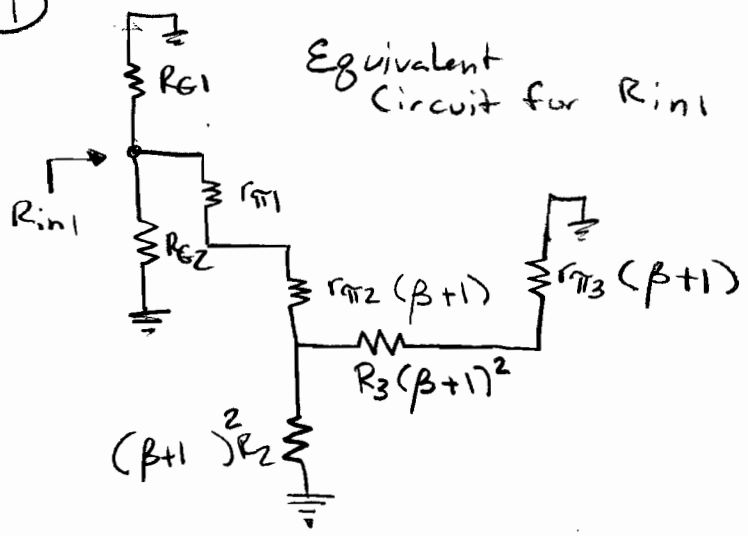
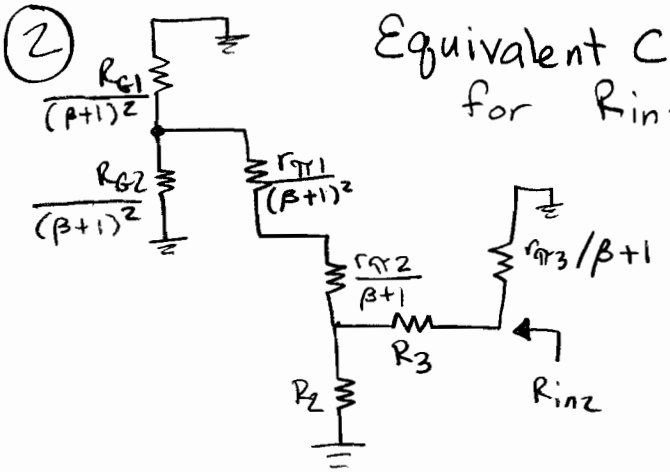
(1)



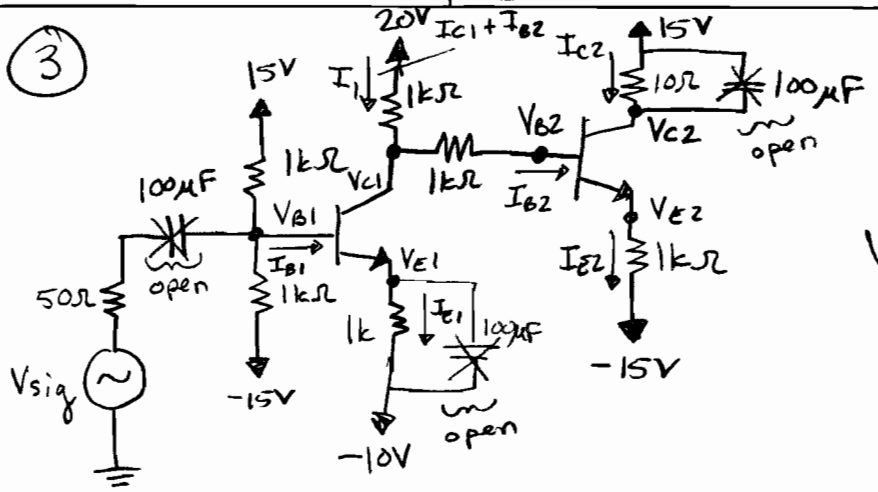
$$R_{in1} = R_{G1} \| R_{G2} \| \left(r_{\pi 1} + r_{\pi 2}(\beta+1) + R_2(\beta+1)^2 \| \left(R_3(\beta+1)^2 + r_{\pi 3}(\beta+1) \right) \right)$$

(2)



$$R_{in2} = \frac{r_{\pi 3}}{\beta+1} \| \left(R_3 + R_2 \| \left(\frac{r_{\pi 2}}{\beta+1} + \frac{r_{\pi 1}}{(\beta+1)^2} + \frac{R_{G1} \| R_{G2}}{(\beta+1)^2} \right) \right)$$

(3)



$V_{out} = V_{E2}$

Assume Active On (both)

