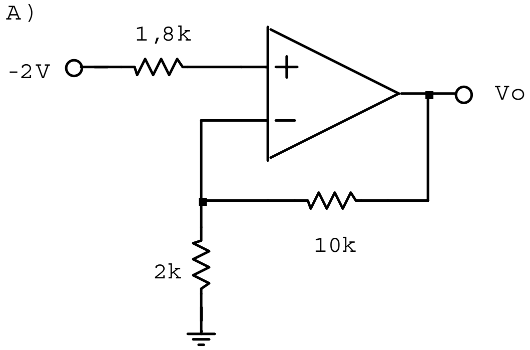
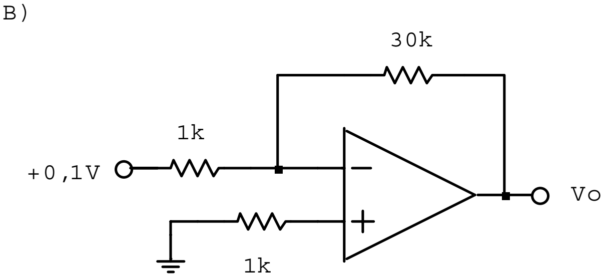
EXERCISE IDEAL OP AMP ANALYSIS

No.1 Assuming ideal op amps, determine V_O for each and every circuit shown below.

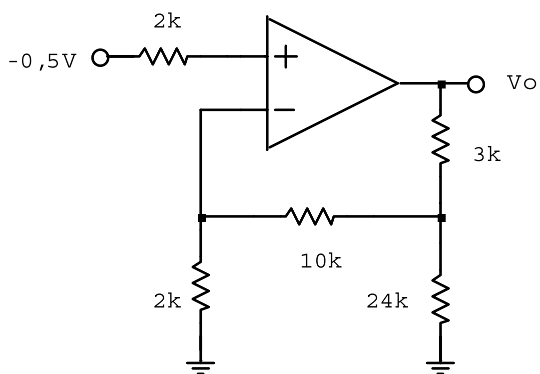
A)



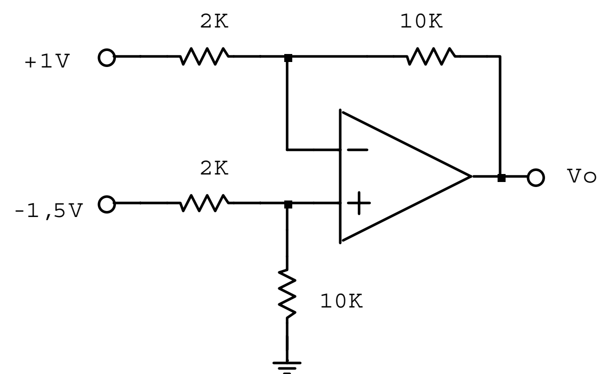
B)



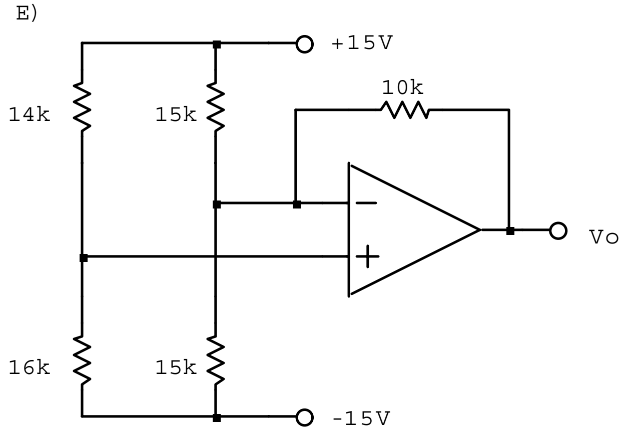
C)



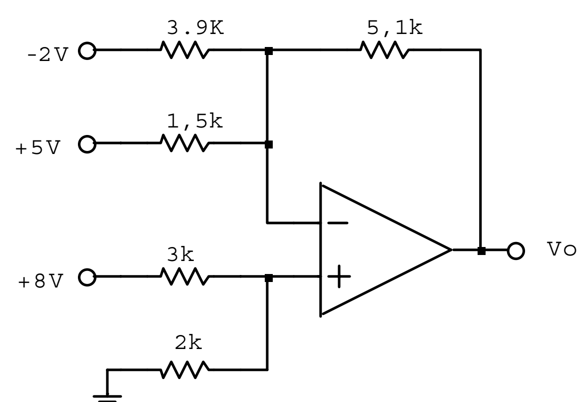
D)



E)



