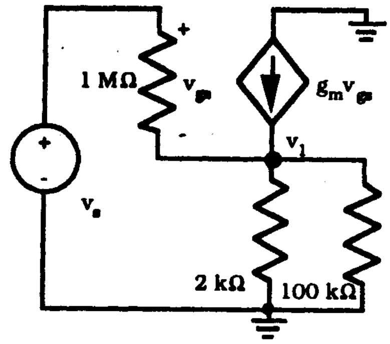
Note: The following solutions are given:

1) Old Jaeger 14.20 or New Jaeger 14.25
2) Old Jaeger 14.21 or New Jaeger 14.27
3) Old Jaeger 14.22 or New Jaeger 14.26
4) Old Jaeger 14.23 or New Jaeger 14.28

20 Defining v_1 as the source node:



(a) $2k\Omega \| 100k\Omega = 1.96k\Omega$

$$\frac{(v_s - v_1)}{10^6} + 3.54 \times 10^{-3}(v_s - v_1) = \frac{v_1}{1960}$$

$$3.541 \times 10^{-3} v_s = 4.051 \times 10^{-3} v_1$$

$v_1 = 0.874 v_s$ | $A_V = 0.874$

$$R_{IN} = \frac{v_s}{i_s} = \frac{v_s}{10^{-6}(v_s - v_1)} = 7.94\ M\Omega$$

Driving the output with current source i_x:

$$R_{OUT}: i_x = \frac{v_1}{10^6} + \frac{v_1}{2000} + 3.54 \times 10^{-3} v_1$$

$R_{OUT} = \frac{v_1}{i_x} = 247\ \Omega$ | (b) $R_{IN} = \infty$

14.21

$V_{EQ} = 18\frac{51k\Omega}{51k\Omega + 100k\Omega} = 6.08V$ | $R_{EQ} = 51k\Omega \| 100k\Omega = 33.8k\Omega$

$I_B = \frac{(6.08 - 0.7 + 18)V}{33.8k\Omega + (126)(4.7k\Omega)} = 37.3\mu A$ | $I_C = 4.67\ mA$ | $V_{CE} = 36 - 2000I_C - 4700I_E = 4.54\ V$

Forward - active region is correct. | $r_\pi = \frac{125(0.025V)}{4.67mA} = 669\Omega$ | $r_o = \frac{(50 + 4.54)V}{4.67mA} = 11.7k\Omega$

$v_{th} = v_s \frac{33.8\Omega}{500\Omega + 33.8k\Omega} = 0.985 v_s$ | $R_{th} = 33.8k\Omega \| 500\Omega = 493\Omega$

$R_L = 24k\Omega \| 4.7k\Omega \| 11.7k\Omega = 2.94k\Omega$ | $A_{Vth} = -\frac{126(2.94k\Omega)}{0.493k\Omega + 0.669k\Omega + 126(2.94k\Omega)} = 0.997$

$A_V = 0.985A_{Vth} = 0.982$ | $R_{IN} = 33.8k\Omega \| [0.669k\Omega + 126(2.94k\Omega)] = 31.0\ k\Omega$

$A_I = A_V \frac{R_S + R_{IN}}{R_3} = 0.982\frac{0.5k\Omega + 31.0k\Omega}{24.0k\Omega} = 1.29$ | $R_{OUT} = \frac{493\Omega + 669\Omega}{126} \| 2.94k\Omega = 9.19\ \Omega$

$v_{be} = 0.982 v_s \frac{0.669k\Omega}{0.493k\Omega + 0.669k\Omega + 126(2.94k\Omega)} = 0.00177 v_s$ | $v_s = \frac{5.00mV}{0.00177} = 2.83\ V$

14.22

$I_B = \frac{(5 - 0.7)V}{1M\Omega + (100 + 1)430k\Omega} = 96.8nA$ | $I_C = 9.68\mu A$ | $V_{CE} = 10 - 430000I_E = 5.80V$ | Forward - active region is correct. $r_\pi = \frac{100(0.025V)}{9.68\mu A} = 258k\Omega$ | $r_o = \frac{(60 + 5.80)V}{9.68\mu A} = 6.80M\Omega$ - neglected

In the ac model, R_1 appears in parallel with r_π. The circuit appears to have a transistor with $r_\pi' = 500k\Omega \| r_\pi = 170k\Omega$ and $\beta_o' = g_m r_\pi' = 40(9.68\mu A)170k\Omega = 65.8$

