

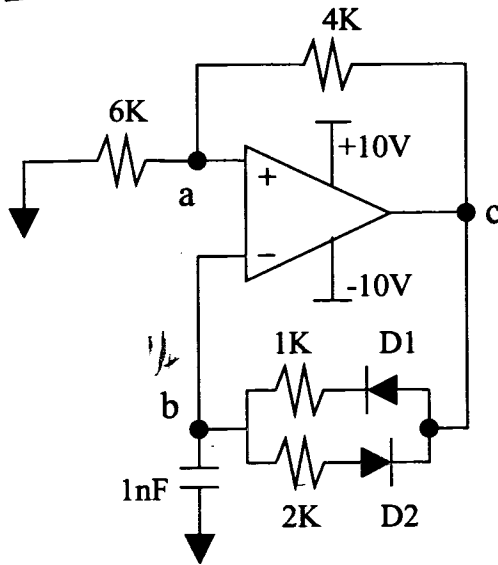
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(Use the other sides of the papers if needed.)

33/50

Questions 1: (20marks)

For the circuit below, make appropriate assumptions, sketch the waveforms at the op-amp terminals (i.e., node a, b, c).



Assume Ideal op-amp

$$a = V_+ = \frac{R_1}{R_1 + R_2} C$$

12

Assume C initially uncharged

Charging

$$V_b = 12 - (12) - (-12 + V_D) e^{-\frac{t}{RC}} \quad \text{Use } R = 2K\Omega \text{ current will flow from } b \text{ to } c.$$

$$= 12 - (24 - V_D) e^{-\frac{t}{(2K)(1n)}} \quad \text{When } t = t_1, V_b = 12V - V_D$$

