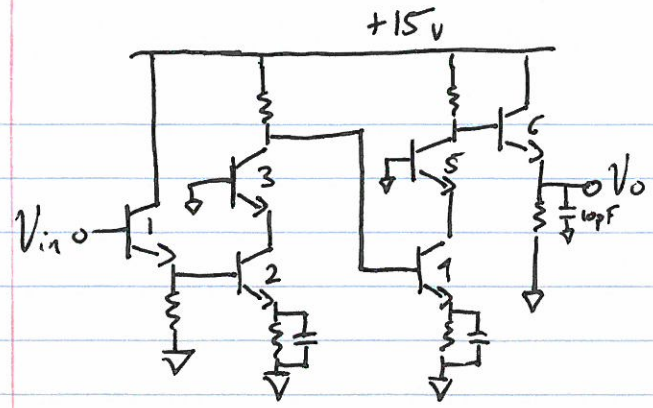


$\tau_F = 500ps \leftrightarrow 300ps$

$C_\pi = 8pF + g_m \tau_F = 8pF + \frac{500ps}{.025V} \cdot 1mA$

$= 8pF + 20pF/mA$

$12pF/mA$

$C_M = \frac{C_{\mu 0}}{\left(1 - \frac{V_{BC}}{\Psi_0}\right)^{m_C}}$, for V_{CB} Big. $C_M < 2pF$

~1 $r_{\pi 10} = \left(\frac{\beta}{g_{m1}} \| r_{\pi 3}\right) \| \left(\frac{R_{S1} + r_b + R_{E1} \| r_{\pi 2}}{1 + g_{m1}(R_{E1} \| r_{\pi 2})}\right) \approx \frac{1}{g_{m1}}$ 2.8 $r_{\mu 10} = \left(R_{S1} + r_b\right) \| \left(\frac{\beta}{g_{m1}} + (\beta+1) R_{E1} \| r_{\pi 2}\right) \approx R_S + r_b$

~~5.6n~~ For just $C_{\pi 2}$

* $r_{\pi 20} = \frac{\beta}{g_{m2}} \| \left(r_b + \frac{R_S \| \frac{1}{g_{m1}}}{\beta}\right) \approx 200\Omega$ ~1 $r_{\mu 20} = r_{\pi 20} + \frac{1}{g_{m3}} + g_{m2} \frac{1}{g_{m3}} r_{\pi 20} \approx 2400\Omega$

~1 $r_{\pi 30} = \frac{\beta}{g_{m3}} \| \left(\frac{R_S + r_b}{1 + g_{m3} R_S}\right) \approx \frac{\beta / g_{m3}}{(\beta+1)} \approx \frac{1}{g_{m3}}$ ~1 * $r_{\mu 30} = r_b + \left(R_{L3} \| \frac{\beta}{g_{m4}} + r_b\right) \approx r_b + R_{L3}$

Biggest → 9.2n * $r_{\pi 40} = \frac{\beta}{g_{m4}} \| \left(r_b + R_{L3}\right) \approx 200\Omega + R_{L3}$ 1.3 $r_{\mu 40} = r_{\pi 40} + \frac{1}{g_{m5}} + g_{m4} \frac{1}{g_{m5}} r_{\pi 40} \approx 2 \times r_{\pi 40}$

~1 $r_{\pi 50} = * \frac{1}{g_{m5}}$ 5.3n * $r_{\mu 50} = r_b + \left(R_{L5} \| \left(\frac{\beta}{g_{m5}} + \beta R_{E6} + r_b\right)\right) \approx r_b + R_{L5}$

~1 $r_{\pi 60} = \frac{\beta}{g_{m6}} \| \frac{R_{L5} + r_b + R_{E6}}{1 + g_{m6} R_{E6}} \approx \frac{1}{g_{m6}}$ 5.3n * $r_{\mu 60} = (R_{L5} + r_b) \| \left(\frac{\beta}{g_{m6}} + (\beta+1) R_{E2}\right) \approx r_b + R_{L5}$

~1 $r_{C_L} = \frac{1}{g_{m6}}$ $\sum = 30.9n \rightarrow 5.1 MHz$

$A_V \approx \left(\frac{-\beta}{\beta+1}\right)^2 \frac{r_{\pi 2} g_{m2} R_{L3}}{\frac{1}{g_{m1}} + r_b + r_{\pi 2}} \frac{r_{\pi 4} g_{m4} R_{L5}}{R_{L3} + r_b + r_{\pi 4}} > 500 < \left(\frac{\beta}{\beta+1}\right)^2 \frac{\beta R_{L3}}{\frac{1}{g_{m1}} + r_b + \frac{\beta}{g_{m2}}} \frac{\beta R_{L5}}{R_{L3} + r_b + \frac{\beta}{g_{m5}}}$