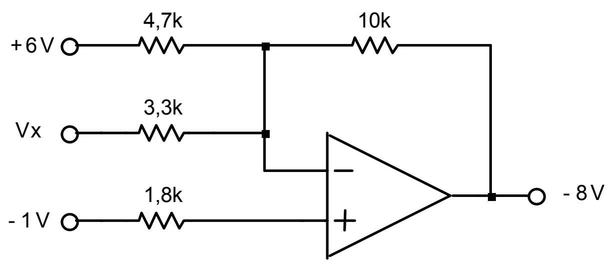
F)



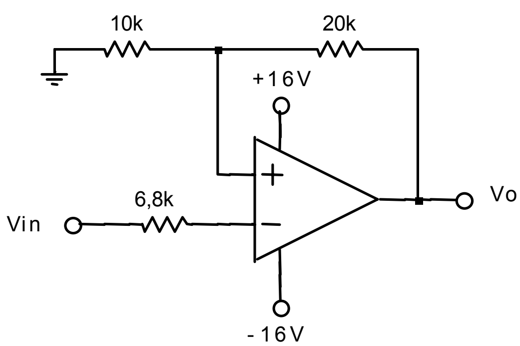
No.2 Assume typical op amp data for circuits A through E and worst case values for circuit F.

Op amp parameters for V_{SUP}=±15V	minimum	typical	maximum
O/P voltage swing	±12V	±13,5V	-
I/P voltage range	±11V	±12,5V	-
Short circuit current	±12 mA	±20 mA	-

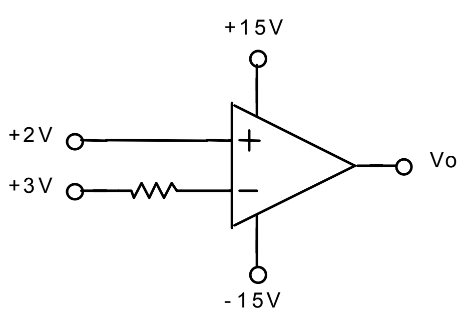
A) Determine V_x.



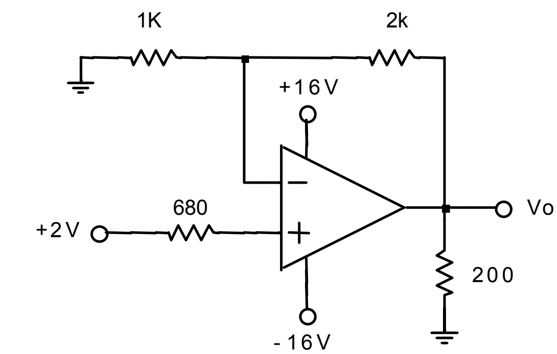
B) Determine V_o for V_{in}=+6V and V_{in} =-6V.



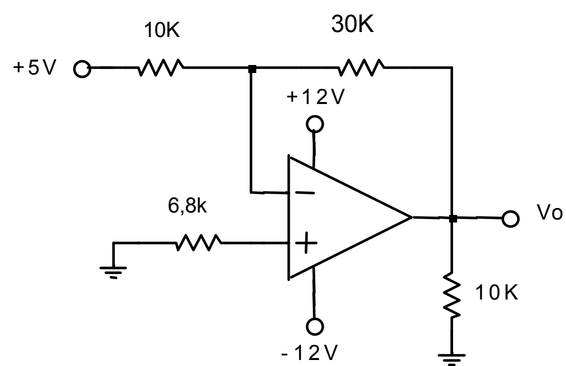
C) Determine V_o.



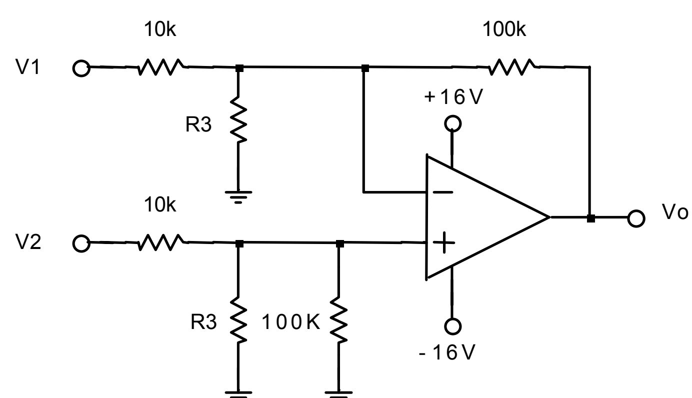
D) Determine V_o.



E) Determine V_o.

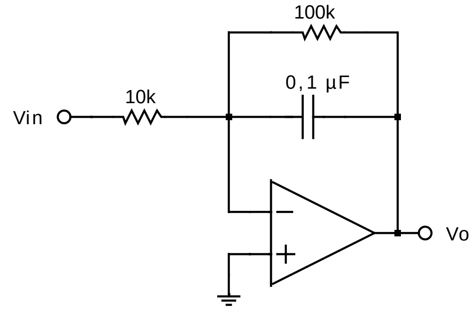


F) Determine the maximum value of R_3 if we do not want to saturate the inputs of the op amp given that V1 and V2 range from 80V to100V .



