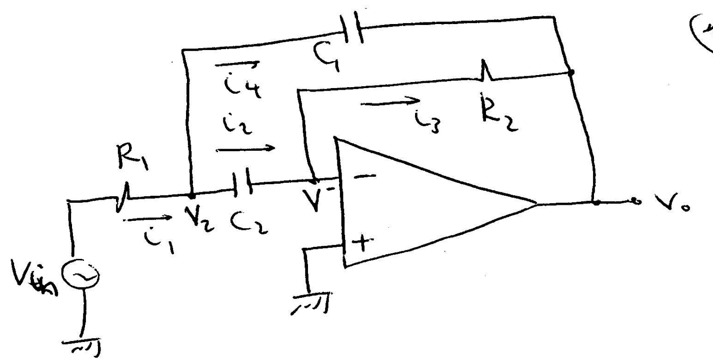


$$i_1 = \frac{V_{in} - V_2}{R_1}$$

$$i_2 = sC_2V_2 \Longrightarrow i_3 = i_2 = sC_2V_2 = \frac{-V_o}{R_2}$$

$$\therefore \boxed{V_o = -sC_2R_2V_2}$$

$$i_1 = i_2 + i_4$$

$$\frac{V_{in} - V_2}{R_1} = V_2 sC_2 + (V_2 - V_o)sC_1 \quad \left(\text{But } V_2 = \frac{-V_o}{sC_2R_2}\right)$$

$$\therefore \frac{V_{in} + \frac{V_o}{sC_2R_2}}{R_1} = -\frac{V_o}{R_2} - V_o\left(\frac{1}{sC_2R_2} + 1\right)sC_1$$

organizing

$$\frac{V_{in}}{R_1} = -V_o\left(\frac{1}{sC_2R_1R_2} + \frac{1}{R_2} + \frac{C_1}{C_2R_2} + sC_1\right)$$

$$\frac{V_o}{V_{in}} = \frac{-1}{\left(\frac{1}{sC_2R_2} + \frac{R_1}{R_2} + \frac{C_1R_1}{C_2R_2} + sC_1R_1\right)}$$

c)

$$\frac{V_o}{V_{in}} = \frac{-sC_2R_2}{(1 + sC_2R_1 + sC_1R_1 + s^2 C_1C_2R_1R_2)}$$

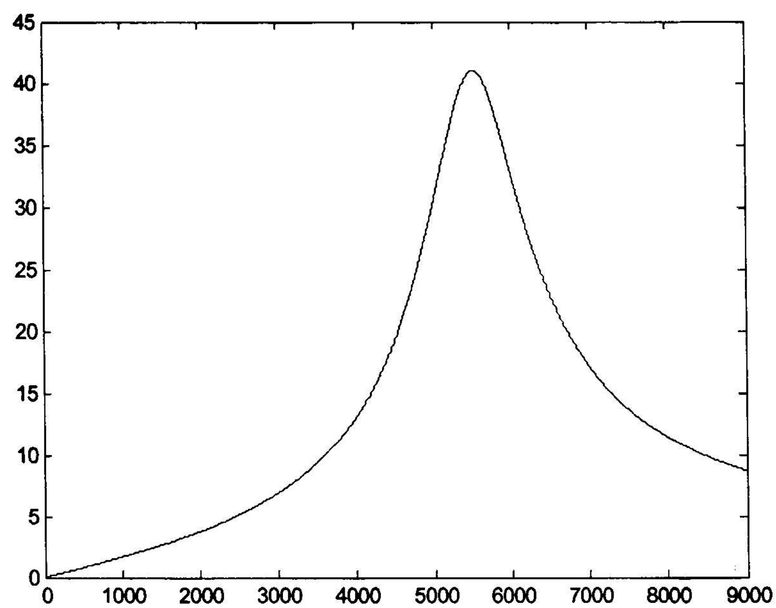
$$\frac{V_o}{V_2} = \frac{\left(-\frac{s}{C_1R_1}\right)}{\left(s^2 + s\left(\frac{1}{C_1R_2} + \frac{1}{C_2R_2}\right) + \frac{1}{C_1C_2R_1R_2}\right)}$$