$v_{th} = v_s$ | $R_{th} = 500\Omega$ | $R_L = 500k\Omega \| 430k\Omega \| 500k\Omega = 158k\Omega$

$A_V = -\frac{66.8(158k\Omega)}{0.500k\Omega + 170k\Omega + 66.8(158k\Omega)} = 0.984$ | $R_{IN} = 170k\Omega + 66.8(158k\Omega) = 10.7\ M\Omega$

$$A_I = A_V \frac{R_S + R_{IN}}{R_3} = 0.984 \frac{500\Omega + 10.7M\Omega}{500k\Omega} = 21.1$$

$$R_{OUT} = \frac{500\Omega + 170k\Omega}{66.8} \| 500k\Omega \| 430k\Omega = 2.53\ k\Omega$$

$$v_{be} = v_s \frac{170k\Omega}{0.500k\Omega + 170k\Omega + 66.8(158k\Omega)} = 0.0159 v_s \ \mid\ v_s \le \frac{5.00mV}{0.0159} = 0.315\ V$$

14.23

$V_{GS} = 5V \mid I_{DS} = \frac{4x10^{-4}}{2}(5-1)^2 = 3.2mA \mid V_{DS} = 5-(-5) = 10V$ - Saturation region operation is correct. | $g_m = \sqrt{2(4x10^{-4})(3.2mA)[1+0.02(10)]} = 1.75mS$

$$r_o = \frac{\frac{1}{0.02} + 10}{3.2mA} = 18.8k\Omega \text{ - Cannot neglect!} \mid R_L = 18.8k\Omega \| 100k\Omega = 15.8k\Omega$$

$$A_V = \frac{10^6}{10^6 + 10^4} \frac{1.75mS(15.8k\Omega)}{1 + 1.75mS(15.8k\Omega)} = 0.956 \ \mid\ A_I = 10^6 \frac{1.75mS(15.8k\Omega)}{1+1.75mS(15.8k\Omega)} \frac{1}{10^5} = 9.56$$

$$R_{IN} = R_G = 1\ M\Omega \ \mid\ R_{OUT} = \frac{1}{g_m} \| r_o = 555\ \Omega$$

$$v_{gs} = v_s \frac{10^6}{10^6 + 10^4} \frac{1}{1 + 1.75mS(15.8k\Omega)} = 0.0346 v_s \ \mid\ v_s \le \frac{0.2(5-1)}{0.0346} = 23.2\ V$$ But,

v_{DS} must exceed $v_{GS} - V_{TN} \cong V_{GS} - V_{TN} = 4V$ for saturation.

$V_{DS} = 10 - v_o = 10 - 0.956 v_s \ge 4 \rightarrow v_s \le 6.28$ V – Limited by the Q-point voltages

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14.24

$$\beta_o = g_m r_\pi = 3.54mS(1M\Omega) = 3540 \ \mid\ R_L = 2k\Omega \| 100k\Omega = 1.96k\Omega$$

$$A_V = \frac{(\beta_o + 1)R_L}{r_\pi + (\beta_o + 1)R_L} = \frac{(3540+1)(1.96k\Omega)}{1M\Omega + (3540+1)(1.96k\Omega)} = 0.874$$

$$R_{IN} = r_\pi + (\beta_o + 1)R_L = 1M\Omega + (3540+1)(1.96k\Omega) = 7.94\ M\Omega$$

$$R_{OUT} = \frac{r_\pi}{(\beta_o + 1)} \| 2k\Omega = \frac{10^6}{(3541)} \| 2k\Omega = 247\ \Omega$$

14.25

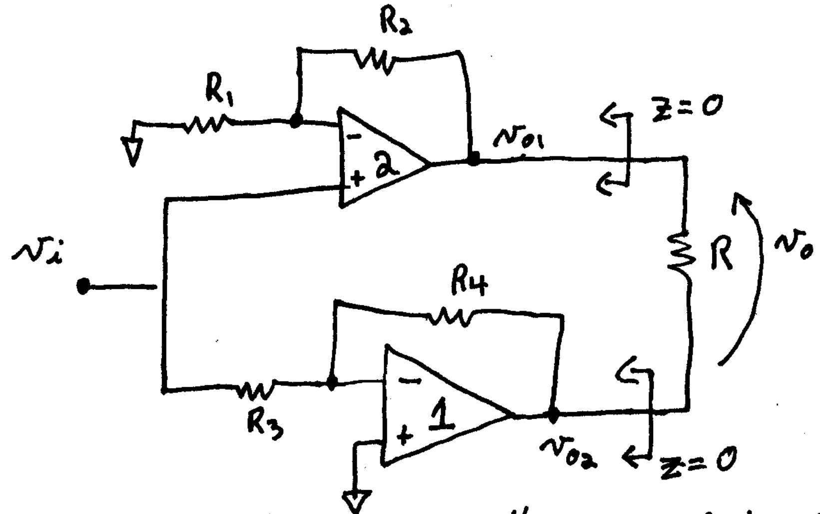
$$v_s \le 0.005(1 + g_m R_L) \ \mid\ R_L = R_4 \| R_7 \cong R_4$$