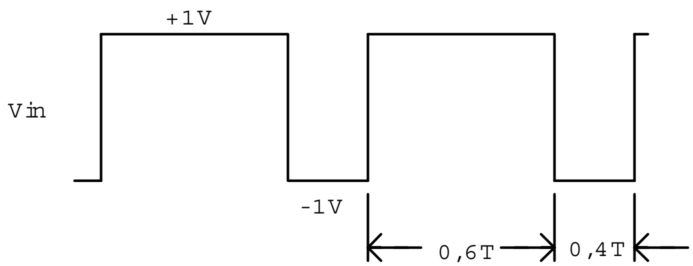
No.3

$$\Delta V_{o(PP)} = V_{o(t_2)} - V_{o(t_1)} = -\left(\frac{1}{R_E C_F}\right)\int_{t_1}^{t_2} V_{in(AC)}\,dt \qquad \text{if } \omega > \frac{10}{R_F C_F}$$



$$V_{in(ave)} = V_{in}^{+}\left(\frac{PW}{T}\right) + V_{in}^{-}\left(\frac{SW}{T}\right)$$ for a squarewave

A) Draw the output waveform with respect to V_{in} shown for frequencies of 50 Hz, 100 Hz, 1 kHz and 10 kHz - label waveforms with AC and DC values as well as PW and SW.



B) If V_{in} is a 2 V_{pp} squarewave with a 50% duty cycle, calculate the frequency of V_{in} that will produce V_o = 1 V_{pp}

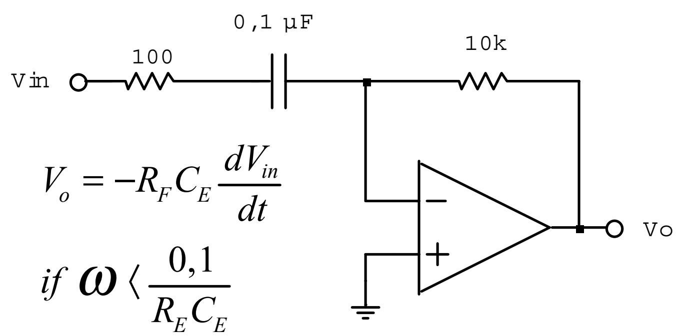
C) Repeat step B for 75% duty cycle.

D) If V_{in} is a 10 V_{pp} triangular wave with a frequency of 5 kHz, draw the expected O/P waveform with respect to V_{in}.

No.4 A) Determine the output waveform relative to an input triangular wave with a 10 V_{PP} amplitude and a frequency of 250 Hz.

B) Determine the output waveform relative to an input square wave with a 2 V_{PP} amplitude and a frequency of 250 Hz.

C) What is the function of the 100Ω resistor?



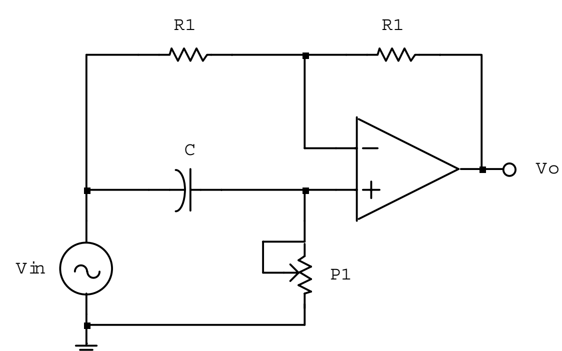
$$V_o = -R_F C_E \frac{dV_{in}}{dt}$$

$$if\ \omega < \frac{0{,}1}{R_E C_E}$$

No.5 **PHASE SHIFTER**

$$A_{VF} = \frac{P1 + jX_C}{P1 - jX_C} \qquad |A_{VF}| = 1$$

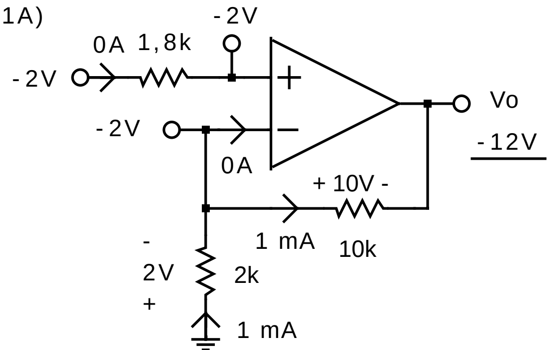
$$\angle A_{VF} = 2\arctan\frac{X_C}{P1}$$



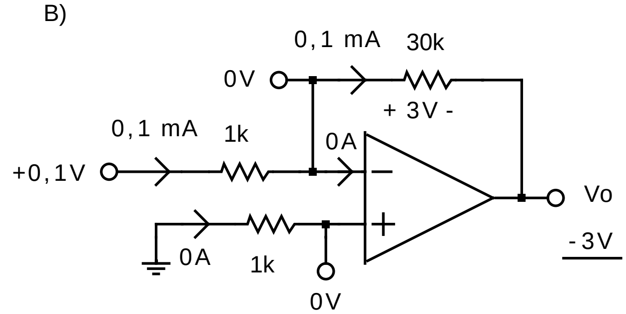
Design the circuit in order to obtain a phaseshift of 20° to 180° with a 100K pot (P1) at a frequency of 1 kHz.