$$12V - V_D = 12 - (24 - V_D) e^{-\frac{t_1}{(2K)(1n)}}$$

$$\frac{V_D}{24 - V_D} = e^{-\frac{t_1}{(2K)(1n)}}$$

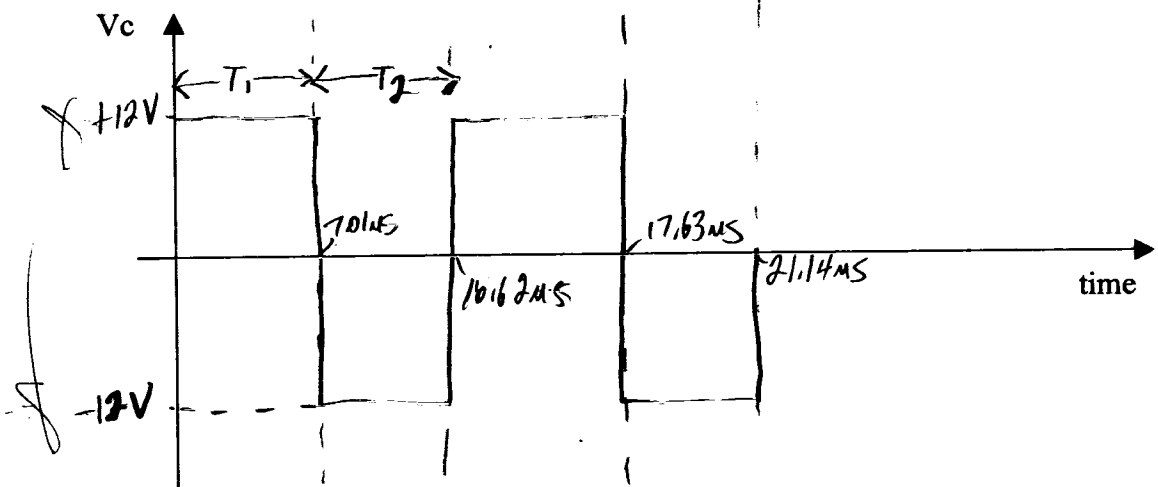
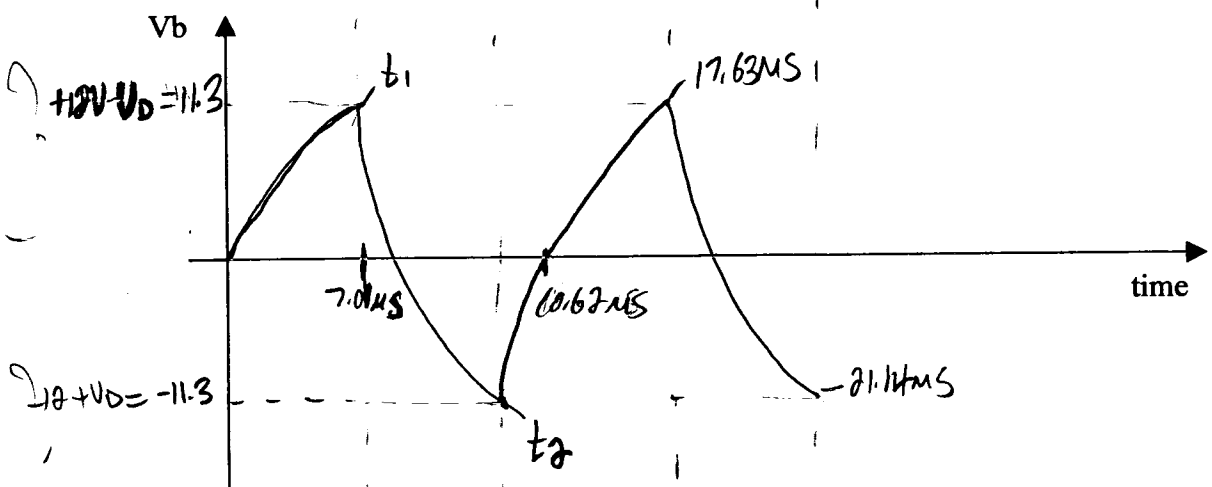
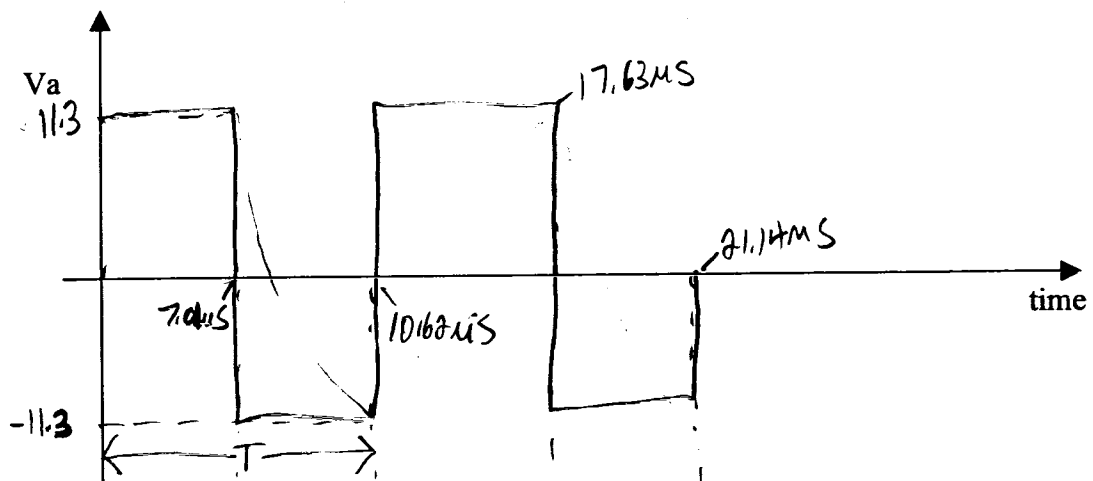
$$\frac{t_1}{2K(1n)} = \ln\left(\frac{24 - V_D}{V_D}\right)$$

$$t_1 = 7.01 \mu s$$

In our case $t_1 \neq t_2$ b/c of different R btw b & c.

$$t_2 = (1K)(1n) \ln\left(\frac{24 - V_D}{V_D}\right) = 3.51 \mu s$$

$$T = 7.01 \mu s + 3.51 \mu s = 10.62 \mu s$$



Question 2: (30marks)

Part 1:

An op-amp has the following open-loop transfer function:

$$A(j\omega) = \frac{v_{out}}{v_{in}} = \frac{10^5}{(1+j\frac{\omega}{\omega_1})(1+j\frac{\omega}{\omega_2})(1+j\frac{\omega}{\omega_3})}$$

where $\omega_1 = 100\text{rad/s}$, $\omega_2 = 10^3\text{rad/s}$, and $\omega_3 = 10^5\text{rad/s}$.