$$v_s \le 0.005(1 + g_m R_L) = 0.005(1 + g_m R_4) = 0.005\left(1 + \frac{I_C R_4}{V_T}\right)$$

$$v_s \le 0.005\left(1 + \alpha_F \frac{I_E R_4}{V_T}\right) \cong 0.005\left(1 + \frac{I_E R_4}{V_T}\right)$$

$$v_s \le 0.005\left(1 + \frac{V_{R_4}}{V_T}\right) = 0.005\left(1 + \frac{V_{R_4}}{0.025}\right) = 0.005 + \frac{V_{R_4}}{5}$$

Bridge Amplifier: Determine the gain of the following.



Zero output impedance allows us to decouple the stages 1+2

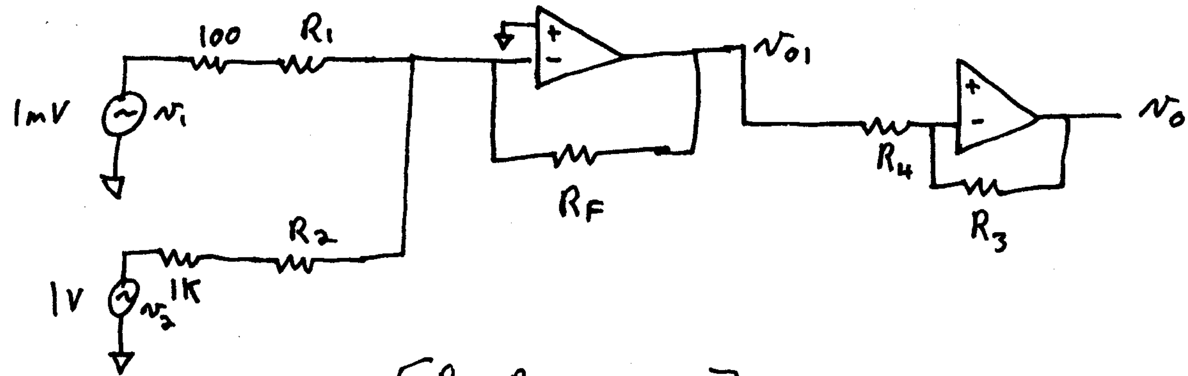
By superposition: $v_{o2} = -\frac{R_4}{R_3} v_i$

$$v_{o1} = \left(1 + \frac{R_2}{R_1}\right) v_i$$

$$v_o = v_{o1} - v_{o2} = v_i \left(1 + \frac{R_2}{R_1} + \frac{R_4}{R_3}\right)$$

$$\frac{v_o}{v_i} = 1 + \frac{R_2}{R_1} + \frac{R_4}{R_3}$$

Mixing signals of different Magnitude



Determine $\begin{bmatrix} R_3, R_4 \\ R_F, R_1 + R_2 \end{bmatrix}$ so that

$$v_o = 10{,}000 v_1 + 10 v_2$$

Let $R_4 = R_3$, then $\frac{v_o}{v_{o1}} = -1$ so,

$$v_o = \frac{R_F}{R_1 + 100} v_1 + \frac{R_F}{1k + R_2} v_2$$

$$\frac{R_F}{R_1 + 100} = 10{,}000 \qquad \frac{R_F}{1K + R_2} = 10$$

$$R_F = 10{,}000 R_1 + 1e6 \iff R_F = 10k + 10R_2$$

$$R_1 = \frac{10k + 10R_2 - 1e6}{10{,}000}$$

choose $R_2 = 999\,k \implies R_F = 10\text{Meg}\,\Omega$

$+ R_1 = 900\,\Omega$