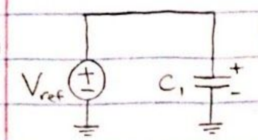
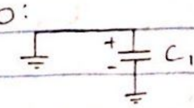
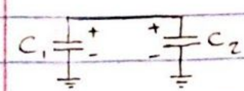
1. MP3 Player

a) 

$b=1$ when $b=0$:



b) 

c) step 3: <u>phase 1:</u>

V_{n_1} connected to ground, so $\boxed{V_{n_1} = 0V}$

<u>phase 2:</u>

$V_2 = \frac{V_{ref}}{2}$ and $V_1 = 0$

$Q_{C_{2i}} = Q_{C_{2f}} + Q_{C_{1f}}$

$C_2 \frac{V_{ref}}{2} = C_2 V_{n_2} + C_1 V_{n_2}$

$C \frac{V_{ref}}{2} = 2C V_{n_2}$

$\boxed{V_{n_2} = \frac{V_{ref}}{4}}$

step 4: <u>phase 1:</u>

V_{n_1} connected to V_{ref}, so $\boxed{V_{n_1} = V_{ref}}$

<u>phase 2:</u>

$V_1 = V_{ref}$ and $V_2 = \frac{V_{ref}}{4}$

$Q_{C_{1i}} + Q_{C_{2i}} = Q_{C_{1f}} + Q_{C_{2f}}$

$C_1 V_{ref} + C_2 \frac{V_{ref}}{4} = C_1 V_{n_2} + C_2 V_{n_2}$

$\frac{5}{4} V_{ref} C = 2C V_{n_2}$

$\boxed{V_{n_2} = \frac{5}{8} V_{ref}}$

Step	b	V_{n_1}	V_{n_2}
1	0	0V	0V
2	1	V_{ref}	$\frac{V_{ref}}{2}$
3	0	0V	$\frac{V_{ref}}{4}$
4	1	V_{ref}	$\frac{5}{8} V_{ref}$

d) step 4 : phase 2:

$$V_{n_2} = \frac{13 V_{ref}}{16}$$

assuming step 4 has $b = 1$

$$C_1 V_{ref} + C_2 V = (C_1 + C_2) V_{n_2}$$

$$V = \frac{1}{C_2}\left((C_1 + C_2) V_{n_2} - C_1 V_{ref} \right) = \frac{C_1}{C_2} V_{n_2} + V_{n_2} - \frac{C_1}{C_2} V_{ref}$$

$$V = \frac{C_1}{C_2} \frac{13}{16} V_{ref} + \frac{13}{16} V_{ref} - \frac{C_1}{C_2} V_{ref} = \frac{13}{16} V_{ref} - \frac{3}{16} V_{ref}$$

$$V = \frac{5}{8} V_{ref}$$

step 3: phase 2:

$$V_{n_2} = \frac{5}{8} V_{ref}$$

$V_{n_2} = \frac{5}{8} V_{ref}$ is equal to V_{n_2} of step 4 in part (c)

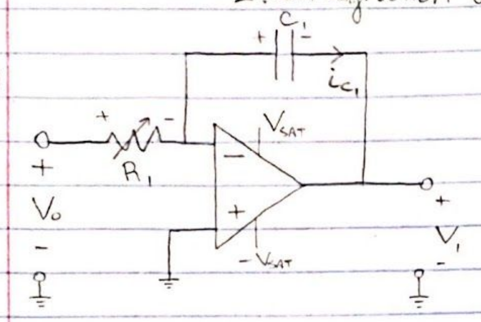
So, this sequence's steps 1-3 are same as steps 2-4 from part (c).

So, the bit sequence is $\boxed{1011}$

Step	b
1	1
2	0
3	1
4	1

2. Integration using Op-Amps

a)



$$I_{R_1} = i_{C_1} = C_1 \frac{dV_{C_1}}{dt}$$

$$I_{R_1} = C_1 \frac{-dV_1}{dt}$$

$$-\frac{dV_1}{dt} = \frac{I_{R_1}}{C_1}$$

$$V_1 = -\frac{I_{R_1}}{C_1} t$$

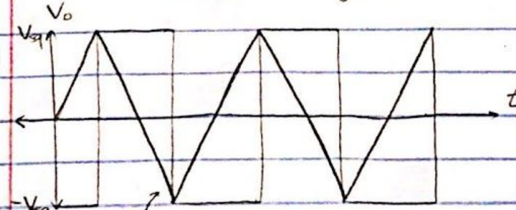
$$\boxed{V_1 = -\frac{V_o}{C_1 R_1} t}$$ slope $= -\frac{V_o}{C_1 R_1}$

b) $i_{C_1} = C_1 \frac{dV_{C_1}}{dt}$

Doubling C_1 doubles the current through C_1.
But, the slope is twice smaller when C_1 is doubled

c) If we connect a load resistor, then V_1 doesn't change. This is because we have an op-amp connected in negative feedback.