Stage ~~Gain~~ 1: low gain

· stage 2: High gain

$R_{L5} = \frac{\left(R_{L3} r_{\pi 2} + r_{\pi 2} r_{\pi 5}\right) 500}{R_{L3} \beta^2} = \frac{500 R_{L3}}{R_{L3} \beta g_m} + \frac{500}{R_{L3} g_{m2} g_{m5}}$

≈ 69 → increase this gain by $6 + R_{L3} g_{m2} g_{m5}$

$\sum \tau$'s w/ R_{L3}: $(r_b + R_{L3}) C_\pi + (r_b + R_{L3}) C_M + 2(r_b + R_{L3}) C_M = R_{L3}(C_\pi + 3C_M) + r_b(C_M + 3C_M)$

$\sum T$'s w/ R_{L5}: $2[r_b + R_{L5}] C_M = 2 R_{L5} C_M + 2 r_b C_M$

$K_2 = \frac{(500\Omega)(C_\pi + 3C_M)}{R_{L3}} C_\pi + 3C_M$ $K_1 = \frac{(500+n) C_M}{R_{L3} g_{m2} g_{m5}}$ → $\sqrt{\frac{K_1}{K_2}} = R_{L3} = \sqrt{\frac{(500+n) C_M}{18 C_M g_{m1} g_{m2}}}$

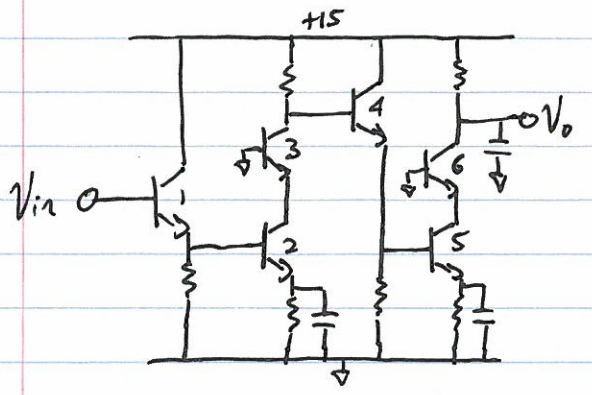
$\tau_{M50} + \tau_{M60} = \tau_{\pi 40} + \tau_{M30}$

$R_{L3} = 131\Omega$

$R_{L5} = 2449\Omega$

6.301 Recitation 11/13/2013

Lab 2 Review



~1 $r_{\pi 10} = \frac{\beta}{g_{m1}} \| \left(\frac{R_{S1} + r_{b1} + R_{E1} \| r_{\pi 2}}{1 + g_{m1} R_{E1} \| r_{\pi 2}} \right) \approx \frac{1}{g_m}$

2.8n $r_{M10} = (R_{S1} + r_b) \| \left(\frac{\beta}{g_{m1}} + (\beta+1) R_{E1} \| r_{\pi 2} \right) \approx R_{S1} + r_b$

5.6 * $r_{\pi 20} = \frac{\beta}{g_{m2}} \| (r_b + \frac{1}{g_{m1}}) \approx 200\Omega$

~1 $r_{M20} = r_{\pi 20} + \frac{1}{g_{m3}} + g_{m2} \frac{1}{g_{m3}} r_{\pi 20} \approx 400\Omega$

~1 $r_{\pi 30} = \frac{\beta}{g_{m3}} \| \left(\frac{R_S + r_b}{1 + g_{m3} R_S} \right) \approx \frac{1}{g_{m3}}$

~~$r_{M30} = r_b + (R_{L3} \| (\beta R_{E4} + \frac{\beta}{g_{m4}}))$~~

2.3n * $r_{M30} = r_b + \left(R_{L3} \| \left(r_b + \frac{\beta}{g_{m4}} + \beta \left(R_{E4} \| \frac{\beta}{g_{m5}} \right) \right) \right)$

$\approx r_b + R_{L3}$

~1 $r_{\pi 40} = \frac{\beta}{g_{m4}} \| \frac{R_{L3} + r_b + R_{E4} \| \frac{\beta}{g_{m5}}}{1 + g_{m4} R_{E4} \| \frac{\beta}{g_{m5}}} \approx \frac{\beta}{g_{m4}} \| \frac{1}{g_{m5}}$ If R_{E4} is large

