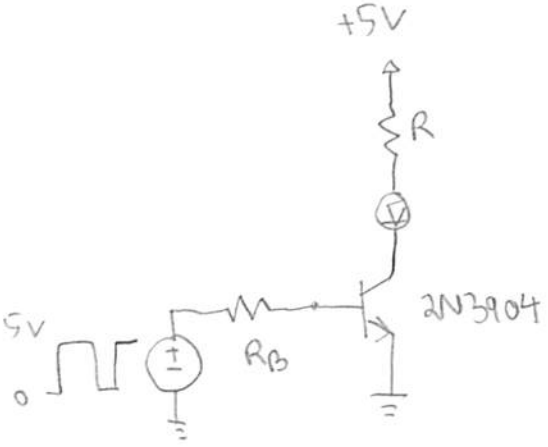
ECE 363
Exam 1 Practice Problems



① 2N3904 : $\beta_{min} = 80$

For 50mA, but use as worst-case for 30mA $\begin{cases} V_{CE,sat} = 0.3V \\ V_{BE,sat} = 0.95V \end{cases}$

ⓐ • Determine R: $5 - .030R - \overset{\text{LED}}{\boxed{2.5}} - \overset{V_{CE,sat}}{\boxed{0.3}} = 0$

$$R = \frac{5-2.8}{.030A} = 73.3\Omega \quad \boxed{\text{Choose } R = 68\Omega}$$

$$\text{Actual } I_c = \frac{5-2.8}{68\Omega} = \underline{\underline{32.4mA}}$$

• Determine R_B: For hard saturation, $I_B \sim \frac{I_c}{0.1\beta}$

$$\frac{5-0.95}{R_B} \sim \frac{.030}{0.1 \times 90}$$

Don't need exact I_c

Choose $\boxed{R_B = 1.2k}$ ← $R_B \sim 1215\Omega$

ⓑ $P = I^2R = (.032)^2(68) = .0696W$

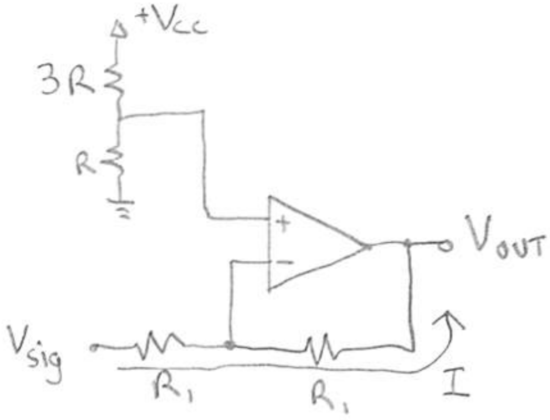
Include duty cycle: $\boxed{0.75} \times .0696 = 52mW \rightarrow 2P = \underline{\underline{104mW}}$ $\boxed{1/8W \text{ is OK}}$

