Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	xcredit_2.ps.732547266
Submitted at:	Fri Mar 19 08:42:39 19933
Printed at:	Fri Mar 19 08:42:40 1993

flm@util
xcredit_2.ps.732547266

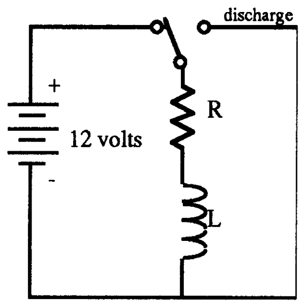
Extra credit problems:

Transients:

DP9-8

1. An experimental electronic valve timing system for an automobile engine uses pneumatic (compressed air) actuators to lift the valves, actuated by electromagnetically operated pneumatic valves (Gould, 1991). The engine valve must open within 2 ms after being commanded to open by the engine control computer.

The pneumatic valve will begin to open when the current in the valve solenoid coil exceeds 300mA, its guaranteed "on" current. The valve will begin to close when the solenoid coil current drops below 225 mA, its guaranteed "off" current. To ensure that the engine valve opens on time, only 1 ms has been allowed for the current in the solenoid to reach its on current after the applied voltage changes from 0 to 12 volts, and 0.2 ms is allowed for the current to decay below its off current after the supply voltage is removed and the coil is shorted (the applied voltage chnages from 12 to 0 volts). Either response may be faster. The solenoid coil can be modeled as an inductance of 3 mH with a series resistance that is determined by the diameter (gauge) of wire chosen for the coil. Smaller-gauge wire will cause higher resistance, lower power dissipation, and allow a smaller solenoid package. What is the maximum value of solenoid resistance that will meet both timing specifications? With this resistance, what is the maximum current in the solenoid coil? Assume that the solenoid is to be energized 25% of the time. What is the approximate average power dissipation in this solenoid coil? What simplifying assumptions did you make?

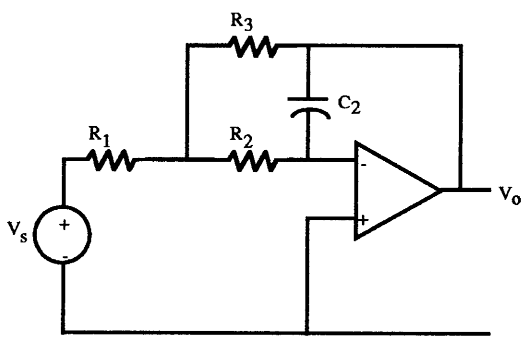


In practice, a solenoid is not directly shorted to turn it off, but is shorted through a diode with a voltage drop of 0.7 volts across it, as this is easier to implement. Why would you not simply open-circuit the coil to achieve zero current? Hint: Check Horowitz and Hill for this one, e.g. Section 1.31.

Laplace transform:

AP14-4

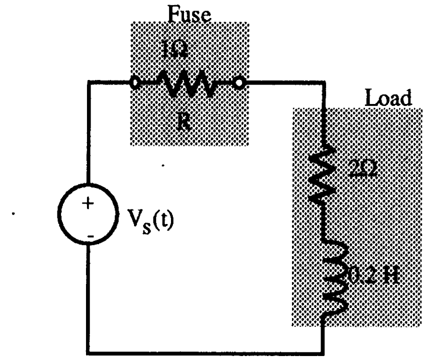
2. A digital-to-analog converter (DAC) uses the op-amp circuit shown below (Garnett, 1992) which filters the pulse output from the DAC and produces a smoother analog voltage. Although a number of different types of such circuits (low-pass filters) can be used, the one necessary requirement is that the input impedance of the filter must be greater than 100,000 ohms; otherwise, the linearity of the DAC will degrade. Determine the transfer function of the filter, Vo(s)/V(s). Select an appropriate op-amp (your choices are the uA741, LF411 and AD847) to achieve the input impedance requirement. The circuit model for the AD847 is included in the file AD847.CIR in the folder SPICEDIV in the public folder on snowhite. WARNING: This model may cause convergence problems in PSpice — it is very complex!



DP9-8

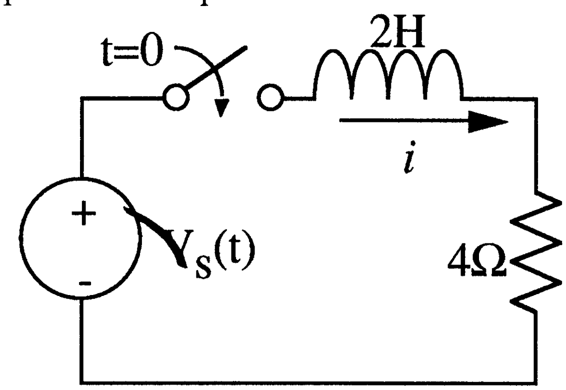
3. Fuses are used to open a circuit when excessive current flows (Wright, 1990). One fuse is designed to open when the power absorbed by R exceeds 10 watts for 0.5 seconds. The source represents the turn on condition for the load where $v_S=A[u(t)-u(t-0.75)]$. Assume that $i_L(0^-)=0$. The goal is to achieve the maximum current while not opening the fuse. Determine an appropriate value of A and sketch the current waveform. The circuit is shown below.

