Final Exam 2004 (warning, may have typos, let me know if you find any).

Q1. (a) $r_o = 50\text{k}\Omega$, $r_\pi = 1.25\text{k}\Omega$, $r_e = 12.5\Omega$, $g_m = 80$ mA/V
(b) maximum symmetric voltage is ±4.3V, $R_{\text{load}} = 86\Omega$, $\eta = 21.5\%$
(c) $\theta = 1.6$°C/W
(d) A = 19 dB
(e) sensitivity = 28

Q2 (b) $\frac{v_o}{v_{b2}} = -g_{m2}R_o \| R_{load}$, $\frac{v_{b2}}{v_{b1}} = \frac{R_3 \| R_5 \| r_{\pi 2}}{r_{e1} + R_3 \| R_5 \| r_{\pi 2}}$, $\frac{v_{b1}}{v_s} = \frac{R_1 \| R_2 \| r_{i1}}{R_S + R_1 \| R_2 \| r_{i1}}$, where $r_{i1} = (r_{e1} + R_3 \| R_5 \| r_{\pi 2})(1+\beta_1)$

(c) $R_{in} = R_1 \| R_2 \| r_{i1}$ where r_{i1} is defined in (b)

(d) $R_{out} = r_{o2} \| R_6$

(e) $R_{Cin} = R_S + R_1 \| R_2 \| r_{i1}$, $R_{C1} = R_3 \left\| \left(\frac{r_{\pi 1} + R_S \| R_1 \| R_2}{1+\beta_1} + R_5 \| r_{\pi 2} \right) \right\| R_4$, $R_{Cout} = R_6 + R_{load}$

(f) $\omega_{\mu 1} = \frac{1}{c_{\mu 1}(R_S \| R_1 \| R_2 \| r_{i1})}$, $\omega_{p2} = \frac{1}{(c_{\pi 2} + C_A)\left(r_{\pi 2} \| R_5 \| R_3 \left\| \frac{r_{\pi 1} + R_S \| R_1 \| R_2}{1+\beta_1} \right. \right)}$, $\omega_{p2} = \frac{1}{C_B(R_6 \| R_{load})}$, where

$C_A = c_{\mu 2}\left(1 - \frac{v_o}{v_{b2}}\right)$, $C_B = c_{\mu 2}\left(1 - \frac{v_{b2}}{v_o}\right)$, where $\frac{v_o}{v_{b2}} = -g_{m2}R_o \| R_{load}$ as in part (b)

(g) $R_1 = 21.444\text{k}\Omega$, $R_2 = 30.7\text{k}\Omega$, $R_4 = 13.954\text{k}\Omega$, $R_5 = 3.5\text{k}\Omega$, $R_6 = 1.125\text{k}\Omega$

Q3 (i) $R_{\text{idm}} = r_{\pi 1} + r_{\pi 2} = 2r_\pi$

(ii) $\frac{v_o}{v_{\pi 4}} = -g_{m2}R_5 \| R_L$, $\frac{v_{\pi 4}}{v_{\pi 2}} \approx -g_{m2}r_{e3} = -\alpha \approx -1$, $\frac{v_{\pi 2}}{v_{dm}} = \frac{r_\pi}{R_s + 2r_\pi}$

(iii) $\frac{v_{\pi 2}}{v_{cm}} = \frac{r_\pi / 2}{R_s + r_\pi/2 + R_{EE}(1+\beta)}$

(iv) $R_{icm} = r_\pi/2 + R_{EE}(1+\beta)$

(v) $\frac{v_{\pi 2}}{v_{cm}} = \frac{2[R_s + r_\pi/2 + R_{EE}(1+\beta)]}{R_s + 2r_\pi}$

(b) pnp current mirrors with $R_{\text{bias}} = 14.3$k
(c) pnp current mirrors with $R_5 = 28.6$k
(c) $v_{\text{inmax}} = 13.7$V, $v_{\text{inmin}} = -14.5$V
(d) ±0.5V/μs

Q4 (a) $$\frac{v_o}{v_i} = \frac{\frac{s}{(K-1)C}}{s^2 + \frac{sK}{(K-1)C}\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{2}{R_2}\left(1 - \frac{1}{K}\right)\right) + \frac{R_1 + R_3}{C^2 R_1 R_2 R_3}}$$

(b) R(s) is LPF with $\omega_o = 1$, Q=1, $H_0 = \pi$, $S(s)$ is HPF with $\omega_o = 10$, high freq gain = 1, gain at $\omega_o = 10$, Adding the two, LPF + HPF results in a band-stop filter: lowpass gain at π, very little overshoot since Q = 1, dropping off in gain at -20dB/decade, but picking up for the high-pass filter with $\omega_o = 10$, quite a bit of a peak since gain at ω_o is equal to 10 then back down to 1 for higher frequencies.

Q5 (a) $\omega_0 = \frac{1}{\sqrt{2}RC}$, $K = \frac{3}{2}$ (b) peak voltage about ±5.7V