ⓒ $P = IV = (.032A)(2.5V) = .080W$

↑ instantaneous power

②

ⓐ $V_+ = V_{cc}\frac{R}{4R} = \frac{1}{4}V_{cc}$

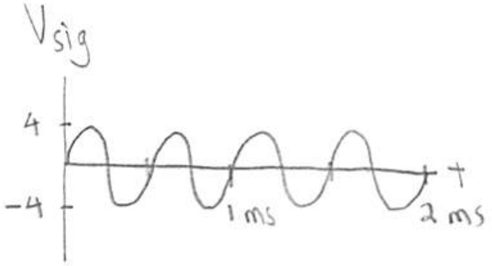


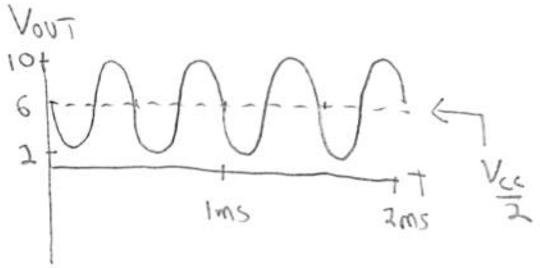
$V_- = V_+ = \frac{1}{4}V_{cc}$

$$I = \frac{V_{sig} - V_-}{R_1} = \frac{V_- - V_{OUT}}{R_1}$$

$$V_{OUT} = 2V_- - V_{sig} = \boxed{\frac{1}{2}V_{cc} - V_{sig}}$$

ⓑ

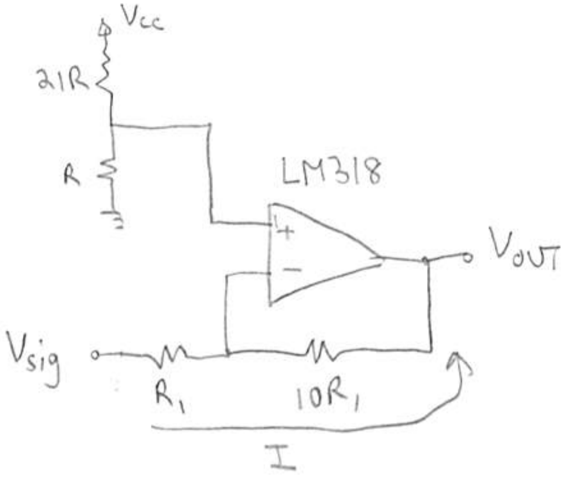




ⓒ $I = \frac{12V}{4 \times 10K} = 0.3mA$

$$p = IV = (0.3mA)(12V) = \boxed{3.6mW}$$

③



ⓐ $V_+ = V_{cc}\frac{R}{22R} = \frac{V_{cc}}{22}$

$V_- = V_+$

$I = \frac{V_{sig} - V_-}{R_1} = \frac{V_- - V_{OUT}}{10R_1}$

$10V_{sig} = 11V_- - V_{OUT}$

$$\boxed{V_{OUT} = \frac{1}{2}V_{cc} - 10V_{sig}}$$

ⓑ $R_{TH(+)} = R // 21R = 10K // 210K = \underline{\underline{9.55K}}$ $G = -\frac{10R_1}{R_1} = \underline{\underline{-10}}$

$R_{TH(-)} = R_1 // 10R_1 = 100K // 1000K = \underline{\underline{90.9K}}$

For LM318, $I_{IN(BIAS)} = 500nA$, $I_{IN(OS)} = 200nA$, $V_{IN(OS)} = 10mV$
(worst case $T_A = 25°C$)

Input Bias current: $\Delta V = \underset{\uparrow |G|}{\boxed{10}} \times 500nA \times (90.9K - 9.55K) = 0.407V = \boxed{407mV}$

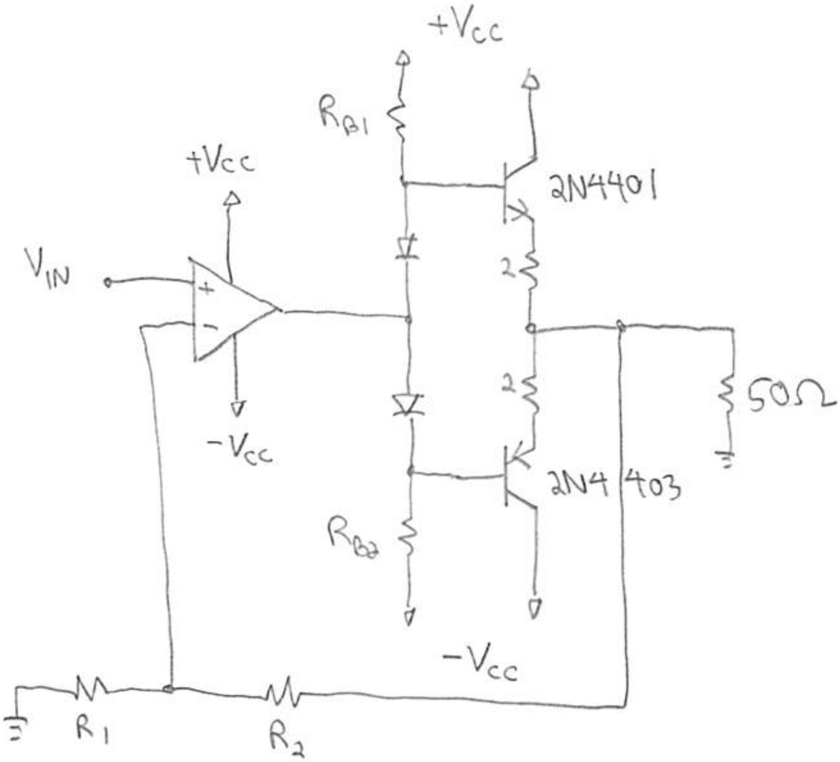
Input offset current: $\Delta V = 10 \times 200nA \times \frac{90.9K + 9.55K}{2} = 0.101V = \boxed{101mV}$