Extra credit problems:



D p9-10

4. An RL circuit as shown below is used to provide an actuating pulse for a laser. The circuit is at steady state at $t=0^-$ and $i(0^-)=0$. The voltage source $v_s=V_0e^{-bt}$ volts is connected at t=0. Select V_0 and b so that the peak magnitude of the current pulse is greater than 0.6 A. Determine i(t) and plot the current pulse.



References:

Garnett, G.H., "A High-Resolution, Multichannel Digital-to-Analog Converter," *Hewlett-Packard Journal,* February 1992, pp.48-52.

Gould, Larry A., "Electronic Valve Timing," *Automotive Engineering*, April 1991, pp.19-24.

Wright, A., "Construction and Application of Electric Fuses," *Power Engineering Journal,* Vol.4, No.3, 1990, pp.141-148.

3/31/93

Extra Credit Problems

Kai-Hsiung Hsu

304-13-4787

Kai-Hsiung Hsu

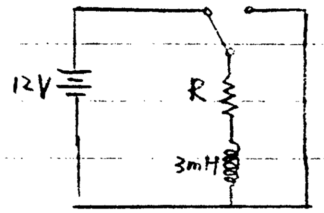
304-13-4787

Extra Credit Problems:

A

1.

(1)

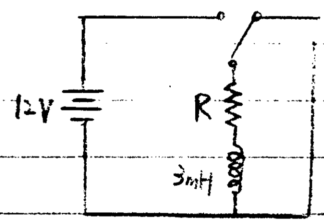


$$12 = i(t)R + L\frac{di(t)}{dt}$$

$$i(t) = \frac{12}{R}(1 - e^{-t/\tau}) \qquad \tau = \frac{L}{R} = \frac{0.3m}{R}$$

when $t = 1ms$, $\quad 0.3 \le \frac{12}{R}(1 - e^{-R/3})$

$$\Longrightarrow R \le 40\Omega$$



$$0 = i(t)R + L\frac{di(t)}{dt}$$

$$i(t) = \frac{12}{R}(1 - e^{-R/3})\, e^{-t/\tau} \qquad \tau = \frac{L}{R} = \frac{0.3m}{R}$$

$$\cong \frac{12}{R} e^{-t/\tau}$$

when $t = 0.2ms$, $\quad 0.225 \ge \frac{12}{R} e^{-0.2R/3}$

$$\Longrightarrow R > 17\Omega$$

$$\Longrightarrow \underline{\underline{R_{max} = 40\Omega}}$$

(2) With $R = 40$ $\qquad i_{max} = i(\infty) = \frac{12}{40}(1 - e^{-\infty}) = \underline{300\ mA}$

(3) 25% of 1ms = 0.25ms

$$P_{AVG} = \left[\int_0^{0.25m} (0.3)(1 - e^{-\frac{40t}{30m}}) * (12)\,dt\right] / 0.25m$$

$$= (3.6 * \frac{m}{40} * 2.107) / 0.25m$$

$$= \underline{2.56 \text{ watts}}$$

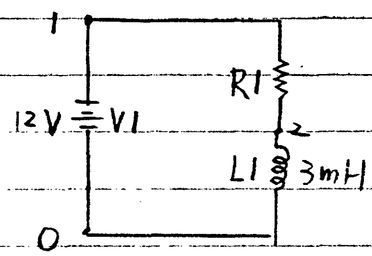
(4) Assumptions: $\underline{i_L(0^-) = 0}$ when charged

$$i_L(1ms) = \frac{12}{R}(1 - e^{-R/3}) \cong \underline{\frac{12}{R}} \text{ when discharge}$$

(see the graph of I(L1) vs. Time)

