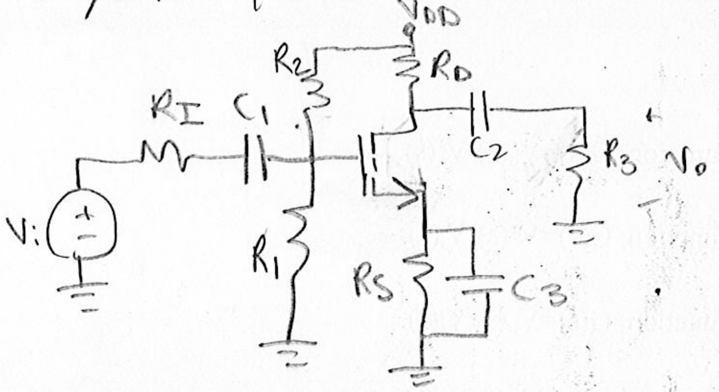
14.91 a)

$R_1 = 500k\Omega$, $R_2 = 1.4M\Omega$, $R_S = 27k\Omega$, $R_D = 75k\Omega$, $V_{DD} = 15V$

$K_n = 400\mu A/V^2$, $V_{TN} = 1V$, $\lambda = 0.02V^{-1}$, P14.1(d)



$R_3 = 470k\Omega$

$R_I = 1k\Omega$

Common Source amplifier

eq. 14.107

$$\frac{1}{\omega C_1} << R_I + R_{in}$$

$R_{in} = R1 // R2 // R_{ig}$, $R_{ig} = \infty$ for FET

$$C_1 >> \frac{1}{\omega(R_I + R_1 // R_2)} = \frac{1}{(500Hz)(2\pi)(1k\Omega + 500k\Omega // 1.4M\Omega)} = 862pF$$

choose $\boxed{C_1 \approx 9nF \approx 10(862pF)}$ next standard value greater.

$$C_2 >> \frac{1}{\omega(R_{out} + R_3)} = \frac{1}{(500Hz)(2\pi)(74k\Omega + 470k\Omega)} = 5.85pF$$

$$R_{out} = R_D // R_{iD} = R_D // r_o(1 + g_m R_S) = 74.0k\Omega$$

DC Analysis: $I_D = 85.0\mu A$, $V_{gs} = 1.65V$, $V_{DS} = 6.32V$
(Not shown)

$$r_o = 662k\Omega = \frac{1 + \lambda V_{DS}}{\lambda I_D} \qquad g_m = 261\mu S = \frac{2I_D}{V_{gs} - V_t}$$

choose $\boxed{C_2 \approx 6nF \approx 10(5.85pF)}$ next standard value greater

14.91 (con) a) (con)

$$C_3 >> \frac{1}{\omega\left[R_4' // (R_S' + \frac{1}{g_m})\right]} = \frac{1}{(500\,Hz)(2\pi)\left[R_S // \frac{1}{g_m}\right]} = 95\,nF$$

$R_4 = R_S$, $R_S' = 0\,\Omega$

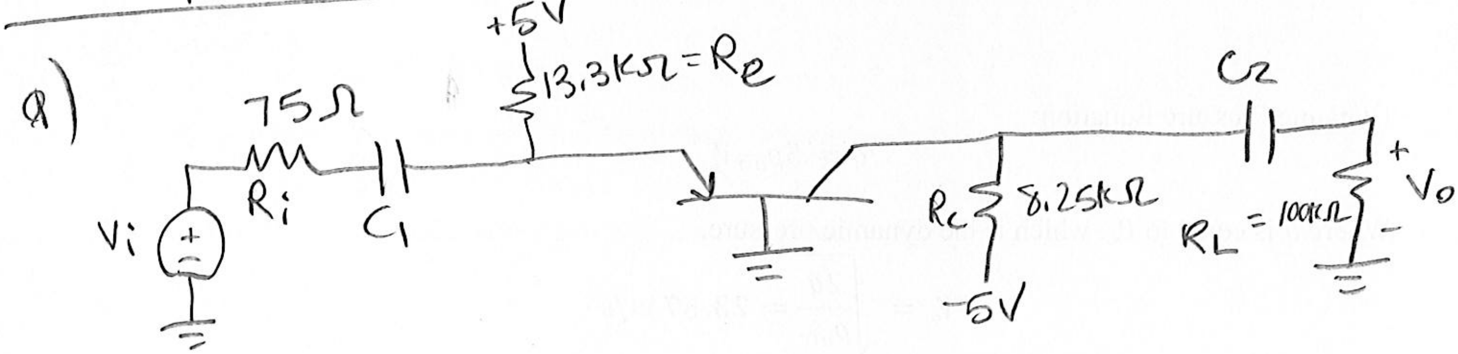
so choose $\boxed{C_3 \approx 10(95\,nF) = 950\,nF \approx 1\,\mu F}$ or closest standard value $\geq 950\,nF$

b) cuttoff freq. for C_1, C_2 is about 50 Hz as chosen, so they can be neglected

$$C_3 = \frac{1}{(4000\,Hz)(2\pi)\left[R_S // \frac{1}{g_m}\right]} = \boxed{11.9\,nF}$$ for 4000 Hz cuttoff freq.