Input Bias voltage: $\Delta V = 10 \times 10mV = \boxed{100mV}$

ⓒ Main source of error is input bias current

④

ⓐ Determine V_{cc}:



First determine max output!

$$P = 0.5W = \frac{V_{MAX}^2}{\boxed{2} \times 50\Omega}$$

For sine wave

$$V_{MAX} = \pm \underline{7.07V}$$

$$I_{MAX} = \pm \frac{7.07V}{50\Omega}$$

$$= \pm \underline{0.142A}$$

$$V_{cc} - \underset{\uparrow}{\boxed{V_{E,max}}} > \underset{\overset{\uparrow}{0.4V}}{\boxed{V_{CE,sat}}} + \underset{\overset{\uparrow}{\text{Head room}}}{\boxed{2V}}$$

$$.142A \times (2 + 50\Omega)$$

$$= 7.38V$$

2N4401 @ 150mA is close enough

$$\beta_{min} = 100$$

$$V_{CE,sat} = 0.4V$$

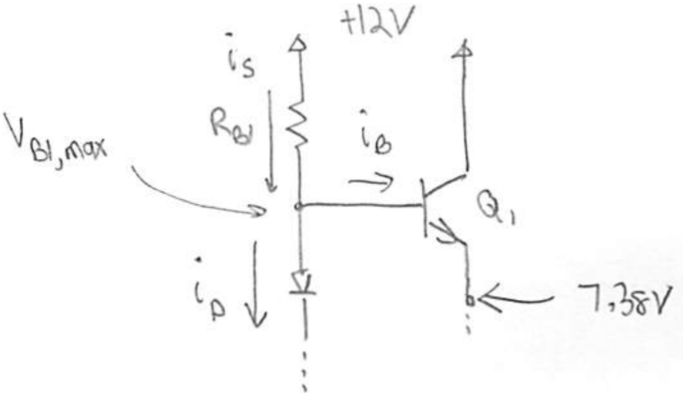
$$V_{BE,sat} = 0.95V$$

$V_{cc} > 9.78V$ Choose $\boxed{V_{cc} = 12V}$

ⓑ Determine R_{B1} and R_{B2}:

$$i_{s,min} > i_D + i_{B,max}$$

$$\frac{V_{cc} - V_{B1,max}}{R_{B1}} > 1mA + \frac{142mA}{100+1}$$



$$R_{B1} < \frac{12-\left(V_{E,max}+V_{BE,max}\right)}{1mA + 1.41mA} = \frac{12-\left(7.38+0.95\right)}{2.41mA} = 1.52k$$

Choose $\boxed{R_{B1} = R_{B2} = 1.5K}$

ⓒ Max $V_{opamp} = V_{B1,max} - 0.7 = (7.38+0.95) - 0.7 = \underline{\underline{7.63V}}$