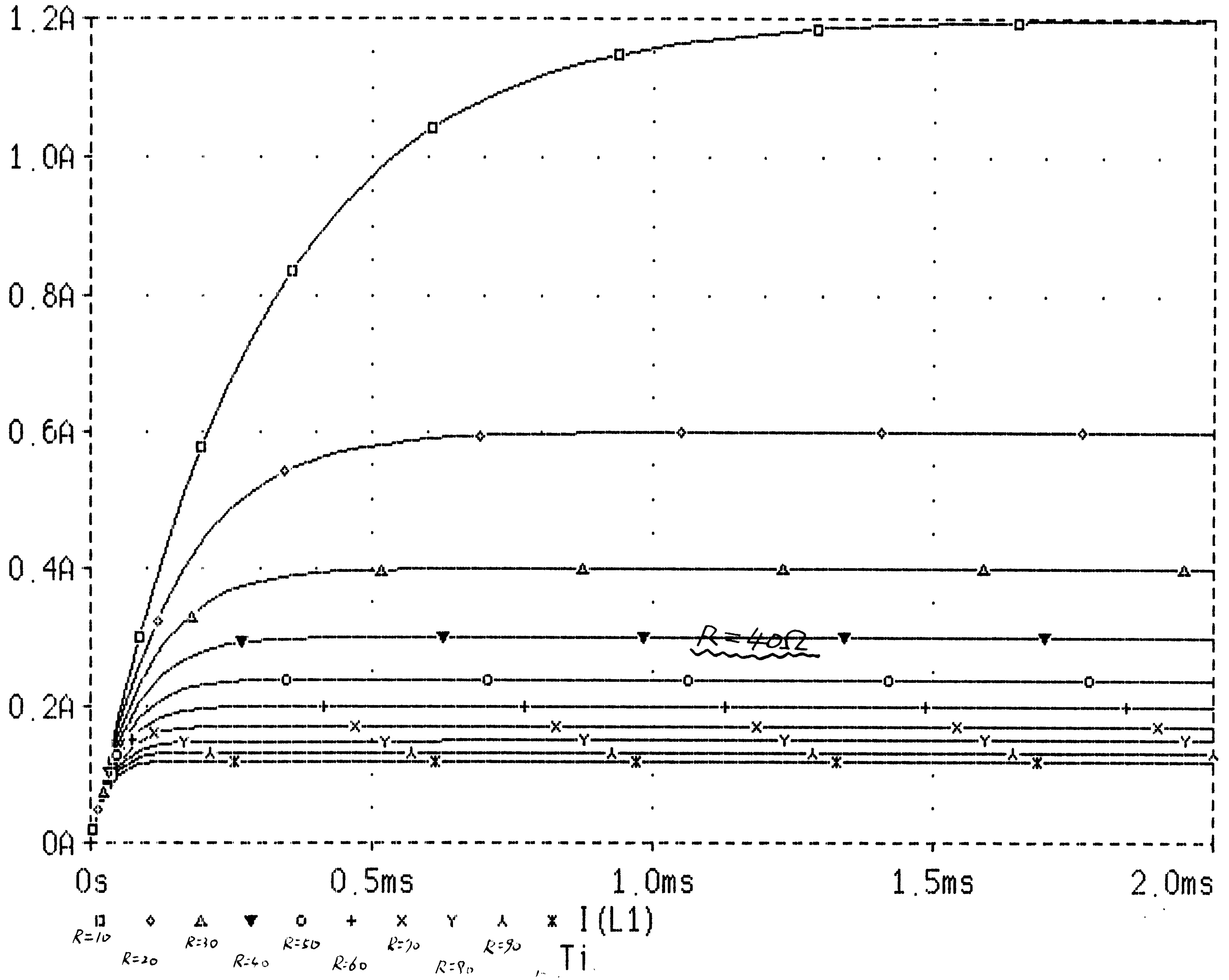
EXTRA CREDIT (1)

```
V1      1      0      DC       12
R1      1      2      RMOD     1
L1      2      0      3m       IC=0
.MODEL  RMOD   RES(R=1)
.STEP   LIN    RES    RMOD(R)  10     100     10
.TRAN   2m     2m     UIC
.END
```



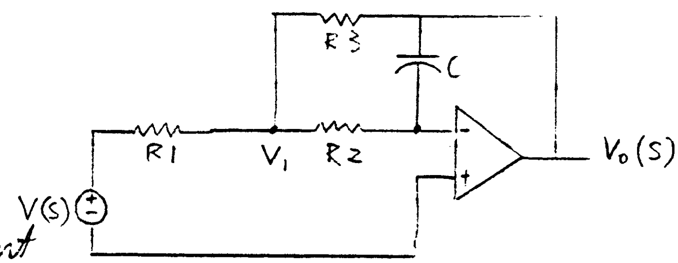
EXTRA CREDIT (1)

Date/Time run: 03/20/93 18:17:59 Temperature: 27.0



2. B

Very nice, but where are the computations for 1) $\overline{s}$-domain input impedance?



First, we assume the op-amp is ideal, and that can get an approximation.

$$\begin{cases} \dfrac{V_1 - V}{R1} + \dfrac{V_1 - V_o}{R_3} + \dfrac{V_1 - 0}{R_2} = 0 \quad \cdots (1) \\ \dfrac{V_1}{R_2} + \dfrac{V_o}{\frac{1}{CS}} = 0 \quad \cdots (2) \end{cases}$$

$$\text{eq. (1)} \Rightarrow V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V}{R_1} - \frac{V_o}{R_3} = 0$$

$$\text{eq. (2)} \Rightarrow V_1 = -V_o R_2 CS$$

$$\Longrightarrow \frac{-(R_1R_2 + R_2R_3 + R_3R_1) V_o R_2 CS - V_o R_1 R_2}{R_1 R_2 R_3} = \frac{V}{R_1}$$

$$\Longrightarrow \checkmark \ \frac{V_o}{V} = -\frac{R_3}{R_1 + C(R_1R_2 + R_2R_3 + R_3R_1)S}$$

So we can get a transfer function $\dfrac{V_o(S)}{V(S)} = -\dfrac{b}{S + a}$

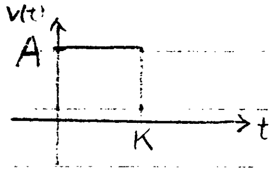
$$a = \frac{R_1}{C(R_1R_2 + R_2R_3 + R_3R_1)}, \quad b = \frac{R_3}{C(R_1R_2 + R_2R_3 + R_3R_1)}$$

in time-domain $-\dfrac{b}{S+a} \Longrightarrow -be^{-at}$

That is, output $V_o(t)$ will be smoother than input $V(t)$ under the influence of e^{-at}

Next, I will use a example for explanation.