$V_{B1} = [\ ] - 1k(I_{B1})\frac{1}{2}$

$V_{B1} - V_{E1} = 0.7\,V$

$V_{E1} = -10V + 1k(I_{E1})$

$V_{C1} = 20 - 1k(I_{C1} + I_{B2})$

$I_{C1} = \alpha I_{E1} = \frac{\beta}{\beta+1} I_{E1} = \frac{160}{161} I_{E1}$

$I_{C1} = \beta I_{B2} = 160 I_{B2}$

$V_{B2} = V_{C1} - 1k(I_{B2})$

$V_{B2} - V_{E2} = 0.7\,V$

$V_{E2} = -15V + 1k(I_{E2})$

$V_{C2} = 15V - 10(I_{C2})$

$I_{C2} = \beta I_{B2} = 160\, I_{B2}$

$I_{C2} = \frac{\beta}{\beta+1} I_{E2} = \frac{160}{161} I_{E2}$

$$V_{B1} = -1k\left(\frac{I_{C1}}{\beta}\right)\frac{1}{2} = V_{E1} + 0.7V = -9.3 + 1k\,\frac{I_{C1}}{\alpha}$$

$$9.3V = 1k\,I_{C1}\left(\frac{1}{2\beta} + \frac{\beta+1}{\beta}\right)$$

$$I_{C1} = \frac{-9.3\,V}{1k\left(\frac{1}{2(160)} + \frac{161}{160}\right)} = 9.21\ mA$$

$$I_{B1} = \frac{I_{C1}}{\beta} = 57.6\,\mu A$$

$$I_{E1} = \frac{I_{C1}}{\alpha} = \frac{9.21mA}{160/161} = 9.27mA$$

$$V_{B1} = -\frac{500}{160}(9.21m) = -28.8mV$$

$$V_{E1} = V_{B1} - 0.7 = -0.729V$$

$$V_{C1} = 20V - (I_{C1} + I_{B2})(1k)$$

$$V_{B2} = V_{C1} - I_{B2}(1k) = 20V - 2k\,I_{B2} - 1k\,I_{C1}$$

$$V_{B2} - V_{E2} = 0.7 \qquad V_{E2} = -15V + 1k\,I_{E2}$$

$$10.79 - \frac{2k\,I_{C2}}{160} + 15 - \frac{1k\,I_{C2}}{160/161} = 0.7$$

$$25.09 = I_{C2}\left(\frac{2k}{160} + \frac{161k}{160}\right) = I_{C2}\left(\frac{163k}{160}\right)$$

$$\Rightarrow I_{C2} = 24.6\ mA$$

$$I_{B2} = 154\,\mu A \qquad I_{E2} = 24.8\,mA$$

$$V_{E2} = -15V + 24.8V = 9.8V$$

$$V_{B2} = 10.5V$$

$$V_{C2} = 15 - (10)(24.6m) = 14.75V$$

$V_{B1} = -28.8mV$
$V_{E1} = -0.729V$

$V_{C1} = 20 - (9.21m + 154\mu)(1k) = 10.6V$

$V_{C1} = 10.6V$

$V_{B2} = 10.5V$
$V_{E2} = 9.8V$
$V_{C2} = 14.75V = V_{out}$

$I_{C1} = 9.21mA$
$I_{B1} = 57.6\mu A$
$I_{E1} = 9.27mA$

$I_{C2} = 24.6mA$
$I_{B2} = 154\mu A$
$I_{E2} = 24.8mA$

$I_1 = I_{B2} + I_{C1} = 9.36mA$

$I_1 = 9.36\ mA$

④

$$r_{\pi 1} = \frac{V_T}{I_{B1}} = \frac{0.0259\,V}{57.6\mu A} = 450\,\Omega$$

$$r_{\pi 2} = \frac{V_T}{I_{B2}} = \frac{0.0259V}{154\mu A} = 168\,\Omega$$

$R_{th_1} = 10\Omega$ $\quad Pole = \dfrac{1}{10\Omega \cdot 100\mu F} = 1k\dfrac{rad}{sec}$

$$R_{th2} = 1k\Omega \,\|\, \frac{450\Omega + 500\Omega}{161} = 5.9\,\Omega$$

$$Pole = \frac{1}{5.9\Omega \cdot 100\mu F} = 1.7k\frac{rad}{sec}$$

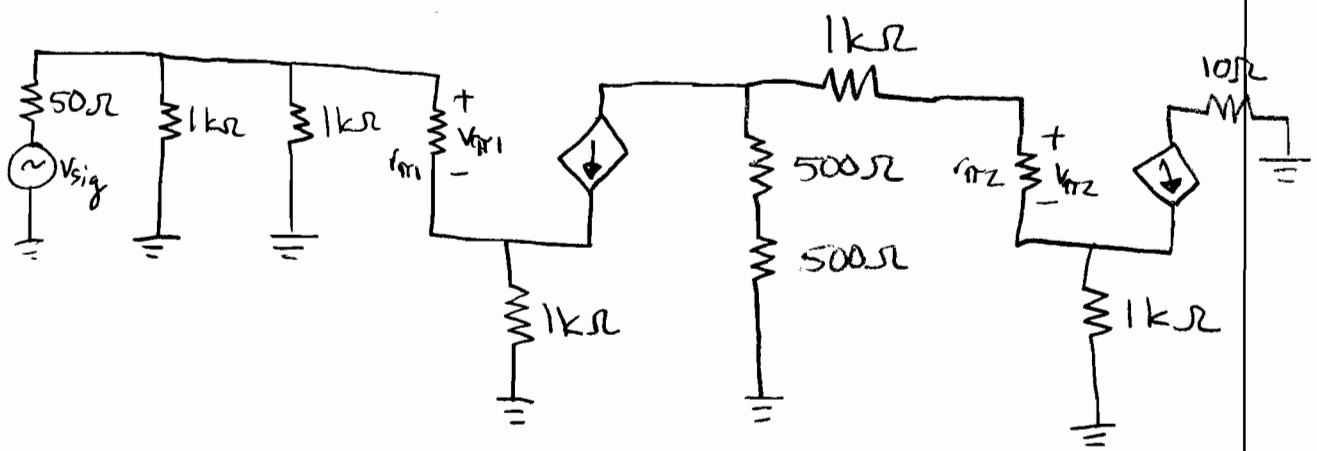
$$R_{th3} = 550 + (450 + 1k\Omega) = 2k\Omega$$