Max $I_{op\,amp} = \dfrac{7.63V}{R_{IN,AB}}$

$$\Rightarrow R_{IN,AB} = \underbrace{(1500 // 1500)}_{750\Omega} // \underbrace{\overbrace{(100+1)}^{\beta+1}\left(\overset{r'_e}{\frac{.026V}{.142A}} + \overset{R_e}{2} + \overset{R_L}{50}\right)}_{5270.5\Omega} = \underline{\underline{656.6\Omega}}$$

So, Max $I_{op\,amp} = \dfrac{7.63V}{656.6\Omega} = .0116\,A \sim \underline{\underline{12mA}}$

According to LF356 datasheet: $V_{cc}=15V$, $V_o = 12V_p$ @ $I = \frac{12V}{1K} = 12mA$

3V difference

So, $V_{cc} = 12V$, $V_o = 9V$ @ $12mA$

$\Rightarrow$ $\boxed{\text{Op amp is OK!}}$

ⓓ Desired $G \geq \dfrac{7.07V}{0.25V} = 28.3$

For non-inverting amplifier, $G = 1 + \dfrac{R_2}{R_1} \Rightarrow \dfrac{R_2}{R_1} \geq 27.3$

Choose

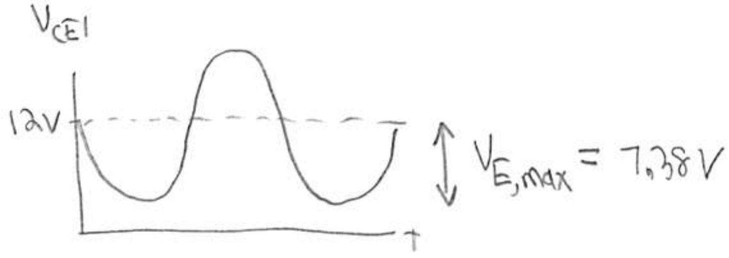
$\boxed{\begin{matrix} R_2 = 330K \\ R_1 = 12K \end{matrix}}$

$(G = 27.5)$

ⓔ Heat sink needed?

$$P_{MAX} = 625\,mW - (5\,mW/^\circ C)(60^\circ - 25^\circ C) = \underline{\underline{450\,mW}}$$

$$\uparrow$$
$$.142 \sin 2\pi f t$$



$$\underset{V_{CC}}{\boxed{12}} - \underset{V_{E,max}}{\boxed{7.38}} \sin 2\pi f t$$

$$P = (.142)(12)\sin 2\pi f t - (.142)(7.38)\sin^2 2\pi f t$$

$$\langle P \rangle = 1.7 \underbrace{\frac{1}{T}\int_0^{T/2} \sin 2\pi f t\, dt}_{1/\pi} - 1.05 \underbrace{\frac{1}{T}\int_0^{T/2} \sin^2 2\pi f t\, dt}_{1/4}$$

$$= 1.7 \times \frac{1}{\pi} - 1.05 \times \frac{1}{4} = 0.166W$$

$$2\langle P \rangle = \underline{\underline{332\,mW}} < P_{MAX} = 450\,mW \quad ✓$$