We choose input $v(t) = A\,[u(t) - u(t-K)]$



$$\Rightarrow v(s) = A\left[\frac{1}{s} - \frac{e^{-Ks}}{s}\right]$$

$$V_o(s) = \frac{V_o(s)}{V(s)}\,V(s) = \frac{-b}{s+a}\,A\left[\frac{1}{s} - \frac{e^{-Ks}}{s}\right]$$

$$= \frac{Ab\,e^{-Ks}}{s(s+a)} - \frac{Ab}{s(s+a)}$$

$$= \frac{Ab\,e^{-Ks}}{a}\left(\frac{1}{s} - \frac{1}{s+a}\right) - \frac{Ab}{a}\left(\frac{1}{s} - \frac{1}{s+a}\right)$$

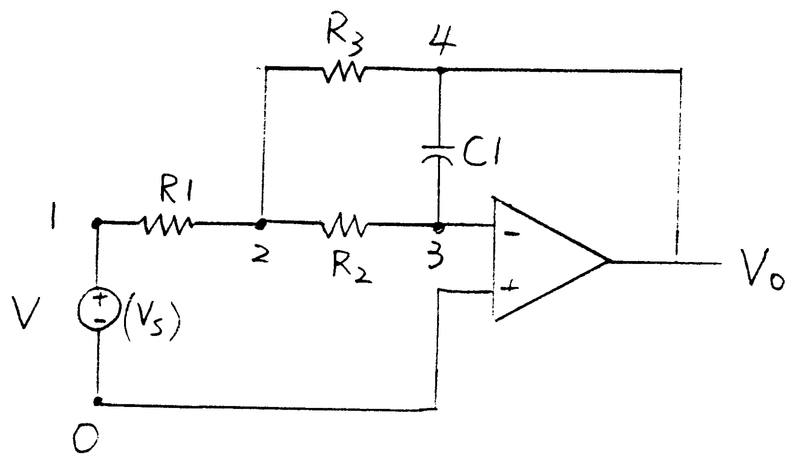
$$= \frac{AR_3\,e^{-Ks}}{R_1}\left(\frac{1}{s} - \frac{1}{s+a}\right) - \frac{AR_3}{R_1}\left(\frac{1}{s} - \frac{1}{s+a}\right)$$

$$\Rightarrow V_o(t) = \frac{AR_3}{R_1}\left[u(t-K) - e^{-at}u(t-K)\right] - \frac{AR_3}{R_1}\left[u(t) - e^{-at}u(t)\right]$$

Now, we use PSpice to simulate a pulse input in that circuit and we will get a smoother output.

EXTRA CREDIT (2)

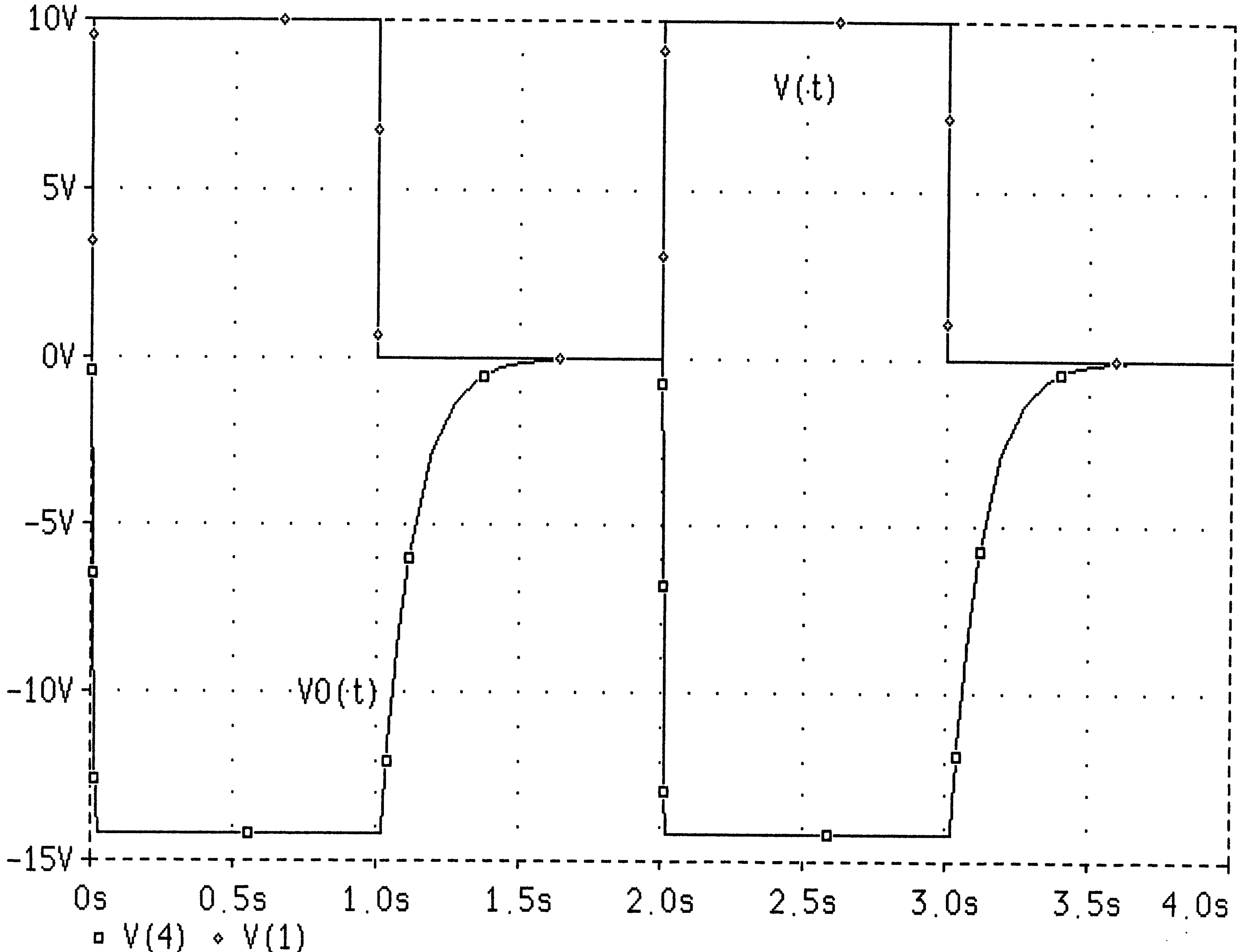
```
VS     1    0    PULSE (0  10  0  1m  1m  1  2)
R1     1    2    1K
R2     2    3    100K
R3     2    4    10K
C1     4    3    1E-7
V1     5    0    DC    15
V2     6    0    DC    -15
X1     0    3    5     6    4    LF411 (or µA741)
.LIB   EVAL.LIB
.TRAN       4    4
.END
```