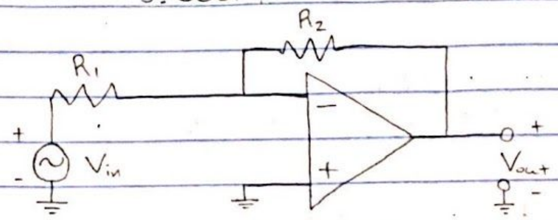
d)



slope $= -\frac{V_{sq}}{C_1 R_1}$

3. Cool for the Summer

a)



$I_{R_1} = I_{R_2}$

$\frac{V_{in}}{R_1} = \frac{-V_{out}}{R_2}$

$-V_{out} = V_{in}\frac{R_2}{R_1}$

$\boxed{V_{out} = -V_{in}\frac{R_2}{R_1}}$

b) $I_{R_{S1}} + I_{R_{S2}} = I_{R_2}$

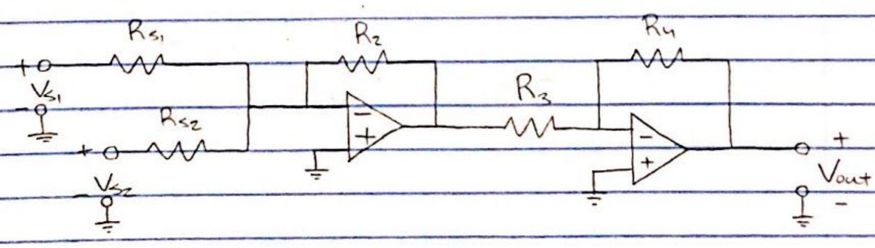
$\frac{V_{S1}}{R_{S1}} + \frac{V_{S2}}{R_{S2}} = -\frac{V_{out}}{R_2}$

$\boxed{V_{out} = -R_2\left(\frac{V_{S1}}{R_{S1}} + \frac{V_{S2}}{R_{S2}}\right)}$

c) $-\left(\frac{R_2}{R_{S1}}V_{S1} + \frac{R_2}{R_{S2}}V_{S2}\right) = -\left(\frac{1}{4}V_{S1} + 2V_{S2}\right)$

If $\underline{R_2 = 2\Omega}$, $\underline{R_{S1} = 8\Omega}$, and $\underline{R_{S2} = 1\Omega}$, then the desired relationship works. There are more than 1 way.

d)

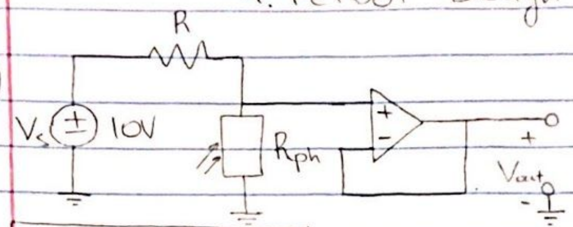


$V_{out} = -\frac{1\Omega}{1\Omega}V_{in}$ $\qquad$ $R_3 = R_4$

$V_{out} = -V_{in}$

4. PetBot Design

a)



$$\boxed{V_{out} = V_s \frac{R_{ph}}{R_{ph}+R}}$$

when close to light: $5V \leq 10V \frac{10k\Omega}{10k\Omega + R}$

$$\frac{1}{2}(10k\Omega + R) \leq 10k\Omega$$

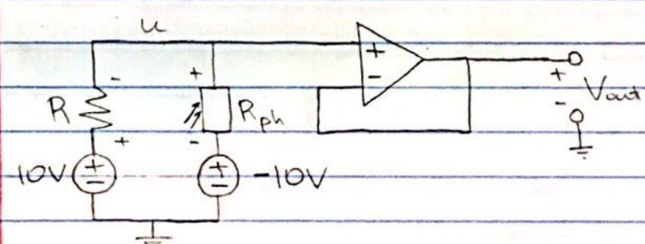
$$\underline{R \leq 10k\Omega}$$

So, $V_{out} = 10V \frac{R_{ph}}{R_{ph}+10k\Omega}$

b) $V_{out} = V_1 + V_2$

at $R_{ph} = 1k\Omega$: $V_1 = -V_2$

$V_s = 10V$



at u: superposition

$$u = \frac{10R_{ph}}{R_{ph}+R} - \frac{10V\,R}{R+R_{ph}} = \frac{10V}{R_{ph}+R}\left(R_{ph} - R\right)$$