For $C_1 = C_2 = 0.02\,\mu f$ & $R_1 = 1k\Omega$, $R_2 = 82k\Omega$

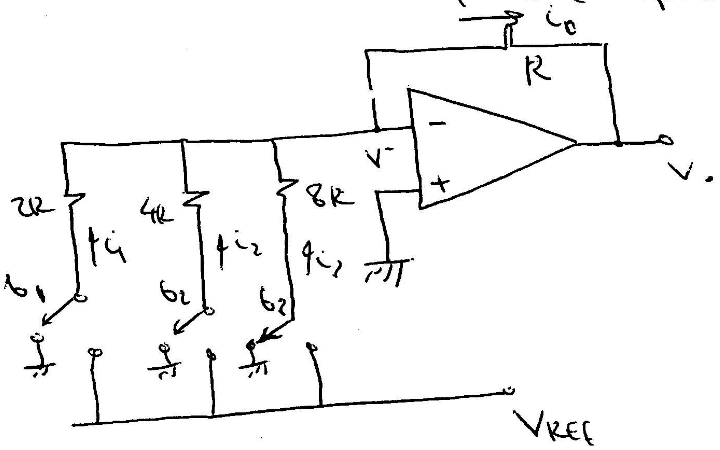
we have

$$\frac{V_o}{V_2} = \frac{-5\times10^4 s}{s^2 + 1.2195e^3 s + 3.0488e^7}$$

```
NumberOfFrequencies=9000;
AvValues=zeros(NumberOfFrequencies,1);
DOmega=1;
for Counter=1:NumberOfFrequencies
  Omega=Counter*DOmega;
  s=i*Omega;
  AvValue(Counter,1)=(-5.0e4*s)/(s*s+1.2195e3*s+3.0488e7);
end
plot(abs(AvValue))
```



Find V_o as a function of the input bits



As $V^+ = 0 \Rightarrow V^- = 0$

$$i_1 = \frac{b_1 V_{REF}}{2R}, \quad i_2 = \frac{b_2 V_{REF}}{4R}, \quad i_3 = \frac{b_3 V_{REF}}{8R}$$

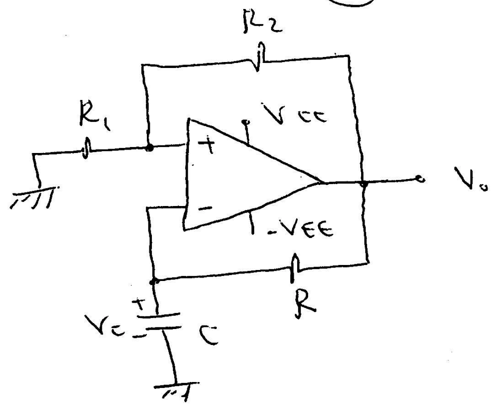
$$V_o = -i_o R = -(i_1 + i_2 + i_3) R$$

$$= -\left(\frac{b_1 V_{REF}}{2R} + \frac{b_2 V_{REF}}{4R} + \frac{b_3 V_{REF}}{8R}\right) R$$

$$V_o = -\left(b_1 2^{-1} + b_2 2^{-2} + b_3 2^{-3}\right) V_{REF}$$

How to fix the −ve sign?

