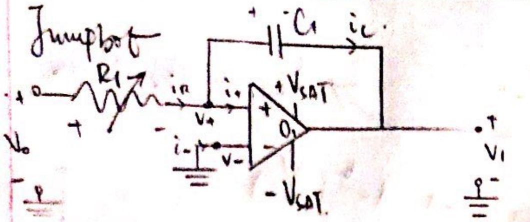
1. Jumpbot

(a)




Since we can verify that the op-amp is in negative feedback, so the Golden Rules gives:

$$\begin{cases} i_+ = i_- = 0 \\ V_+ = V_- = 0 \quad (\text{grounded } V_-) \end{cases}$$

Then, using KCL, so $i_R = i_+ + i_C \Rightarrow i_R = i_C$

Then, since $V_0 - V_+ = V_{R_1} = i_R \cdot R_1$ with $V_+ = 0$.

so $i_c = i_R = \dfrac{V_0}{R_1}$

Now, $V_1 - V_+ = -V_{C_1} \Rightarrow V_1 = -V_{C_1}$ (1)

which could be calculated by having $i_c = C_1 \dfrac{dV_{C_1}}{dt} = \dfrac{V_0}{R_1}$

$$\Rightarrow \int_0^t dV_{C_1} = \int_0^t \frac{V_0}{R_1 C_1}\, dt$$

$$\Rightarrow V_{C_1}(t) - V_{C_1}(0) = \frac{V_0}{R_1 C_1}(t-0)$$

with $V_{C_1}(0) = 0V$, so $V_{C_1}(t) = \dfrac{V_0}{R_1 C_1} \cdot t$

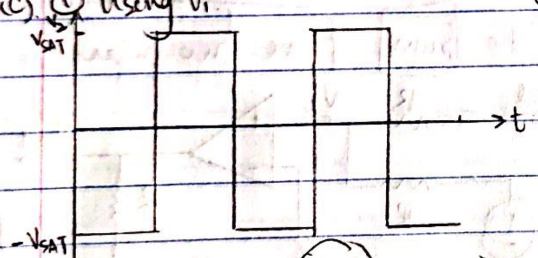
$$\Rightarrow V_1 = -V_{C_1} = \boxed{-\frac{V_0 \cdot t}{R_1 C_1}}$$

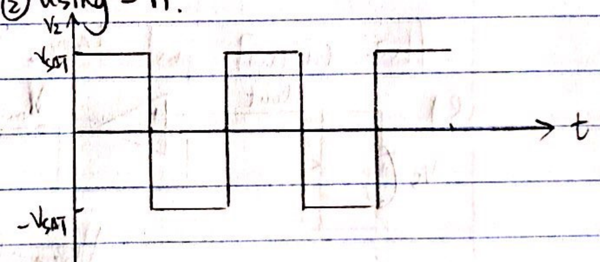
(b) $T_1 = T_2 = \dfrac{-V_{TH} - V_{TH}}{-\dfrac{V_{SAT}}{R_1 C_1}} = \dfrac{2V_{TH} R_1 C_1}{V_{SAT}}$ by analyzing the eq 1 line and its slope given.

(c) ① Using $V_1$. ② Using $-V_1$.

$V_+ = \dfrac{R_4}{R_4+R_5} \cdot V_2$

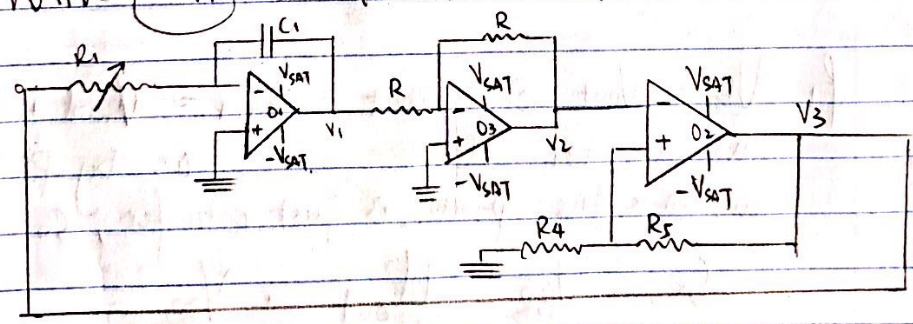
$V_2 = \pm V_{SAT}$




With $-V_1$ as input matches (b)

(d)




(e) First, $+V_{TH} = \dfrac{R_4}{R_4+R_5} V_{SAT}$ with $+V_{SAT} = 10V$, $C_1 = 0.01mF$, $R_4 = 10k\Omega$, and $+V_{TH} = 5V$,

so $R_5 = 10\,k\Omega$.