14.94 part (a) only

a)



DC analysis

$$I_c \approx I_e \approx \frac{5V - 0.7V}{R_e} = 323\mu A$$

$$C_1 >> \frac{1}{\omega(R_I + R_{in})} = \frac{1}{(50000)(2\pi)(75\Omega + 77\Omega)} = 21\,nF$$

$$R_{in} = R_e // R_{ie} = R_e // \frac{1}{g_m} \approx 77\Omega$$

$$g_m = \frac{I_c}{V_T} \approx 12.9\,mS$$

$$\boxed{\text{Choose } C_1 = 10(21nF) = 220nF}$$

$$C_2 >> \frac{1}{\omega(R_{out} + R_3)} = \frac{1}{\omega(R_C + R_L)} = \frac{1}{(50000)(8.25k\Omega + 100k\Omega)(2\pi)} = 29.4\,pF$$

$$R_{out} = R_C // R_{iC} = R_C // r_o(1 + g_m(R_i // R_e)) \approx R_C$$

No V_A is given, so assume $V_A = \infty$, $r_o = \infty$.

$R_{out} = R_C$

$$\boxed{\text{choose } C_2 = 10(29.4pF) \approx 300pF}$$

14.97

In the example, all capacitor values are chosen so that their cuttoff frequency at 100 Hz. This is because they multiplied the capacitance value by 10 after calculating the capacitence values for the 1000 Hz cuttoff frequency. Therefore simply chose $\boxed{C_3 = 67.2\ nF}$, as calculated in example 14.7 for 1000 Hz, and

$\boxed{C_1 = 1.8\,nF \quad \text{and} \quad C_2 = 15\,nF}$ as previously chosen for 100 Hz.

$$C_3 = \frac{1}{1000(2\pi)\left(R_4 // \left(R_e + \frac{1}{g_m}\right)\right)} = 67.2\ nF$$

$$C_1 = \frac{1}{100(2\pi)(R_I + R_{in})} = 1.78\ nF \approx 1.8\,nF$$

$$C_2 = \frac{1}{100(2\pi)(21.0\ k\Omega + R_3)} = 13.1\,nF \approx 15\,nF$$

$$R_{out} = R_D // R_{iD} = 22k\Omega // 442k\Omega = 21.0\,k\Omega$$

For spice, $K_n = 0.5\,mA/V^2$, $V_{TN} = 1V$, $\lambda = 0.0133\,V^{-1}$

Qpoint: $I_D = 0.241\,mA$, $V_{DS} = 3.81V$ (from example 14.3 pg. 881)

16.8

a) $$\frac{I_o}{I_{Ref}} = \frac{(\frac{W}{L})_2}{(\frac{W}{L})_1} \frac{(1+\lambda V_{DS2})}{(1+\lambda V_{DS1})}$$

Find $V_{gs1} = V_{DS1}$

$$I_D = \frac{1}{2} K_n' \left(\frac{4}{1}\right)(V_{gs1} - V_{TN})^2$$

$I_D = 35\mu A$ $K_n' = 25\mu A/V^2$ $V_{TN} = 0.75V$

Solve for V_{gs}, $V_{gs1} = 1.59V = V_{DS1}$

$$I_{o2} = \frac{10}{4} \frac{(1+0.01 \cdot 10V)}{(1+0.01 \cdot 1.59V)} (35\mu A) = 94.7\mu A$$

$$I_{o3} = \frac{20}{4} \frac{(1+0.01 \cdot 8V)}{(1+0.01 \cdot 1.59V)} (35\mu A) = 186\mu A$$

$$I_{o4} = \frac{40}{4} \frac{(1+0.01 \cdot 12V)}{(1+0.01 \cdot 1.59V)} (35\mu A) = 386\mu A$$