EXTRA CREDIT (2)

Date/Time run: 03/24/93 20:20:03

Temperature: 27.0

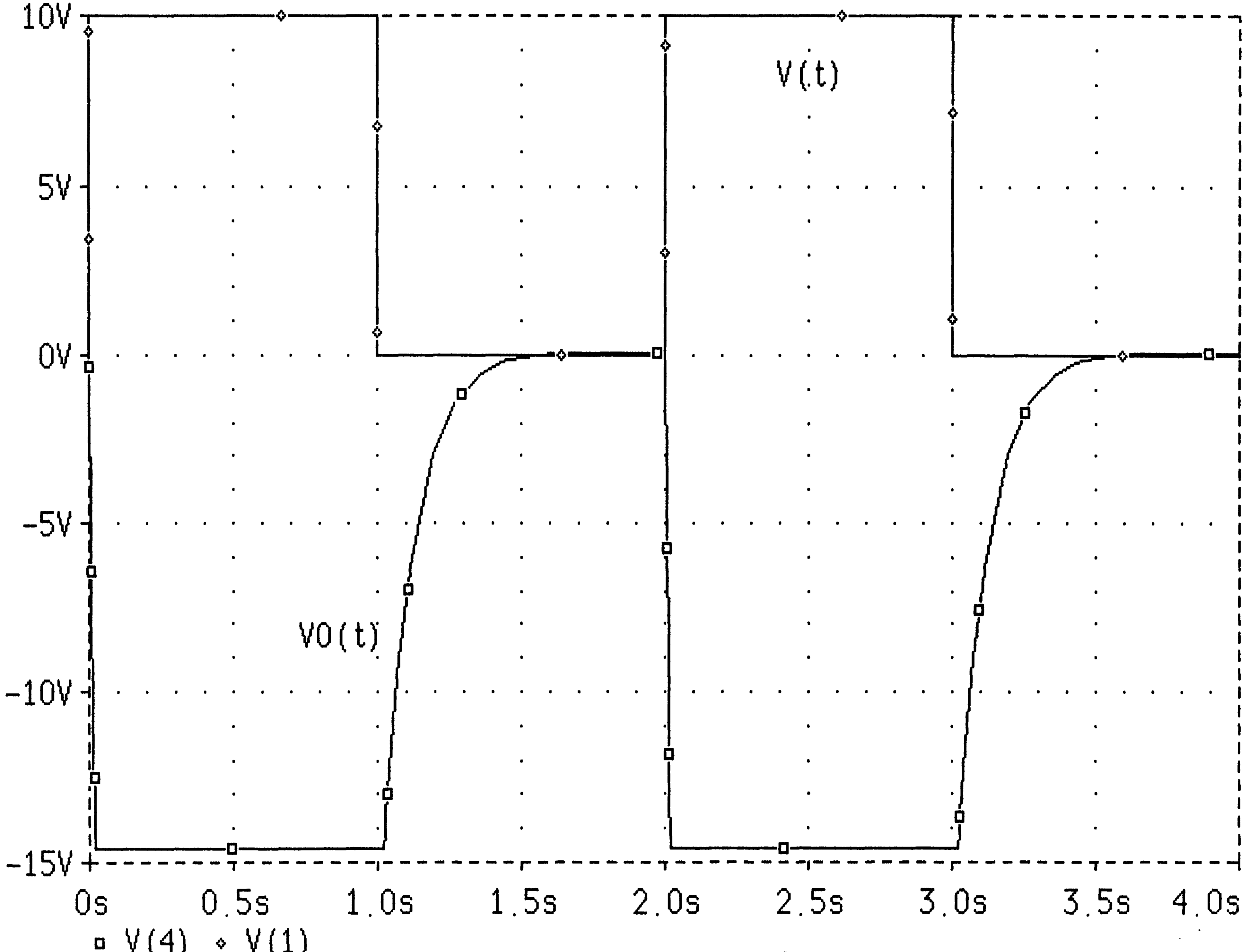


Ti

Op-Amp : LF411

EXTRA CREDIT (2)

Date/Time run: 03/24/93 20:22:41 Temperature: 27.0



Ti

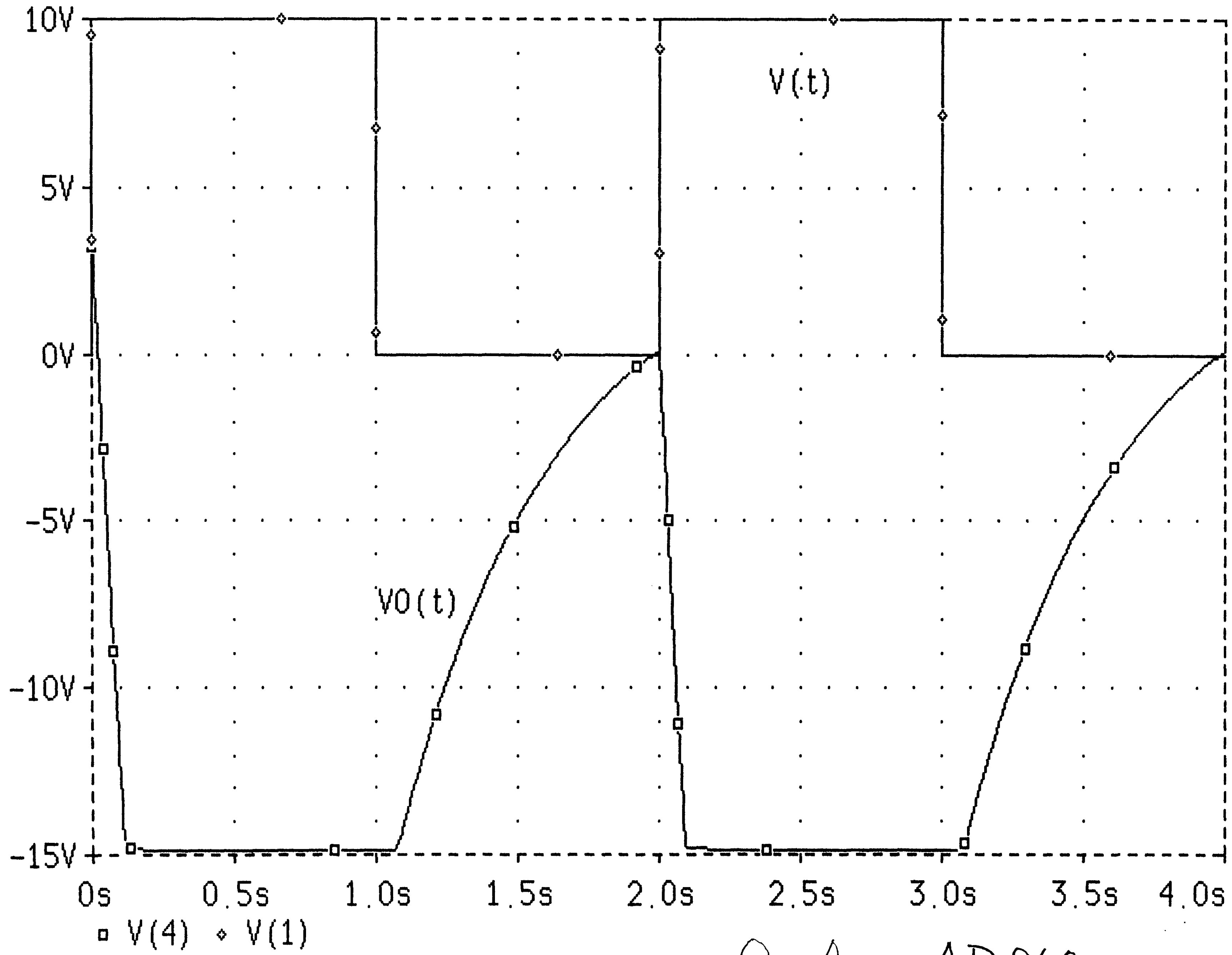
Op-Amp : μA741

```
EXTRA CREDIT (2)
VS      1       0       PULSE   (0  10  0   1m  1m  1  2)
R1      1       2       1K
F       2       3       100K
R3      2       4       10K
C1      4       3       5E-7
V1      5       0       DC      15
V2      6       0       DC      -15

.SUBCKT AD847   1 2 99 50 30
*
* INPUT STAGE & POLE AT 300 MHZ
*
R1   2  3     5E11
R2   1  3     5E11
R3   5 99     443
R4   6 99     443
CIN  1  2     1.5E-12
C2   5  6     0.599E-12
I1   4  50    2.22E-3
IOS  1  2     25E-9
EOS  9  1     POLY(1)  19 23  0.5E-3  1
Q1   5  2 10  QX
Q2   6  9 11  QX
R5   10 4     419.8
R6   11 4     419.8
*
EREF 98 0     23  0  1
*
:  AIN STAGE & DOMINANT POLE AT 8.8 KHZ
R7  12 98     2.44E6
C3  12 98     7.4E-12
G1  98 12     5  6  2.25E-3
V2  99 13     0.8
V3  14 50     0.8
D3  12 13     DX
D4  14 12     DX
*
* ZERO/POLE PAIR AT 70MHz/200MHz
*
R8  15 16     1E6
R9  16 98     1.86E6
L1  16 98     1.48E-3