⑤



if $V_o = V_{CC}$

$$V^+ = \frac{V_o R_1}{R_1 + R_2} = \beta V_{CC}$$

$V^- = V_C \Rightarrow$ Capacitor charges until

$V_C = V^+ \Rightarrow$ output switches to $-V_{EE}$

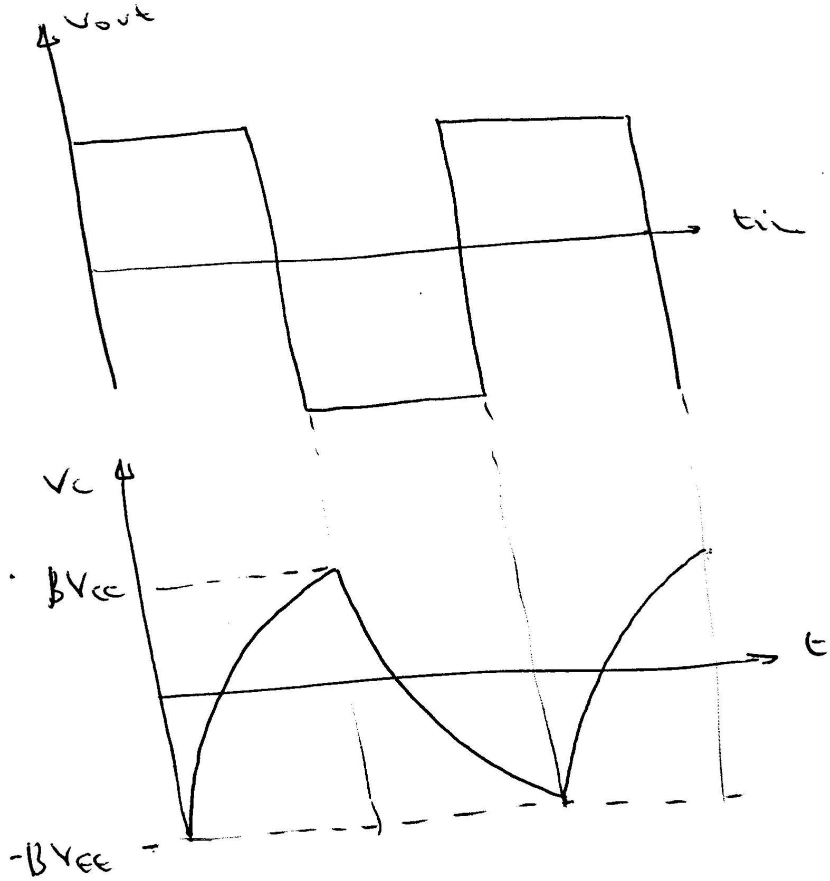
if $V_o = -V_{EE}$

$$V^+ = -V_{EE} \frac{R_1}{R_1 + R_2} = -\beta V_{EE}$$

$V^- = V_C \Rightarrow$ Capacitor discharges until

$V_C = V^-$, output becomes V_{CC}

(6)

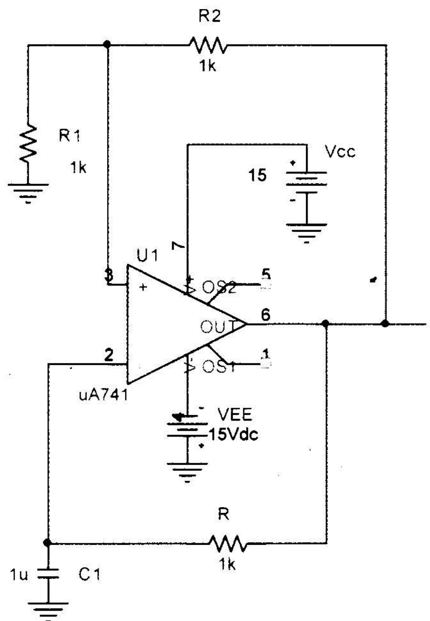


at charging:

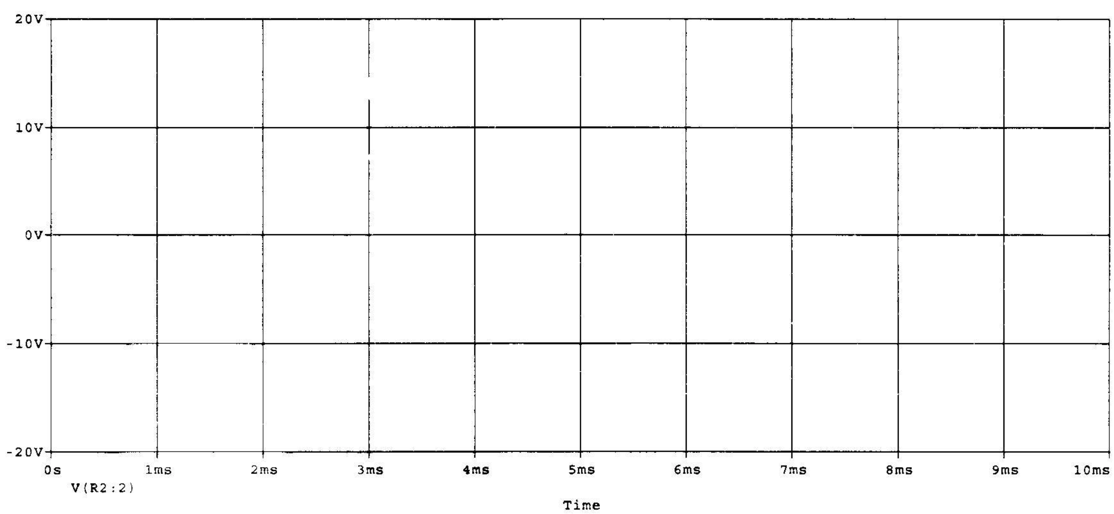
$$V_c(t) = V_{cc} - (V_{cc} + \beta V_{EE})\, e^{\left(-\frac{t}{RC}\right)}$$

at discharging:

$$V_c(t) = -V_{EE} - (-V_{EE} - \beta V_{cc})\, e^{-\frac{t}{RC}}$$



R2
1k
R1
1k
Vcc
15
U1
7
3
+
OS2
5
6
OUT
2
OS1
1
uA741
VEE
15Vdc
R
1k
1u
C1



20V
10V
0V
-10V
-20V
0s
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms
V(R2:2)
Time