SOLUTIONS

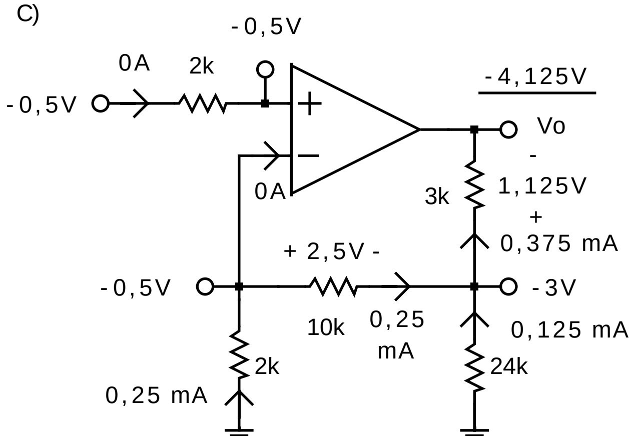
No.1A)



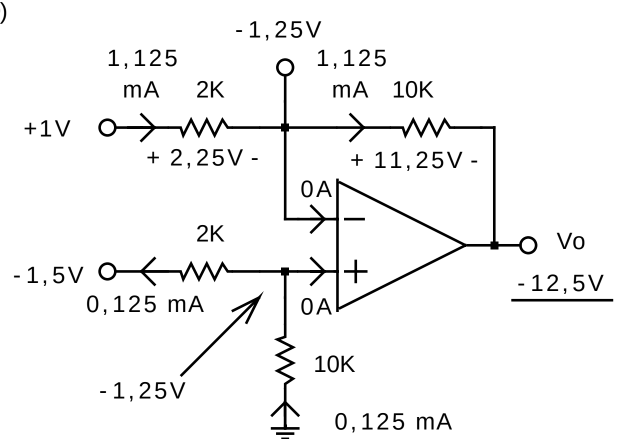
B)



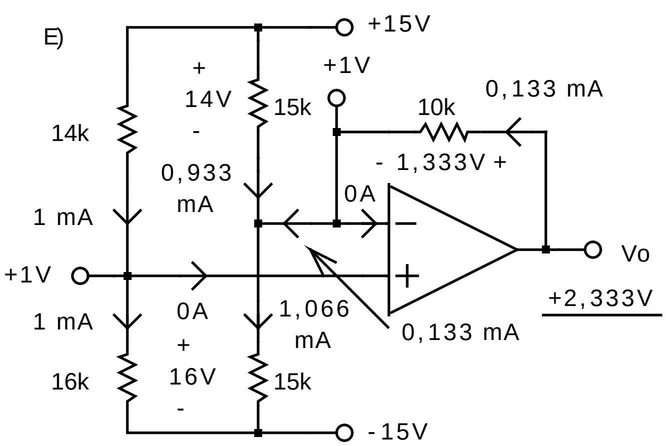
C)



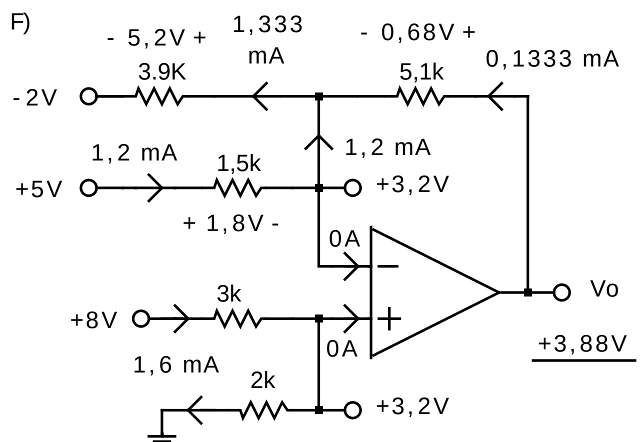
D)



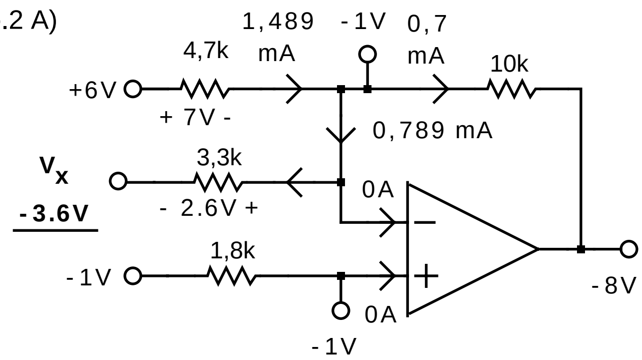
E)



