14.16

a) when $g_m R_E >> 1$, we can approximate the common emitter gain as

$$A \approx \frac{-R_L}{R_E} = \frac{-8.2k\Omega // 47k\Omega}{390\Omega + 620\Omega} \approx -6.91 \frac{V}{V}$$

b)

$$A \approx \frac{-R_L}{R_e} = \frac{-8.2k\Omega // 47k\Omega}{620\Omega} = -11.3$$

Place a bypass capacitor in parallel with the 390Ω resistor.

c) $$A \approx \frac{-R_L}{R_e} = \frac{-8.2k\Omega // 47k\Omega}{390} = -17.9 \frac{V}{V}$$

Place a bypass capacitor in parallel w/ the 620 Ω resistor (or from the node between the 390Ω and 620 Ω resistors to ground).

d) Maximum gain is achieved when $R_e = 0\Omega$. Therefor place the bypass capacitor from the emitter Node to AC ground.

e) $A \approx -10 V_{cc} = -10(24V) = -240 \frac{V}{V}$

14.28

$R_{in} = R_G$ for common drain amplifier

$R_{in} = 2M\Omega$.

$$R_{out} = R_{iS} = \frac{1}{g_m} = \frac{1}{8mS} = 125\Omega$$

$$A_V = \left(\frac{g_m R_L}{1+g_m R_L}\right)\left(\frac{R_G}{R_I+R_G}\right) = \left(\frac{(2k\Omega)(8mS)}{1+(2k\Omega)(8mS)}\right)\left(\frac{2M\Omega}{100k\Omega+2M\Omega}\right)$$

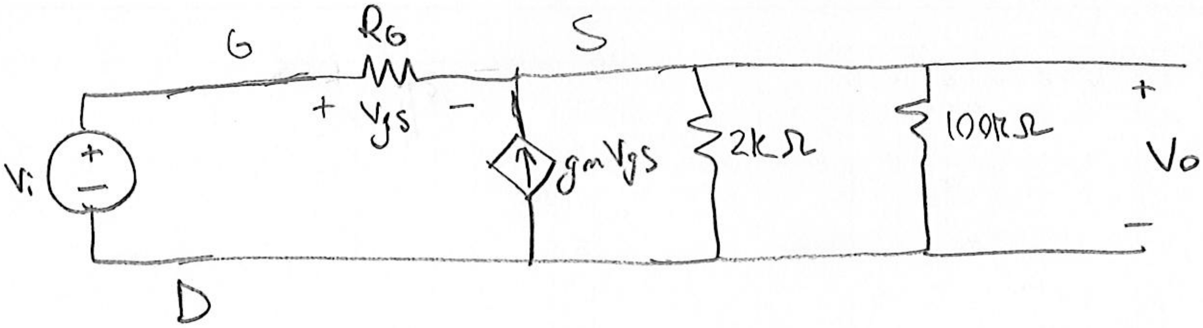
$$= \left(\frac{16}{17}\right)\left(\frac{2}{2.1}\right)$$

$$= 0.896\,\frac{V}{V}$$

$$A_i = \frac{i_o}{i_i} = \frac{V_o/R_L}{V_i/(R_I+R_G)} = A_V\left(\frac{R_I+R_G}{R_L}\right) = (0.896\tfrac{V}{V})(1050) = 941\,\frac{A}{A}$$

14.32

a)



$A_v = \frac{V_o}{V_i}$ Node eq. at source:

$$\frac{V_o - V_i}{R_G} - g_m V_{gs} + V_o/2k\Omega + V_o/100k\Omega = 0$$

$$\frac{V_o - V_i}{R_g} - g_m(V_i - V_o) + V_o/2k\Omega + V_o/100k\Omega = 0$$

$$\frac{V_o}{100k\Omega} + \frac{V_o}{2k\Omega} + \frac{V_o}{R_g} + g_m V_o = \frac{V_i}{R_g} + g_m V_i$$

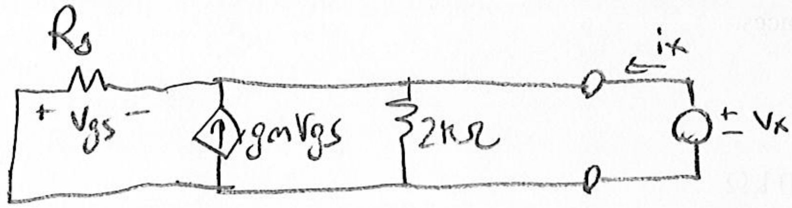
$$A_v = \frac{V_o}{V_i} = \frac{100k\Omega // 2k\Omega // R_G // 1/g_m}{R_g // 1/g_m} = \boxed{0.874 \frac{V}{V}}$$

$$R_{in} = \frac{V_i}{i_i} = \quad i_i = \frac{V_i - V_o}{R_G} = \frac{V_i - A_v V_i}{R_g} \Rightarrow R_{in} = \frac{R_g}{1 - A_v}$$

$$R_{in} = \frac{R_g}{1 - A_v} = \frac{1M\Omega}{1 - 0.874} = \boxed{7.94 M\Omega}$$

14.32 (continued)