Then, since we wish to have $f = 1kHz$, so $t = \dfrac{1}{f} = 1ms$.

So $R_1 C_1 = 1ms$, with $C_1 = 0.01mF$,

so $R_1 = 100\,\Omega$

$\Rightarrow \boxed{R_1 = 100\,\Omega,\ R_5 = 10k\Omega}$

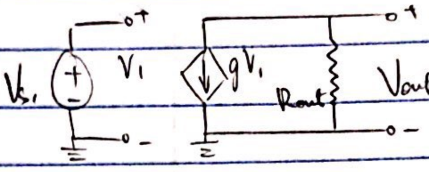
2. (a). ○ $I_s$ ○ $V_s$ ● $R_1$ ○ $R_2$ ○ $R_3$ ○ $R_4$

(MT Q3). (b) ● $u_1$ ● $u_2$ ● $u_3$ ○ $u_4$ ○ $u_5$ ○ $u_6$

(c). $u_5 - u_4 = i_3 R_3$.

(d). $i_{I_s} + i_2 - i_4 = 0$

3. (MT Q4) (a) Due to the direction of the current, we have that $V_{out,1} = -gV_1R_{out}$.
Then, $V_1 = V_{s1}$, so $V_{out,1} = \boxed{-gV_{s1}R_{out}}$

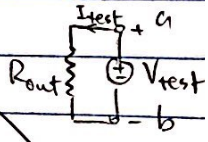



(b) Similarly, $V_{out,2} = -gV_2R_{out} = \boxed{-gV_{s2}R_{out}}$

(c). Thus, $V_{out} = V_{out,1} + V_{out,2} = \boxed{-gV_{s1}R_{out} - gV_{s2}R_{out}}$

With $g = \frac{1}{R_{out}}$, so $V_{out} = \boxed{-V_{s1} - V_{s2}}$

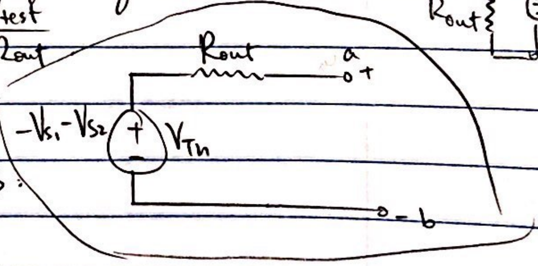
(d) Now, $V_{Th} = V_{out} = -V_{s1} - V_{s2}$ as calculated in part (c).
Then, we can zero all the independent sources and calculate $I_{test}$.
So $V_1 = V_2 = V_{s1} = V_{s2} = 0\,V$, so $gV_1 = gV_2 = 0\,(A)$.




Supplying a $V_{test}$, we have $I_{test} = \frac{V_{test}}{R_{out}}$

So $R_{Th} = \frac{V_{test}}{I_{test}} = R_{out}$

Thus, the Thevenin equivalent is:




4. (MT Q5). (a) Using voltage divider, $V_{Daisy} = \frac{4k\Omega}{4k\Omega + 4k\Omega} \cdot 1kV = 500\,V$.

So $W_{Daisy} = \frac{V_{Daisy}^2}{R_{Daisy}} = \frac{(500V)^2}{4k\Omega} = 62.5W > 10W = W_{breakdown}$.

So, Daisy is $\boxed{\text{not}}$ safe.

(b) $R_{eq} = R_{Tree} \parallel R_{Daisy} \parallel R_{Elton} = 4k\Omega \parallel 4k\Omega \parallel 2k\Omega = 1k\Omega$

$\Rightarrow V_{Daisy} = V_{Elton} = \frac{1k\Omega}{4k\Omega + 1k\Omega} \cdot 1kV = 200V$ using voltage divider.

