Delta i_o}{i_o} = \frac{\Delta i_1}{i_1} + \frac{\Delta i_2}{i_2} - \frac{\Delta I_1}{I_1}$$

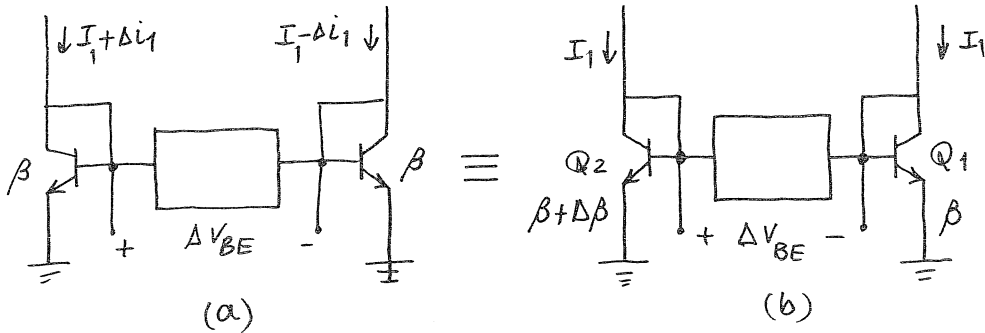
Assuming constant i_1 & i_2 to find Δi_o due to ΔI_1 :

$$\frac{\Delta i_o}{i_o} = \frac{-\Delta I_1}{I_1} \Rightarrow \Delta i_o = -i_o \frac{\Delta I_1}{I_1} = -i_o \frac{5\mu}{100\mu} = \underline{-0.05 i_o}$$

(cont.)

8.15) (cont.) Δi_o due to a change in I_2 is $\underline{0}$ since i_o is not a function of I_2 .

8.16)



$$\text{For (a): } \Delta V_{BE} = V_T \ln \frac{I_1 + \Delta i_1}{I_1 - \Delta i_1} = V_T \ln \left(1 + \frac{2\Delta i_1}{I_1 - \Delta i_1} \right)$$

$$\begin{aligned} \text{For (b): } \Delta V_{BE} &= V_T \ln \frac{I_{c2}}{I_{c1}} = V_T \ln \frac{(\beta + \Delta\beta)(\beta + 1)}{(\beta + \Delta\beta + 1)\beta} \\ &= V_T \ln \left(1 + \frac{\Delta\beta}{\beta(\beta + \Delta\beta + 1)} \right) \approx V_T \ln \left(1 + \frac{\Delta\beta}{\beta^2} \right) \end{aligned}$$

For the same ΔV_{BE} , we have:

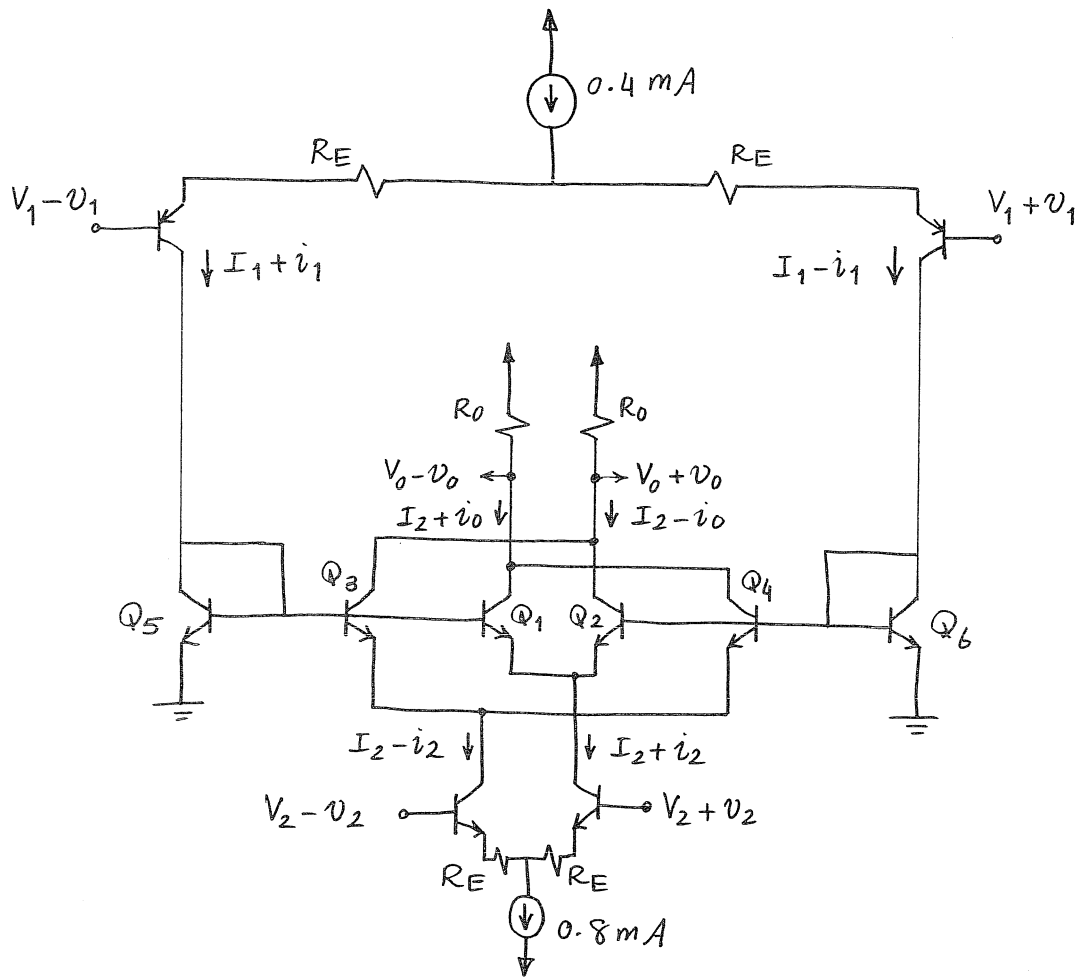
$$\frac{\Delta\beta}{\beta^2} \approx \frac{2\Delta i_1}{I_1}$$

In other words, a β -mismatch is equivalent to a

$$\Delta i_1 = \frac{I_1}{2} \frac{\Delta\beta}{\beta^2} \quad \text{Assuming } \frac{\Delta\beta}{\beta} = 0.05 \text{ results in}$$

$$\Delta i_o = \frac{0.05}{2\beta} i_2$$

8.17)



With the bias circuit shown, the bias currents of Q_1 to Q_6 are all 0.2 mA !

$$i_1 = \frac{v_1}{R_E + r_e} \quad \& \quad i_2 = \frac{v_2}{R_E + r_e}$$

Assuming $R_E \gg r_e$, we have: $i_1 = \frac{v_1}{R_E}$, $i_2 = \frac{v_2}{R_E}$

$$\text{Using (8.68): } i_0 = \frac{i_1 i_2}{I_1} = \frac{v_1 v_2}{R_E^2 I_1} \Rightarrow v_0 = R_0 \frac{v_1 v_2}{R_E^2 I_1}$$

$$v_1 = v_2 = 0.5 \text{ V} \Rightarrow v_0 = 0.5 \text{ V} \quad \therefore \quad 0.5 = R_0 \frac{0.25}{R_E^2 (0.2 \text{ mA})}$$

$$\text{Assuming } \underline{R_E = 2 \text{ k}\Omega} \Rightarrow \underline{R_0 = 1.6 \text{ k}\Omega}$$