R_{out}



$$-i_x + -g_m V_{gs} + V_x/2k\Omega + \frac{V_x}{R_g} = 0$$

$$-i_x = -g_m(-V_x) + \frac{V_x}{2k\Omega} + \frac{V_x}{R_g}$$

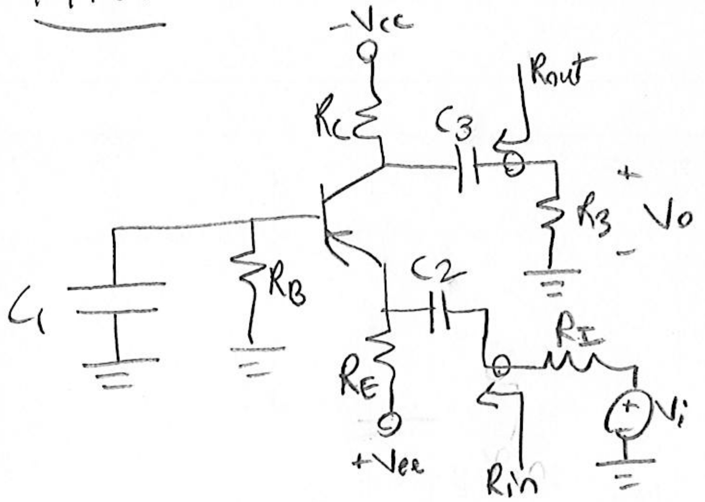
$$R_{out} = \frac{V_x}{i_x} = \frac{1}{g_m} \,||\, 2k\Omega \,||\, R_g = \boxed{247\,\Omega}$$

b) If $A_v = 1\frac{V}{V}$,

$$R_{in} = \frac{R_g}{1-A_V} = \frac{R_g}{0} = \infty\,\Omega$$

$$\boxed{R_{in} = \infty\,\Omega \text{ as } A_V \to 1\frac{V}{V}}$$

14.81



$R_I = 500\Omega$
$R_B = 100k\Omega$
$R_3 = 100k\Omega$
$R_E = 82k\Omega$
$R_C = 39k\Omega$
$V_{EE} = V_{CC} = 12V$
$\beta_F = 50$
$V_A = 50V$

$C_1 = 4.7\mu F$
$C_2 = 47\mu F$
$C_3 = 10\mu F$
$f = 12KHz$

Common base amplifier

DC Q point (Assume Veb = 0.7V as in previous chapters)

$$V_{ee} - I_e R_E - V_{eb} - I_B R_B = 0$$

$$V_{ee} - (\beta+1) I_B R_E - V_{eb} - I_B R_B = 0$$

$$I_B = \frac{V_{ee} - V_{eb}}{(\beta+1)R_E + R_B} = \frac{12V - 0.7V}{(51)(82k\Omega) + 100k\Omega} = 2.64\mu A$$

$$I_c = \beta I_B = (50)(I_B) = 132\mu A$$

$$r_o = \frac{V_A - V_{CE}}{I_c} = \frac{50 - I_c R_c - I_E R_E}{I_c} = 256k\Omega$$

$$g_m = \frac{I_c}{V_T} = \frac{132\mu A}{0.025V} = 5.28mS$$

14.81

$$A_V = \frac{g_m R_L}{1+g_m R_{th}}\left(\frac{R_{th}}{R_I+R_{th}}\right)$$

$$= \frac{g_m (R_3 // R_C)}{1+g_m (R_I // R_E)}\left(\frac{R_E}{R_I+R_E}\right)$$

$$= \frac{(5.28\,mS)(100k\Omega // 39k\Omega)}{1+(5.28\,mS)(500\Omega // 82k\Omega)}\left(\frac{82k\Omega}{500\Omega+82k\Omega}\right)$$

$$\boxed{A_V = 40.6\ \frac{V}{V}}$$

$$R_{in} = R_E // R_{ie} = R_E // \frac{1}{g_m} = \boxed{189\,\Omega = R_{in}}$$

$$R_{out} = R_C // R_{ic} = R_C // r_o(1+g_m R_{th})$$

$$= R_C // r_o(1+g_m(R_I // R_E))$$

$$= R_C // 929k\Omega$$

$$\boxed{R_{out} = 37.4\,k\Omega}$$

Spice Results:

$$\boxed{A_V = \frac{39.0\,mV}{1\,mV}\frac{V}{V} = 39.0\frac{V}{V}}$$

$$R_{out} = \frac{V_x}{i_x} = \frac{1\,mV}{26.3\,nA} = \boxed{38.0\,k\Omega}$$

$$R_I + R_{in} = \frac{1\,mV}{-1.42\,\mu A} = 704\,\Omega$$

$$R_{in} = 704\,\Omega - R_I = 704\,\Omega - 500\,\Omega = \boxed{204\,\Omega = R_{in}}$$