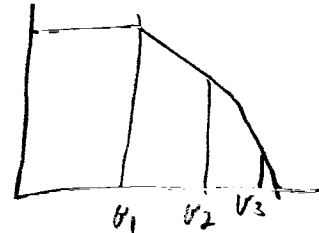
X If the op-amp is connected in a unity positive feedback configuration. What is the output frequency of the op-amp?

ACSW = 1 in unity feedback

$$10^5 = \left(1+j\frac{\omega}{\omega_1}\right) \left(1+j\frac{\omega}{\omega_2}\right) \left(1+j\frac{\omega}{\omega_3}\right)$$

$\omega > \omega_3$ when gain = 1

$$\boxed{\omega \approx 87000 \text{ rad/s}}$$



-100000

X If the op-amp is to be connected in a negative feedback configuration. What is the maximum feedback coefficient that can be tolerated before instability results? What is the minimum closed-loop gain of this op-amp without oscillation?

Find ω

$$-180^\circ = -\tan^{-1}\left(\frac{\omega}{100\text{rad/s}}\right) - \tan^{-1}\left(\frac{\omega}{10^3\text{rad/s}}\right) - \tan^{-1}\left(\frac{\omega}{10^5\text{rad/s}}\right)$$

$$\omega = 65928.55 \text{ rad/s}$$

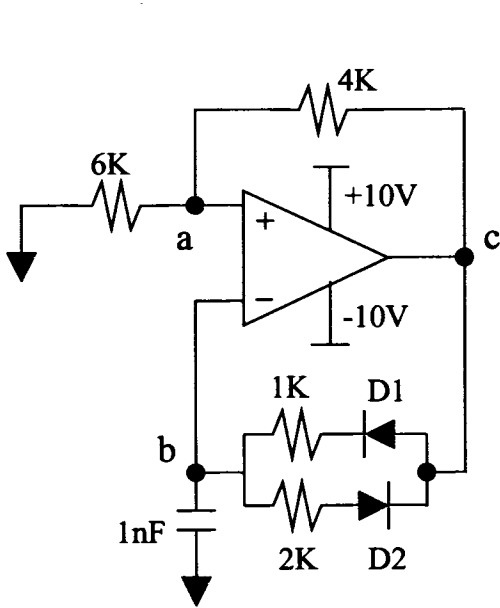
$$|A|_{180} = \left| \frac{10^5}{\left(1+j\left(\frac{65929}{100}\right)\right) \left(1+j\left(\frac{65929}{1000}\right)\right) \left(1+j\left(\frac{65929}{100000}\right)\right)} \right| = 1.92 \approx \underline{\underline{2}}$$

$$B \leq \frac{1}{2} = \boxed{0.5}$$

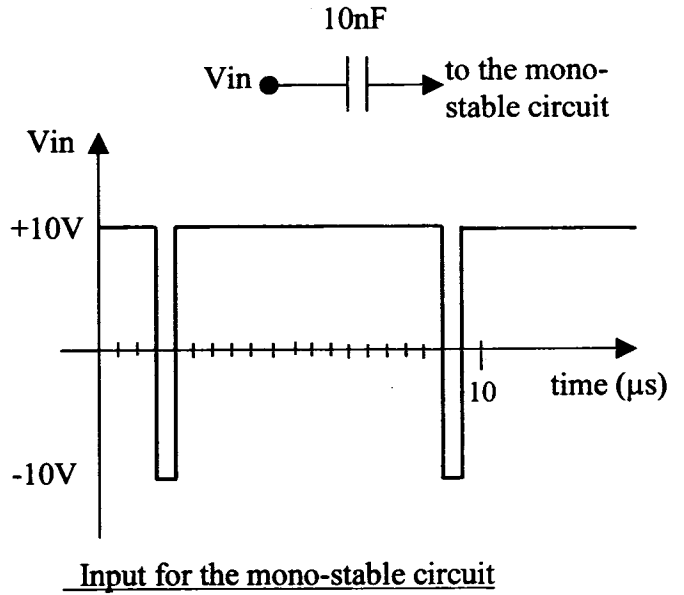
$$\boxed{A_{CL} \geq 2}$$

Part 2:

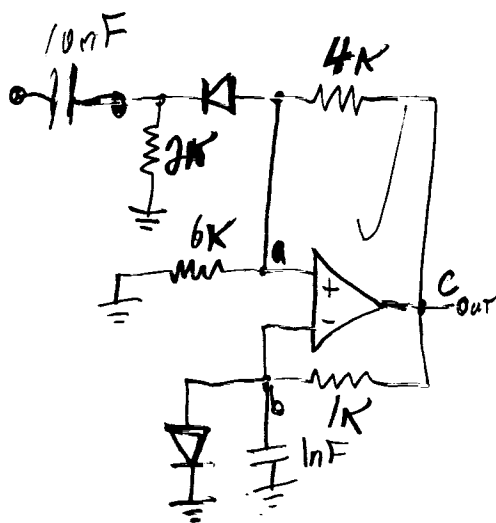
The circuit in Question 1 is shown below (a); without adding or deleting any component, rearrange the circuit to make it function as a mono-stable circuit. Connect your circuit to the input V_{in} given in (b), sketch the waveforms at the op-amp terminals a, b, c of your modified circuit.



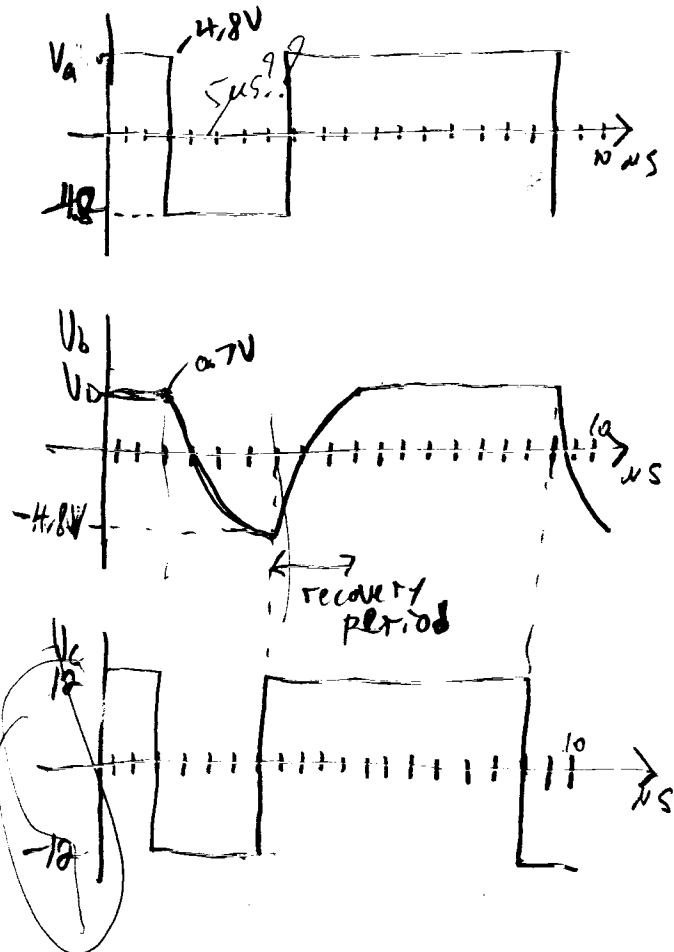
(a)



(b)