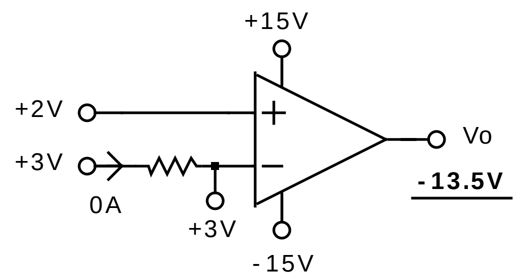
F)



No.2 A)



C)

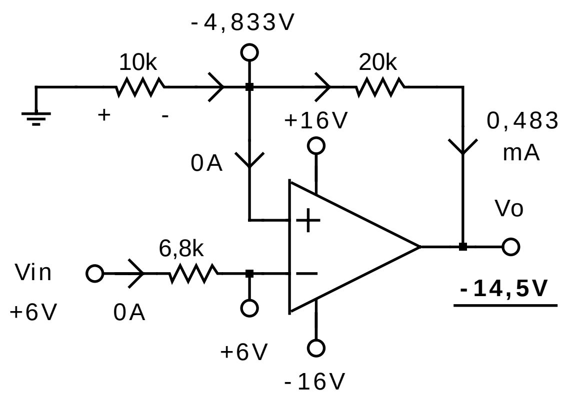


No feedback, the output saturates with a polarity determined by the sign of the differential I/P voltage:

$V_o = A_d\,(V^+ - V^-) = \quad (2-3) = -$

$\mathbf{V_o = -V_{sat} = \underline{-13{,}5V}}$

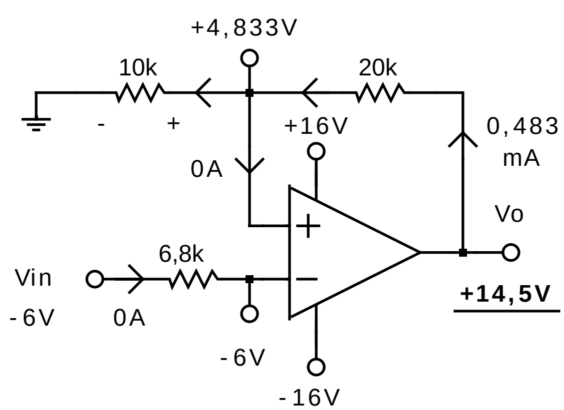
B)



Positive feedback will make the output saturate with a polarity determined by the sign of the differential I/P voltage. With +6V applied to the -ve I/P of the op amp, the O/P should be of the opposite polarity, therefore <u>assume</u> $\mathbf{V_o = -V_{sat} = -14{,}5V}$ and determine the V^+ and verify the sign of the differential I/P voltage in order to validate your assumption of $V_o = -V_{sat}$, that is:

$V_o = A_d\,(V^+ - V^-) = \quad (-4{,}83-6) = -$

therefore the assumption was valid.



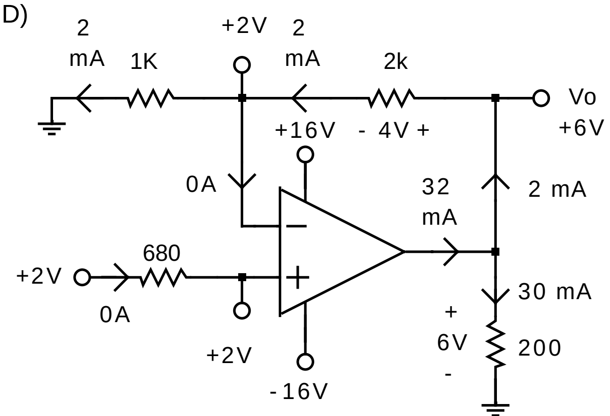
Same procedure here, except now V^- is negative, therefore the O/P polarity is expected to be positive:

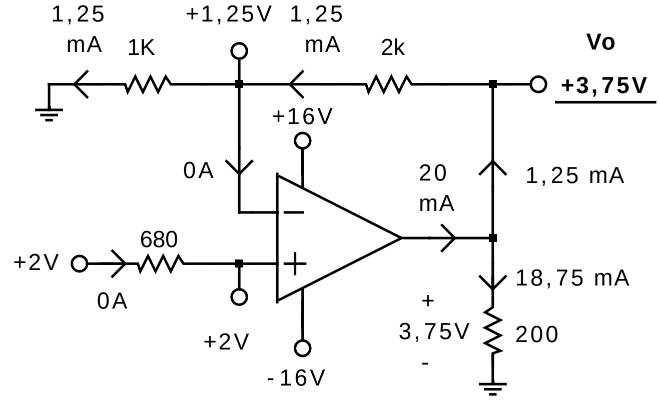
$\mathbf{V_o = +V_{sat} = +14{,}5V}$

Verify assumption with sign of $V_d = (V^+ - V^-)$

$V_o = A_d\,(V^+ - V^-) = \quad (+4{,}83-(-6)) = +$

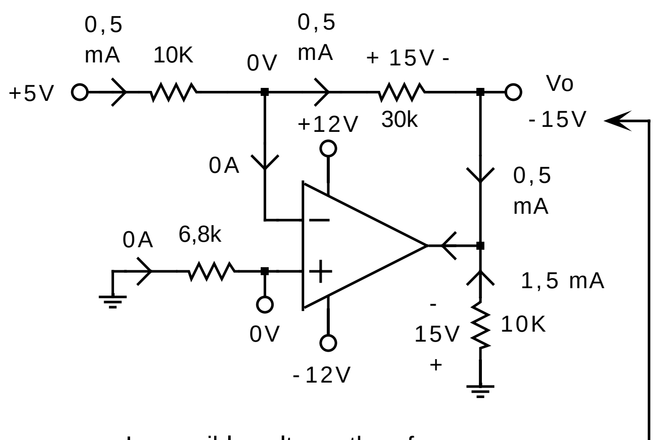
2 D)

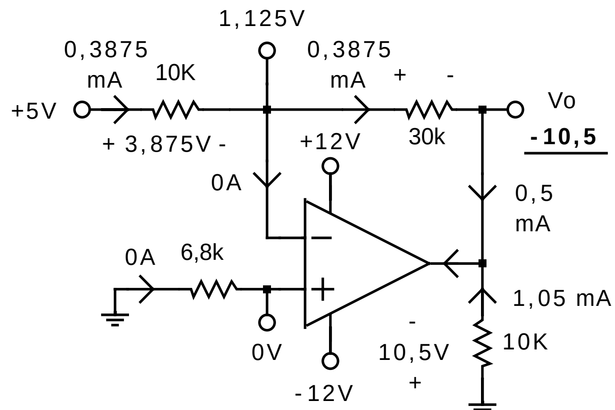




Output of op amp has reached current limit, notice that $V^- \neq V^+$ and -ve feedback is rendered ineffective not forcing $V^- = V^+$

E)

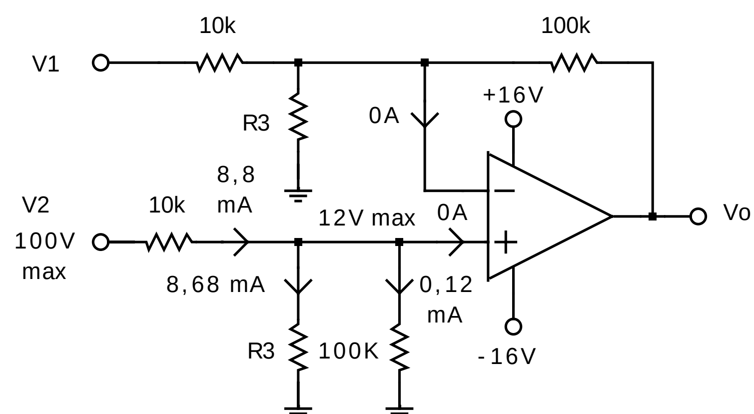




Impossible voltage, therefore $V_o = -V_{sat} =$ **-10,5V typical.**

Output of op amp has reached saturation, notice that $V^- \neq V^+$ and -ve feedback is rendered ineffective not forcing $V^- = V^+$

F)



V^- or V^+ max = 16 - 4 = 12V

R_3 < 12V/8,68 mA = **1382**

R_3 should be less than 1382 in order to keep V^- and V^+ inside a safe range of ±12V.

No.3

$$If \quad F \rangle \frac{10}{2\pi\, R_F C_F} = \frac{10}{2\pi\, 100k \times 0{,}1\mu} = 159\ Hz \quad then \quad \Delta V_{o\,(PP)} = -\left(\frac{1}{R_E C_F}\right)\int_{t_1}^{t_2} V_{in\,(AC)}\, dt$$