14.118

3rd Stage DC Analysis

$$V_g = \frac{R_6\,\Omega}{R_5 + R_6}(15V) = 8.53V$$

$$V_{gs3} = V_{g3} - I_{D3}R_{E3} = 8.53V - I_D(3.0k\Omega)$$

$$I_{D3} = (1mA/V^2)(\tfrac{1}{2})(V_{gs3} - V_T)^2$$

$$= (1mA/V^2)(\tfrac{1}{2})(V_{gs3} - 1V)^2$$

Solve for I_{D3}, $\underline{I_{D3} = 1.87mA}$

$V_{gs} = 2.93V$

2nd Stage DC Analysis

$$\frac{15V - 0.7V - (\beta+1)I_{B2}R_{E2}}{R_3} = \frac{0.7V + (\beta+1)I_{B2}R_{E2}}{R_4} + I_{B2}$$

Solve for I_{B2}, $I_{B2} = 12.7\mu A$, $I_{C2} = \beta I_{B2} = \underline{1.27mA}$

1st Stage DC Analysis

$$\frac{15V - 0.7V - (\beta+1)I_{B1}R_{E1}}{R_1} = \frac{0.7V + (\beta+1)I_{B1}R_{E1}}{R_2} + I_{B1}$$

Solve for $I_{B1} = 3.20\mu A$ $I_{C1} = \beta I_{B1} = \underline{319\mu A}$

14.118

3rd Stage Common Drain Amplifier

$$A_{v3} = \frac{v_o}{v_3} = \frac{g_{m3}R'_{L3}}{1+g_{m3}R'_{L3}}\cancelto{1}{\left(\frac{R_{G3}}{\underbrace{R_I}_{0\Omega} + R_{G3}}\right)} = \frac{g_{m3}R'_{L3}}{1+g_{m3}R'_{L3}} = 0.308\ \frac{V}{V}$$

$R_{I3} = 0\,\Omega$

$R_{G3} = R_5 // R_6 = 518k\Omega$

$R'_{L3} = R_L // R_{E3} = 231\,\Omega$

$$g_{m3} = \frac{2I_{D3}}{V_{GS}-V_T} = \frac{2(1.87mA)}{2.93V-1V} = 1.93mS$$

$R_{in3} = R_5 // R_6 = 518k\Omega$

2nd Stage Common Emitter

$$A_{v2} = \frac{V_3}{V_2} = \frac{-g_{m2}R'_{L2}}{1+g_{m2}R_{E2}} = -2.88\ \frac{V}{V}$$

$R'_{L2} = R_{in3} // R_{C2} = 4.66k\Omega$

$$g_m = \frac{I_C}{V_T} = \frac{1.27mA}{0.025V} = 50.7mS$$

$R_{in2} = R_3 // R_4 // R_{ib} = R_3 // R_4 // r_{\pi 2}(1+g_{m2}R_{E2}) = 28.0k\Omega$

$$r_{\pi 2} = \frac{\beta_o}{g_{m2}} = \frac{100}{50.7mS} = 1.97k\Omega$$

1st Stage common emitter

$$A_{v1} = \frac{V_1}{V_2} = \frac{-g_{m1}R'_{L1}}{1+g_{m1}R_{E1}} = -5.27\ \frac{V}{V}$$

$R'_{L1} = R_{in2} // R_{C1} = 11.0k\Omega$

$$g_{m1} = \frac{I_C}{V_T} = \frac{319\mu A}{0.025V} = 12.8mS$$

$$r_{\pi 1} = \frac{\beta_o}{g_{m1}} = \frac{100}{12.8mS} = 7.82k\Omega$$

$R_{in1} = R_1 // R_2 // R_{ib1} = R_1 // R_2 // r_{\pi 1}(1+g_{m1}R_{E1}) = 62.4k\Omega$

14.118

$$\frac{V_1}{V_S} = \frac{R_{in1}}{10k\Omega + R_{in1}} = 0.861 \frac{V}{V}$$

$$A_V = \frac{V_1}{V_S} \cdot \frac{V_2}{V_1} \cdot \frac{V_3}{V_2} \cdot \frac{V_o}{V_3} = \boxed{4.03 \frac{V}{V}}$$

Input signal range

~~1st stage~~

$$V_{1max} \leq 0.005(1+g_{m1}R_{E1}) = 133mV$$

$$V_{2max} \leq 0.005(1+g_{m2}R_{E2}) = 411mV$$

$$V_{3max} \leq 0.2(V_{gs3} - V_{TN})(1+g_{m3}R'_{L3}) = 559mV$$

$$V_S \leq \left(\frac{V_S}{V_1}\right) \cdot V_{1max} = 154mV \text{ for stage 1}$$

$$V_S \leq \left(\frac{V_S}{V_1}\right)\left|\frac{V_1}{V_2}\right| V_{2max} = 90.3mV \text{ for stage 2}$$

$$V_S \leq \left(\frac{V_S}{V_1}\right)\left|\frac{V_1}{V_2}\right|\left|\frac{V_2}{V_3}\right| V_{3max} = 42.7mV \text{ for stage 3}$$

So the input signal range for V_S is 42.7mV

The input signal range is enhanced by a factor of ~460 at the expense of gain, which decreases by a factor of about 250. The order of magnitude difference betwen R_{S1} and R_{E1} should be the key contributor to the change in performance. $A \propto \frac{1}{R_E}$ signal range $\propto R_E^4$