G2  98 15     12 23  1E-6
*
* POLE AT 300 MHZ
*
R41 41 98     1E6
C41 41 98     531E-18
G41 98 41     15 23  1E-6
*
* POLE AT 300 MHZ
*
R42 42 98     1E6
C   42 98     531E-18
G42 98 42     41 23  1E-6
```

```
*
  'OLE AT 400 MHZ
*
R43 43 98       1E6
C43 43 98       398E-18
G43 98 43       42 23  1E-6
*
* COMMON-MODE GAIN NETWORK WITH ZERO AT 40 kHZ
*
R11 18 19       1E6
C6  18 19       3.98E-12
R12 19 98       1
E2  18 98       3  23  17.8
*
* POLE AT 400 MHZ
*
R15 22 98       1E6
C8  22 98       398E-18
G3  98 22       43 23  1E-6
*
* OUTPUT STAGE
*
RF  30 60       500
CF  60 12       12.5p
R16 23 99       100k
R17 23 50       100k
ISY 99 50       2.95E-3
    25 99       90
R19 25 50       90
L2  25 30       3E-8
G4  28 50       22 25  11.11E-3
G5  29 50       25 22  11.11E-3
G6  25 99       99 22  11.11E-3
G7  50 25       22 50  11.11E-3
V4  26 25       0.8
V5  25 27       0.8
D5  22 26       DX
D6  27 22       DX
D7  99 28       DX
D8  99 29       DX
D9  50 28       DY
D10 50 29       DY
*
* MODELS USED
*
.MODEL QX NPN(BF=336)
.MODEL DX   D(IS=1E-15)
.MODEL DY   D(IS=1E-15 BV=50)
.ENDS   AD847

X1      0       3       5       6       4       AD847
.TRAN   4       4
  'D
```