$\Rightarrow W_{Daisy} = \frac{V_{Daisy}^2}{R_{Daisy}} = \frac{(200V)^2}{4k\Omega} = 10W \le W_{Daisy,breakdown}$.

$W_{Elton} = \frac{V_{Elton}^2}{R_{Elton}} = \frac{(200V)^2}{2k\Omega} = 20W \le 25W = W_{Elton,breakdown}$.

Thus, Both Daisy and Elton are $\boxed{\text{safe}}$.

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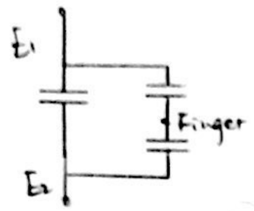
5. (MT Q6)

(a)


(b)




(c) $C = \varepsilon \frac{A}{d}$

$= (12\,\text{F/mm} + n\,\text{F/mm}) \cdot A/d$

$= \boxed{(12+n) \cdot \frac{A}{d} \quad \text{F/mm}}$

(d) 1. This is when the finger is touching,

so $C_{touch} = C_{no\ touch} + C_{F-E_1} \parallel (C_{F-E_2L} + C_{F-E_2R})$

$= (12+n) \cdot \frac{4\,mm^2}{2\,mm} \cdot \text{F/mm} + 8F \parallel (4F + 4F)$

$= (24 + 2n)F + 4F = \boxed{(28 + 2n)\,F}$

(2) $C_{no\ touch}$ is when the other branch is open circuit,

So $C_{no\ touch,eq} = C_{no\ touch} = \boxed{(24 + 2n)\,F}$

Thus, we can calculate for the display to work: $\frac{(28+2n)F - (24+2n)F}{(24+2n)F} \geq 10\%$

$\Rightarrow \quad 4 \geq 2.4 + 0.2n$

so $\quad n \leq 8$

Thus, maximum five times is $\boxed{8}$

6 (a) (MT Q7) Since $I_c = -I_{PD}$ and $I_c = C_{PD} \cdot \frac{dV_{PD}}{dt}$

so $-I_{PD} = C_{PD} \cdot \frac{dV_{PD}}{dt}$

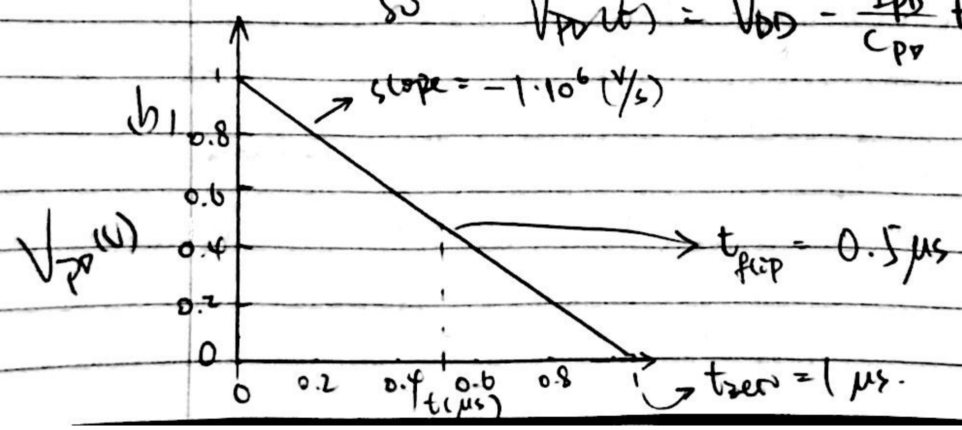
$\Rightarrow \int_0^t -\frac{I_{PD}}{C_{PD}}\, dt = \int_0^t dV_{PD}$

$\Rightarrow -\frac{I_{PD}}{C_{PD}} (t - 0) = V_{PD}(t) - V_{PD}(0)$

and given that $V_{PD}(t=0) = V_{DD}$,

so $V_{PD}(t) = V_{DD} - \frac{I_{PD}}{C_{PD}} t$, as desired Q.E.D.