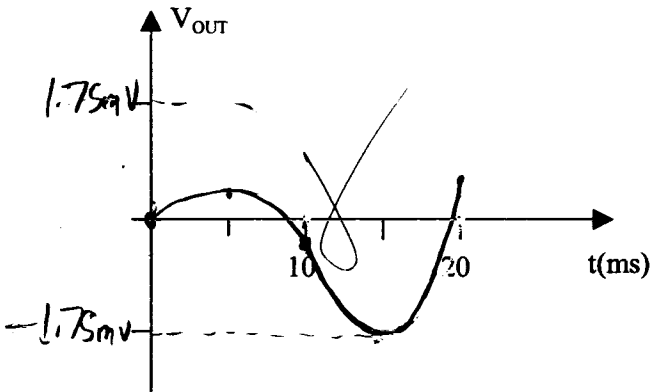
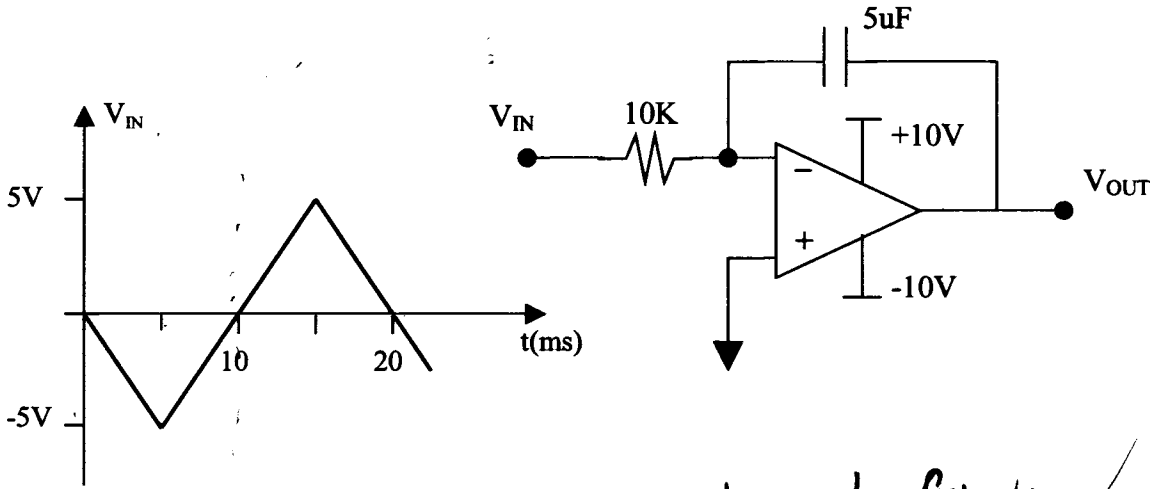
$$V_{L+} = \frac{4K}{10nF} \cdot 12 = +4.8V$$



?

Question 3: (10marks)

A 5V peak triangular voltage with a period of 20ms, depicted on the axis shown below, is applied to an ideal op-amp integrator. Sketch V_{OUT} as a function of time. The capacitor has zero initial charge.



$$V_o = -\frac{1}{RC} \int V_i dt$$

b/w 0-5

$$V_o = -\frac{1}{RC} \int_0^{5ms} -t dt = +\frac{1}{RC} \frac{t^2}{2} \Big|_0^{5ms}$$

$$= \frac{1}{RC} \frac{1}{2} (5ms)^2 = \frac{1}{(10k)(5 \times 10^{-6})} \frac{1}{2} (5 \times 10^{-3})^2 = 0.25mV$$

at $t = 5ms$ $V_{out} = 0.25mV$

at $t = 10ms$ $V_{out} = -0.5mV$

b/w 5-15ms

$$V_o = -\frac{1}{RC} \int_5^{15ms} t dt + V_o = -\frac{1}{(10k)(5 \times 10^{-6})} \frac{t^2}{2} \Big|_5^{15ms} + 0.25mV = -1.75mV$$

at $t = 15ms$ $V_{out} = -1.75mV$

b/w 15ms-20ms

$$V_o = -\frac{1}{RC} \int_{15ms}^{20ms} -t dt + V_o = +\frac{1}{(10k)(5 \times 10^{-6})} \frac{t^2}{2} \Big|_{15ms}^{20ms} - 1.75mV = 0$$