b) $I_{ref} = 50\mu A \Rightarrow V_{gs} = 1.75V$

$I_{o2} = 135\mu A$, $I_{o3} = 265\mu A$, $I_{o4} = 550\mu A$

c) for $35\mu A = I_{ref}$ in part (a) w/ $\lambda = 0$ / $50\mu A$ I_{ref}

$I_{o2} = (35\mu A)\left(\frac{10}{4}\right) = 87.5\mu A$

$I_{o3} = (35\mu A)\left(\frac{20}{4}\right) = 175\mu A$

$I_{o4} = (35\mu A)\left(\frac{40}{4}\right) = 350\mu A.$

$I_{o2} = 125\mu A$

$I_{o3} = 250\mu A$

$I_{o4} = 100\mu A$

16.8 (con)

output resistances (small signal)

a) $r_o = \dfrac{1+\lambda V_{DS}}{\lambda I_D}$

$r_{o2} = \dfrac{1+\lambda(10V)}{\lambda I_{o2}} = 1.16 M\Omega$

$r_{o3} = \dfrac{1+\lambda(8V)}{\lambda I_{o3}} = 580 K\Omega$

$r_{o4} = \dfrac{1+\lambda(12V)}{\lambda I_{o4}} = 290 K\Omega$

b) $r_{o2} = 814 K\Omega$, $r_{o3} = 407 K\Omega$, $r_{o4} = 204 K\Omega$

c) for $\lambda = 0$, $r_{o1} = r_{o2} = r_{o3} = r_{o4} = \infty\ \Omega$

16.12

$R = 24\,k\Omega$, $K_p' = 15\,\mu A/V^2$, $V_{TP} = -0.90V$, $\lambda = 0.01V^{-1}$

$V_{GS1} = I_{d1} \cdot R - 5V$

$I_{d1} = \frac{1}{2}(K_p')(2)(V_{GS1} - V_{TP})^2$

Solve, $V_{GS1} = -3.16V$, $I_{d1} = 76.6\,\mu A$

$$I_{O2} = \frac{8}{2} \frac{(1+\lambda(5V))}{(1+\lambda\cdot(-3.16V))}(76.6\,\mu A) = \boxed{312\,\mu A}$$

should be positive $|V_{DS}|$ for pmos.

$$r_{O2} = \frac{1+\lambda(5V)}{\lambda \cdot I_{O2}} = \boxed{336\,k\Omega}$$

$$I_{O3} = \frac{16}{2} \cdot \frac{(1+\lambda\cdot 10V)}{(1+\lambda\cdot 3.16V)}(76.6\,\mu A) = \boxed{654\,\mu A}$$

$$r_{O3} = \frac{1+\lambda\cdot 10V}{\lambda \cdot I_{O3}} = \boxed{168\,k\Omega}$$

16.16 part a only

$R = 68\,k\Omega \quad \beta_{FO} = 50 \quad V_A = 60V$

Frirst, find Iref through resistor R.

$$\cancel{I_{Ref} = I_{C1} + I_{B1} + I_{B2} + I_{B3}}$$
$$\cancel{= I_{C1} + I_{B1} + 5 \cdot I_{B1} + 8.3 \cdot I_{B1}}$$
$$\cancel{I_{ref} = (\beta + 14.3) I_{B1}}$$

$$I_{ref} \approx \frac{12V - 0.7V}{R} \approx 166\mu A.$$

$$I_{o2} = n_2 I_{ref} \frac{1 + \frac{V_{CE2}}{V_A}}{1 + \frac{V_{BE}}{V_A} + \frac{1 + n_2 + n_3}{\beta}} = 5(166\mu A) \frac{1 + \frac{5V}{60V}}{1 + \frac{0.7V}{60V} + \frac{1+5+8.3}{50}}$$

$V_{BE} \approx 0.7\,V$ (assumed)

$n_2 = 5$

$n_3 = 8.3$

$$\boxed{I_{o2} = 694\,\mu A}$$

$$I_{o3} = n_3 I_{ref} \frac{1 + \frac{V_{CE3}}{V_A}}{1 + \frac{V_{BE}}{V_A} + \frac{1 + n_2 + n_3}{\beta}} = 8.3(166\mu A) \frac{1 + \frac{3V}{60V}}{1 + \frac{0.7V}{60V} + \frac{1+5+8.3}{50}}$$

$$r_{o2} = \frac{V_A + V_{CE2}}{I_{C2}} = \frac{60V + 5V}{694\mu A} = \boxed{93.7\,k\Omega}$$

$$\boxed{I_{o3} = 1.12\,mA}$$

$$r_{o3} = \frac{V_A + V_{CE3}}{I_{C3}} = \frac{60V + 3V}{1.12mA} = \boxed{56.5\,k\Omega}$$