(b)




[slope $= \frac{dV_{PD}}{dt}$]

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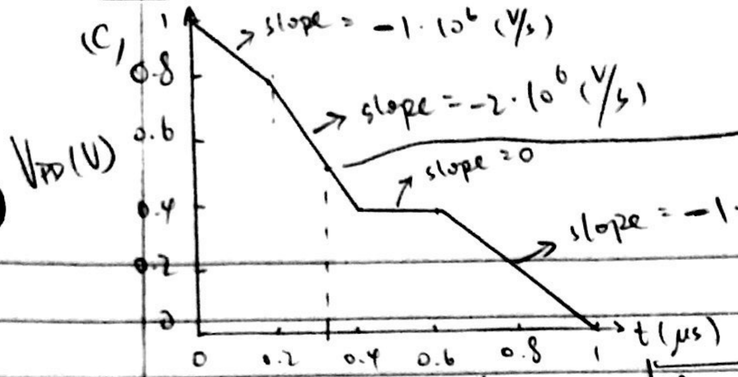
(c)




$\rightarrow t_{flip} = 0.35\,\mu s.$

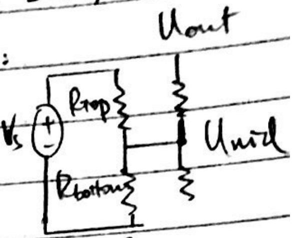
$\left[\text{slope} = \frac{\partial V_{PD}}{dt}\right]$

7. (MT Q8)

(a) Since $R = \rho\frac{L}{A}$. So $\boxed{R_{bottom} = \rho\frac{x}{A},\ R_{top} = \rho\cdot\frac{L-x}{A}}$

(b) Since there's no current through the right resistive bar, so we can use just a voltage divider and get:

$U_{mid} = U_{out} = \frac{R_{bottom}}{R_{top}+R_{bottom}} V_s$ (equiv. graph:




(c) $\boxed{No}$ because $U_{out}$ can go as low as 0V with $x \to 0$. But $V_{BB,min} > 0$, so we can't utilize the full range.

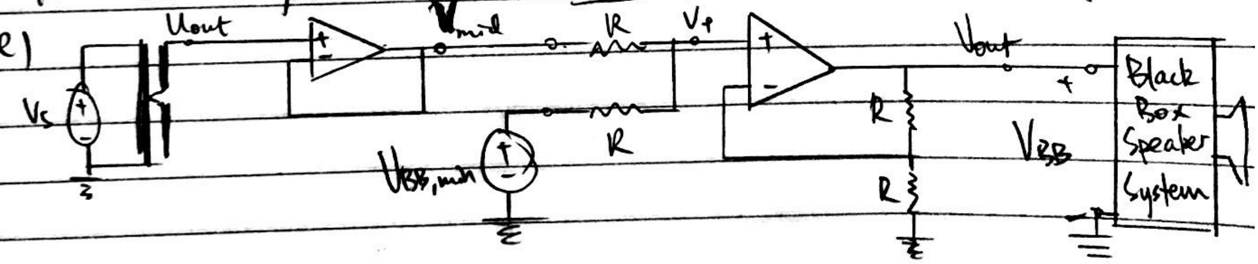
(d) First $V_+ = \frac{R}{R+R}\cdot V_{in} + \frac{R}{R+R}V_{BB,min}$

$= \frac{1}{2}(V_{in} + V_{BB,min})$

Then, using formula for a non-inverting negative feedback op-amp, so $V_{out} = V_+\cdot\left(1+\frac{R}{R}\right) = \boxed{V_{in} + V_{BB,min}}$

This circuit just takes the $\boxed{\text{sum}}$ of the two input voltages.

(e)




(f) $V_{BB} = V_{out} - 0 = V_{out} = 2V_+ = V_{mid} + V_{BB,min}$ as by part (d)

Then, since the op-amp is just a buffer, so $V_{mid} = U_{out}$,

So, $V_{BB} = U_{out} + V_{BB,min}$

$= \frac{R_{bottom}}{R_{top}+R_{bottom}}\cdot V_s + V_{BB,min} = \boxed{\frac{x}{L}V_s + V_{BB,min}}$

(g) I'd click "like" ✓

$\Rightarrow$ 8. I worked alone without help, except memory from MT and Discussion.