EXTRA CREDIT (2)

Date/Time run: 03/24/93 20:35:20 Temperature: 27.0



Ti

Op-Amp : AD847

3. $V_s(t) = i(t) * 1 + i(t) * 2 + L\frac{di(t)}{dt}$

A

Laplace Transform

$$A\left(\frac{1}{s} - \frac{e^{-0.75s}}{s}\right) = I(s) + 2I(s) + L(sI(s) - 0)$$

$$I(s) = \frac{A(1-e^{-3/4\,s})}{(0.2s+3)s} = \frac{5A(1-e^{-3/4\,s})}{(s+15)s}$$

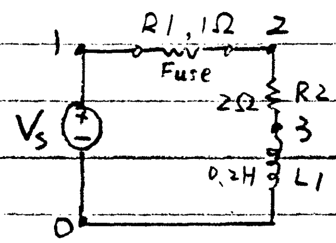
$$= \frac{A}{3}\left[\left(\frac{1}{s} - \frac{e^{-3/4\,s}}{s}\right) - \left(\frac{1}{s+15} - \frac{e^{-3/4(s+15)}\,e^{45/4}}{s+15}\right)\right]$$

$$\Rightarrow i(t) = \frac{A}{3}\left[\left(u(t) - u(t-0.75)\right) - \left(e^{-15t}u(t) - e^{-15(t-0.75)}u(t-0.75)\right)\right]$$