A)

$$V_{(ave)} = V^{+}\left(\frac{PW}{T}\right) + V^{-}\left(\frac{SW}{T}\right)$$

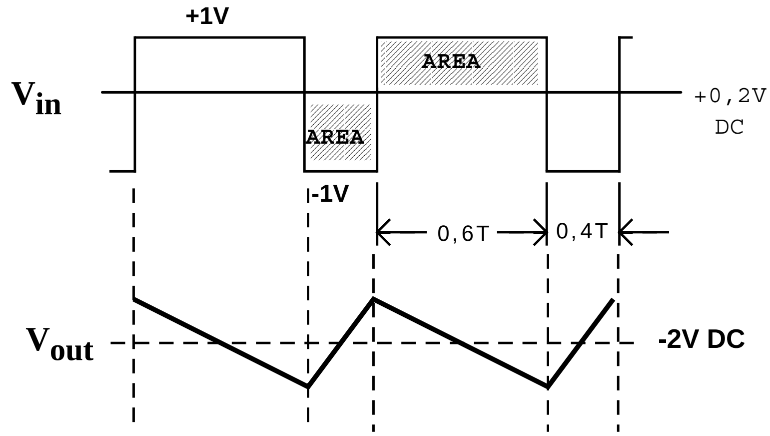
$V_{in(DC)}$ = +0,2V

$$\Delta V_{o\,(PP)} = -1000\int_{t_1}^{t_2} V_{in\,(AC)}\,dt$$

$$\Delta V_{o\,(PP)} = -1000 \times area$$

$$\Delta V_{o\,(PP)} = -1000 \times 0.8 \times 0.6T$$

Integral does not apply for 50 Hz and 100 Hz.



ΔV_{out} = 0,48V_{pp} at 1 kHz
and 48 mV_{pp} at 10 kHz

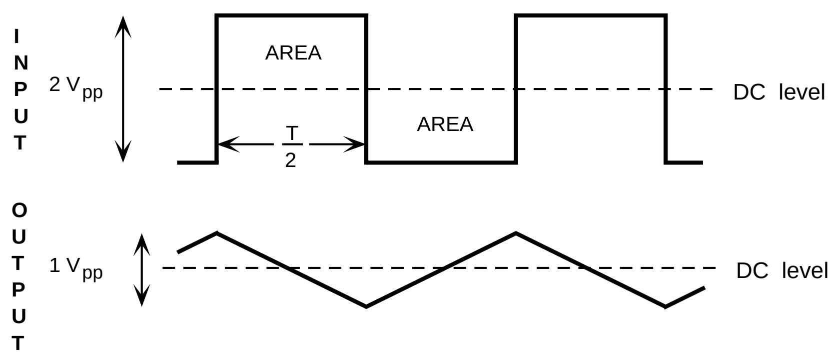
B)

$$\Delta V_{o\,(PP)} = -1000\int_{t_1}^{t_2} V_{in\,(AC)}\,dt$$

$$\Delta V_{o\,(PP)} = -1000 \times area$$

$$= 1000 \times \frac{T}{2} \times 1V_P = \frac{1000}{2F} = 1V_{PP}$$

F = <u>500 Hz</u>
F > 159 Hz integral OK.



C)

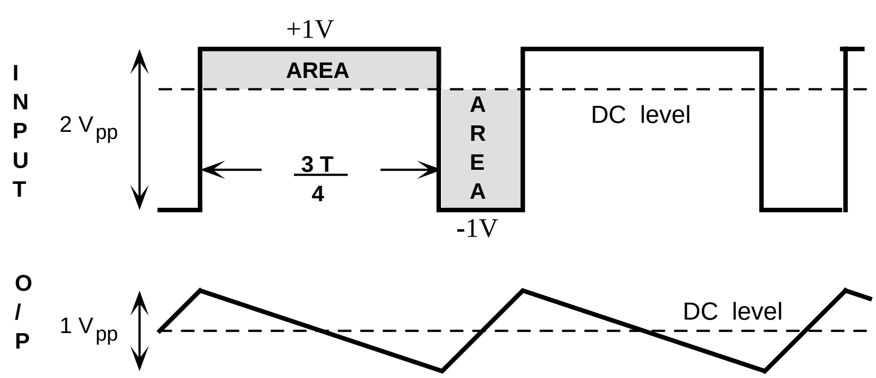
$$\Delta V_{o\,(PP)} = -1000\int_{t_1}^{t_2} V_{in\,(AC)}\,dt$$

$$\Delta V_{o\,(PP)} = -1000 \times area =$$

$$1000 \times \left(0{,}5 \times \frac{3T}{4}\right) = \frac{375}{F} = 1V_{PP}$$

$$F = 375Hz$$

F > 159 Hz integral OK.



$$V_{(ave)} = V^{+}\left(\frac{PW}{T}\right) + V^{-}\left(\frac{SW}{T}\right)$$

$V_{in(DC)}$ = +0,5V

No.3 D)