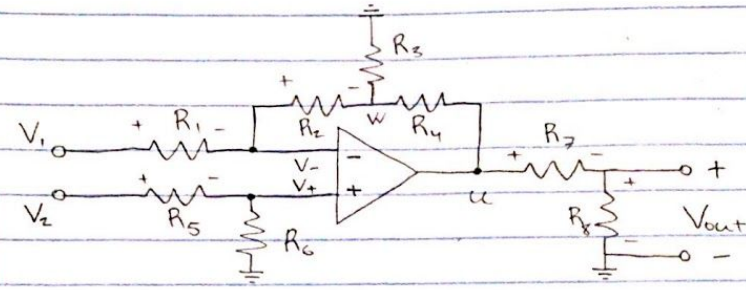
at $R_{ph} = 1k\Omega$: $u = 0$, so $R = 1k\Omega$

$$V_{out} = \frac{10V\,R_{ph}}{R_{ph}+1k\Omega} - \frac{(10V)(1k\Omega)}{1k\Omega + R_{ph}}$$

$$\boxed{V_{out} = \frac{V_s R_{ph}}{R_{ph}+R} - \frac{V_s\,R}{R_{ph}+R} = V_s \frac{R_{ph}-R}{R_{ph}+R}}$$

5. Op Amp Nodal Analysis

a)



b)

$$I_{R_7} = I_{R_8}$$

$$\frac{u - V_{out}}{R_7} = \frac{V_{out}}{R_8}$$

$$uR_8 - V_{out}R_8 = R_7 V_{out}$$

$$V_{out} = \frac{uR_8}{R_8 + R_7}$$

$$V_+ = V_2 \frac{R_6}{R_5 + R_6} = V_-$$

$$I_{R_2} = I_{R_3} + I_{R_4}$$

$$\frac{V_- - W}{R_2} = \frac{W}{R_3} + \frac{W - u}{R_4}$$

$$R_3R_4(V_- - W) = R_2R_4W + R_2R_3(W - u)$$

$$W(R_2R_4 + R_2R_3 + R_3R_4) = R_3R_4V_- + R_2R_3u$$

$$I_{R_1} = I_{R_2}$$

$$\frac{V_1 - V_-}{R_1} = \frac{V_- - W}{R_2}$$

$$V_1R_2 - V_-R_2 = V_-R_1 - WR_1$$

$$WR_1 = V_-(R_1 + R_2) - V_1R_2$$

$$W = \frac{R_1 + R_2}{R_1} \cdot \frac{V_2R_6}{R_5 + R_6} - V_1R_2$$

$$u = \frac{1}{R_2R_3}\left[W(R_2R_4 + R_2R_3 + R_3R_4) - R_3R_4V_-\right]$$

$$u = W\left(\frac{R_4}{R_3} + 1 + \frac{R_4}{R_2}\right) - \frac{R_4}{R_2} \cdot V_2 \frac{R_6}{R_5 + R_6}$$

$$u = \left(\frac{V_2R_6(R_1 + R_2)}{R_1(R_5 + R_6)} - V_1R_2\right)\left(\frac{R_4}{R_3} + \frac{R_4}{R_2} + 1\right) - \frac{V_2R_4R_6}{R_2(R_5 + R_6)}$$

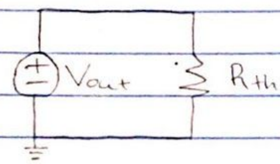
$$V_{out} = u \frac{R_8}{R_8 + R_7}$$

$$V_{out} = \frac{R_8}{R_8 + R_7}\left[\left(\frac{V_2R_6}{R_5 + R_6} + \frac{V_2R_6R_2}{R_1(R_5 + R_6)} - V_1R_2\right)\left(\frac{R_4}{R_3} + \frac{R_4}{R_2} + 1\right) - \frac{V_2R_4R_6}{R_2(R_5 + R_6)}\right]$$

c) $R_{th} = \frac{V_{out}}{I_{sc}} = \frac{u \frac{R_8}{R_8 + R_7}}{\frac{u}{R_7}}$

$$\boxed{R_{th} = \frac{R_8 R_7}{R_8 + R_7}}$$

d)



6. Homework Process

I worked on this homework alone. I read all the notes and was able to do the problems.