$$Pole = \frac{1}{2k\Omega \cdot 100\mu F} = 5\frac{rad}{sec}$$

$$f_L = \frac{1.7k\frac{rad}{sec}}{2\pi} = 271\ Hz$$

$\boxed{f_L = 271\ Hz}$

⑤

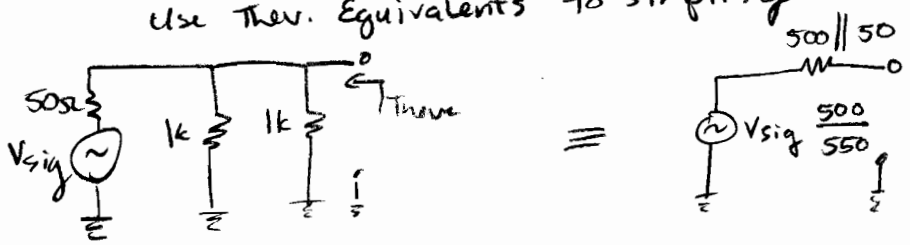


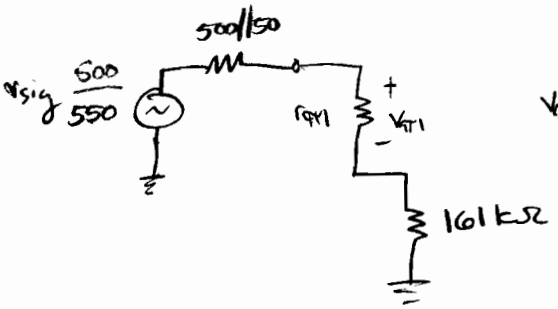
6) $R_{in} = 500\Omega + (161)(r_{\pi 1} + 1k\Omega) = 234k\Omega$

$R_{out} = 1k\Omega \| \frac{2k\Omega}{(161)} = 12.3\Omega$

7) $\frac{V_{out}}{V_{sig}} = ?$

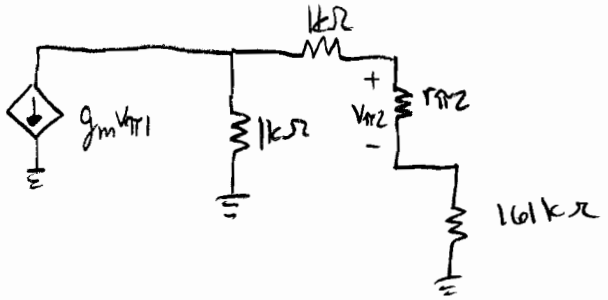
use Thev. Equivalents to simplify





$V_{\pi 1} = V_{sig}\frac{500}{550} \cdot \frac{r_{\pi 1}}{500\|50 + r_{\pi 1} + 161k\Omega}$

$\frac{V_{\pi 1}}{V_{sig}} = \frac{500}{550} \cdot \frac{r_{\pi 1}}{500\|50 + r_{\pi 1} + 161k\Omega}$



$V_{\pi 2} = -g_{m1}V_{\pi 1}\frac{1k}{163k + r_{\pi 2}} r_{\pi 2}$

$\frac{V_{\pi 2}}{V_{\pi 1}} = \frac{-g_{m1}r_{\pi 2}(1k)}{163k + r_{\pi 2}}$

$\frac{V_{out}}{V_{\pi 1}} = \frac{-g_{m1}(1k)(161k)}{163k + r_{\pi 2}}$

$\frac{V_{out}}{V_{sig}} = \frac{V_{out}}{V_{\pi 1}}\frac{V_{\pi 1}}{V_{sig}} = \frac{500}{550}\frac{r_{\pi 1}}{(500\|50 + 161k\Omega + r_{\pi 1})}\frac{(-g_{m1}(1k)(161k))}{(163k + r_{\pi 2})}$

$\frac{V_{out}}{V_{sig}} = \frac{-500\, r_{\pi 1} g_{m1}(161M)}{550(500\|50 + 161k + r_{\pi 1})(163k + r_{\pi 2})}$

$\frac{V_{out}}{V_{sig}} = -0.889\ V/V$

8) Changing the Bias on V_{B2} by changing the 1kΩ resistor could increase the gain. (or on V_{B1})

Increasing the 1kΩ resistor at Vout would also increase the output.