2.8n $r_{M40} = (R_{L3} + r_b) \| \left(\frac{\beta}{g_{m4}} + (\beta+1) R_{E4} \| \frac{\beta}{g_{m5}} \right)$

$\approx r_b + R_{L3}$

5.6 * $r_{\pi 50} = \frac{\beta}{g_{m5}} \| (r_b + \frac{1}{g_{m4}}) \approx 200\Omega$

~1 $r_{M50} = r_{\pi 50} + \frac{1}{g_{m6}} + \frac{g_{m5}}{g_{m6}} r_{\pi 50} \approx 400\Omega$

~1 $r_{\pi 60} = \frac{1}{g_{m6}}$

~1 * $r_{M60} = r_b + R_{L6}$

3.2n * $r_{C_L} = R_{L6}$

$\sum = 25.88 \rightarrow 6.1\ MHz$

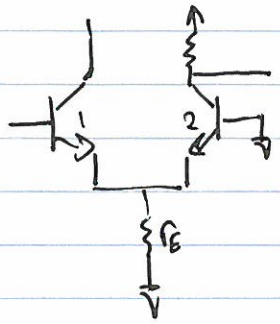
$$A_V \approx \left(\frac{\beta}{\beta+1} \right)^2 \frac{\beta R_{L3}}{\frac{1}{g_{m1}} + r_b + \frac{\beta}{g_{m2}}} \frac{\beta R_{L6}}{\frac{1}{g_{m4}} + r_b + \frac{\beta}{g_{m5}}} > 500$$

$\sum \tau$'s associated w/ R_{L3}: $\left(\left[\underbrace{r_b + R_{L3}}_{r_{M30}} \right] C_M + \left[\underbrace{r_b + R_{L3}}_{r_{M40}} \right] C_M \right) = 2(r_b + R_{L3}) C_M = 2C_M R_{L3} + 2C_M r_b$

$\sum \tau$'s associated w/ R_{L6}: $\left[r_b + R_{L6} \right] C_M + R_{L6} C_{L6} = R_{L6} \left(C_{L6} + C_M + \frac{r_b}{R_{L6}} C_M \right) = R_{L6} (C_{L6} + C_M) + r_b C_M$

$$R_{L3} = \frac{500 \left(\frac{1}{g_{m1}} + r_b + \frac{\beta}{g_{m2}} \right) \left(\frac{1}{g_{m4}} + r_b + \frac{\beta}{g_{m5}} \right)}{\beta^2 R_{L6}} \approx \frac{500}{g_{m2} g_{m5} R_{L6}} \Rightarrow \frac{K_1}{R_{L6}} = \frac{2 C_M 500}{g_{m2} g_{m5} R_{L6}}, \quad K_2 R_{L6} = C_{L6} + C_M$$

Optimize $R_{L6} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{2 C_M 500}{g_{m2} g_{m5} (C_{L6} + C_M)}} \approx \sqrt{\frac{2 C_{L6} 500}{6 C_{L6} g_{m2} g_{m5}}} = 322$ for $I_C = 1mA$



$$A_V = \frac{r_\pi g_m R_L}{R_S + r_b + 2r_\pi} \approx \frac{1}{2} g_m R_L$$

$$R_E = R_E \| r_{in\,CB} = R_E \| \frac{1}{g_m}$$

$$r_{\pi 10} = r_\pi \left\| \left(\frac{R_S + r_b + \frac{1}{R_E}}{1 + g_m \frac{1}{R_E}} \right) \right. \approx r_\pi \left\| \left(\frac{R_S + r_b}{2} \right) \right.$$

$$r_{M10} = (R_S + r_b) \| (2r_\pi + r_b)$$

$$r_{\pi 20} = r_\pi \left\| \left(\frac{r_b + \frac{R_S + r_\pi}{\beta+1}}{1 + g_m \frac{R_S + r_\pi}{\beta+1}} \right) \right. = r_\pi \left\| \left(\frac{r_b + \frac{R_S}{\beta} + \frac{1}{g_m}}{1 + g_m \frac{R_S}{\beta} + 1} \right) \right.$$

$$r_{M20} = r_b + R_L + \frac{g_m r_\pi r_b R_L}{R_S + r_b + 2r_\pi}$$