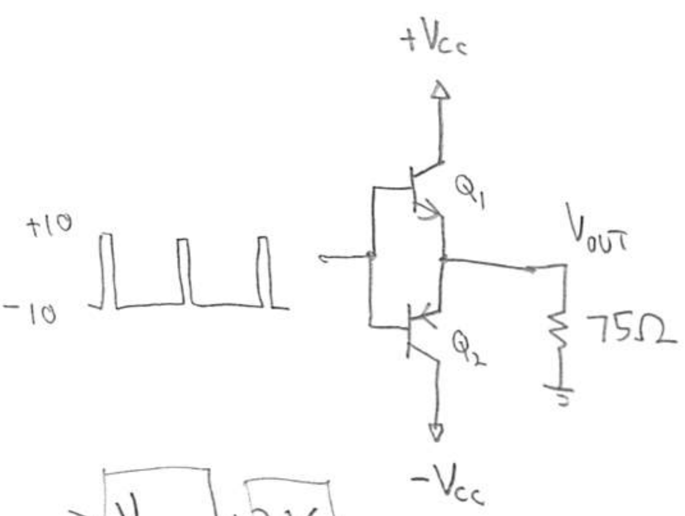
$$\boxed{\text{No heat sinks needed}}$$

⑤

ⓐ $V_{OUT} = V_{B1} - V_{BE}$

$= 10 - 0.75$

$= \underline{\underline{9.25V}}$

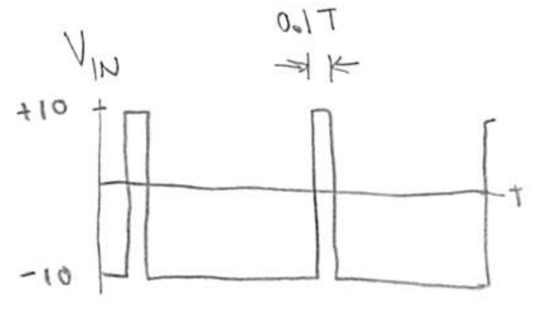


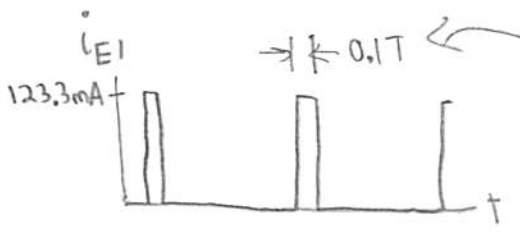
For active mode, $V_{cc} - V_{E,max} > \underset{0.4V}{\underset{\uparrow}{\boxed{V_{CE,sat}}}} + \underset{\text{Headroom}}{\underset{\uparrow}{\boxed{2V}}}$

$V_{cc} > 9.25 + 0.4 + 2$

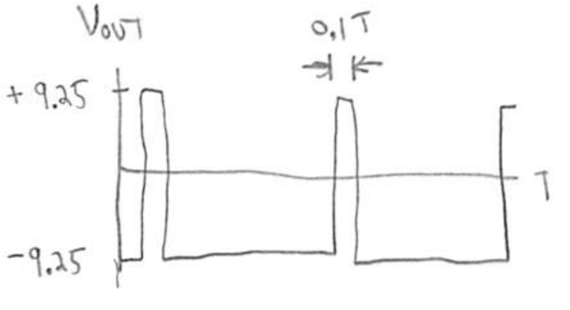
$> 11.65V \Longrightarrow$ choose $\boxed{V_{cc} = 12V}$

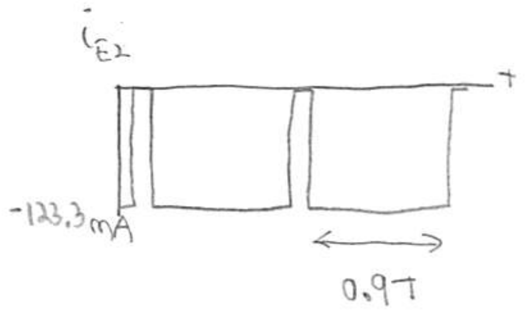
ⓑ $|I_{MAX}| = \frac{9.25V}{75\Omega} = .1233A = \underline{\underline{123.3mA}}$





Q1 is ON 10% of time





Q2 is ON 90% of time

ⓒ $|V_{CE}| = |12 - 9.25| = 2.75V$

Q_1: $\langle P_1 \rangle = \boxed{0.10} \times (.1233A)(2.75V) = .0339W = \boxed{34\ mW}$

↑

Q_1 Duty cycle

Q_2: $\langle P_2 \rangle = \boxed{0.90} \times (.1233A)(2.75V) = 0.305W = \boxed{305\ mW}$

↑

Q_2 duty cycle