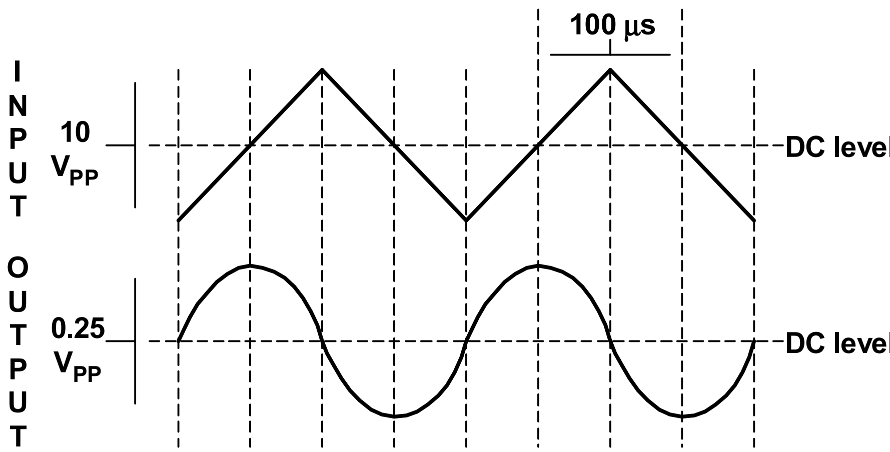
$$\Delta V_{o(PP)} = -1000 \int_{t_1}^{t_2} V_{in(AC)}\, dt$$

$$\Delta V_{o(PP)} = -1000 \times area$$

$$= 1000 \times \left(\frac{100\mu \times 5}{2} \right)$$

$$\Delta V_{o(PP)} = 0{,}25 V_{PP}$$

O/P is a parabolic wave, not a sine wave.

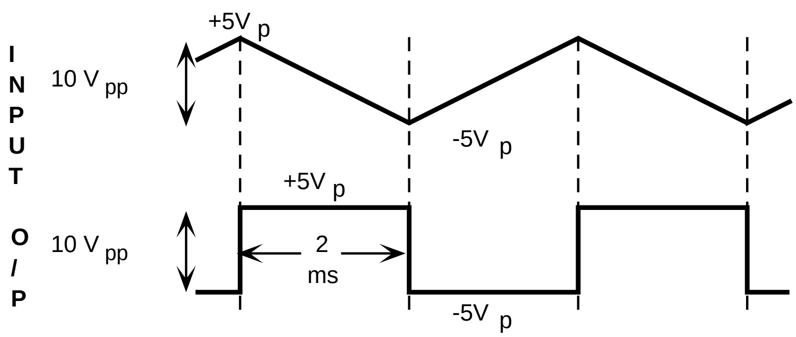


No.4 A)

$$V_o = -R_F C_E \frac{dV_{in}}{dt}$$

$$V_o = -10K \times 0{,}1\mu \left(\pm \frac{10V}{2ms} \right)$$

$$V_o = \mp 5 V_P$$



B) On edges we have:

$$V_o = -10K \times 0{,}1\mu(\pm\infty)$$

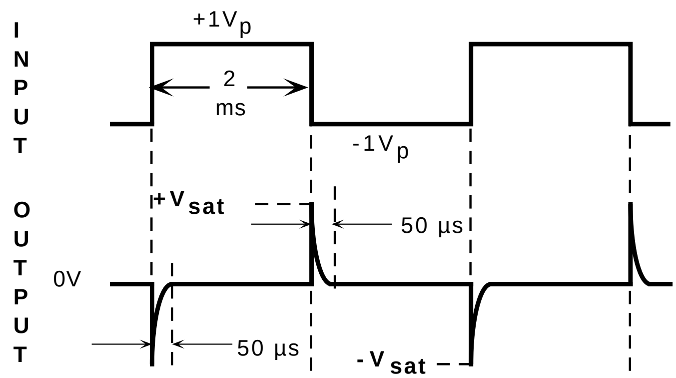
$$V_o = \mp\infty \quad \Rightarrow \quad \mp V_{sat}$$

On flat portions we have:

$$V_o = -10K \times 0{,}1\mu(\pm 0)$$

$$V_o = 0$$

The O/P spikes settle down in $5\tau = 5R_E C_E = 50\ \mu s$



C) To stabilise negative feedback in order to avoid self oscillations from the circuit.

No. 5 Phase shifter $\quad P_1 = 0 \quad \Phi = 2 \times ATAN\left(\frac{X_C}{0}\right) = 180^o$

$$\Phi = 20^o = 2 \times ATAN\left(\frac{X_C}{P_1}\right) \Rightarrow 10^o = ATAN\left(\frac{X_C}{P_1}\right) \Rightarrow TAN(10^o) = \frac{X_C}{P_1} = \frac{1}{2\pi\ FCP_1}$$

$$P_1 = \frac{1}{2\pi\ FC \times TAN(10^o)} = \frac{1}{2\pi\ 1000 \times 100k \times TAN(10^o)} = 9.026\ nF \quad \Rightarrow \quad 9.1\ nF \quad std$$

The +ve input sees 0 to 100k DC wise, average of 50k, and the –ve input sees $R_1 II R_1 = R_1/2 = 50k$ $R_1 = 100K$. This means that O/P DC offset will not be minimized for all P_1 settings.