$$= \frac{A}{3}\left[(1-e^{-15t})u(t) - (1-e^{-15(t-0.75)})u(t-0.75)\right]$$

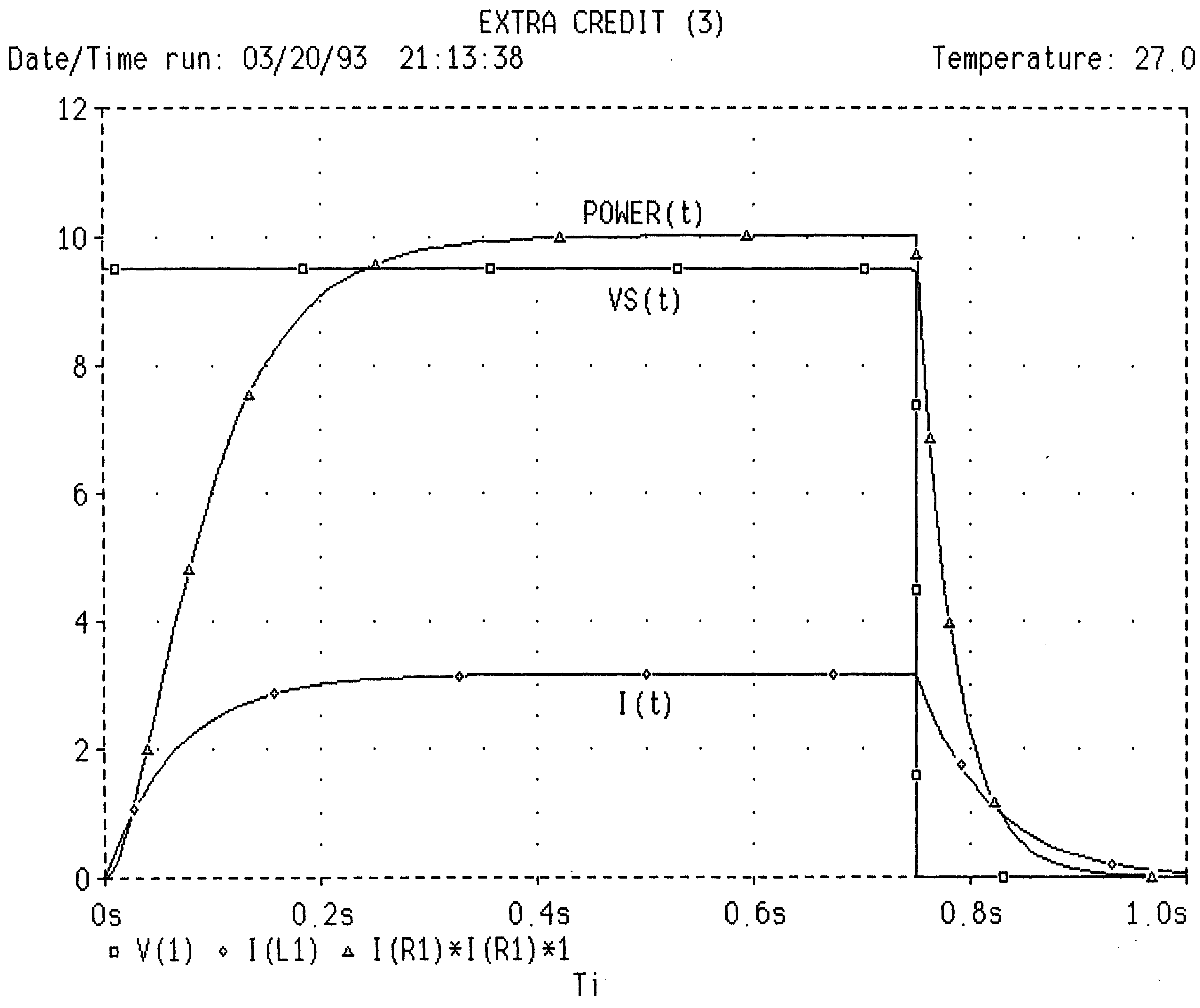
PSPICE Program

```
Vs  1  0  PWL(0 9.5 0.75 9.5 0.75000001 0 10 0)
R1  1  2  1
R2  2  3  2
L1  3  0  0.2  IC=0
.TRAN  1  1  UIC
.PROBE
.END
```



$P = I(R1) * I(R1) * 1$

$P \geq 10$ watts for 0.5 seconds when $\underline{A = 9.5}$


EXTRA CREDIT (3)
Date/Time run: 03/20/93 21:13:38
Temperature: 27.0
12
10
8
6
4
2
0
POWER(t)
VS(t)
I(t)
0s
0.2s
0.4s
0.6s
0.8s
1.0s
V(1) I(L1) I(R1)*I(R1)*1
Ti

4. $V_s = V_0 e^{-bt} = L\frac{di}{dt} + iR \qquad L = 2H \ , \ R = 4\Omega$

A

Laplace Transform

$$\frac{V_0}{S+b} = LS\,I(s) + 4\,I(s)$$

$$I(s) = \frac{V_0}{(2S+4)(S+b)} = \frac{V_0}{2}\left(\frac{1}{(S+b)(S+2)}\right)$$

$$= \frac{V_0}{2(2-b)}\left(\frac{1}{S+b} - \frac{1}{S+2}\right)$$

$$\Longrightarrow I(t) = \frac{V_0}{2(2-b)}\left[e^{-bt} - e^{-2t}\right]$$

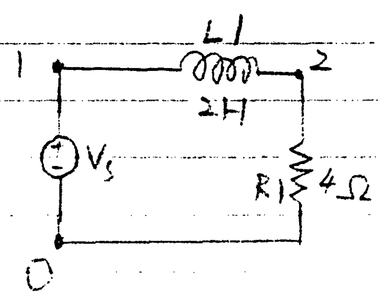
PSPICE Program

V_0 b^{-1}

```
VS   1   0   EXP(0  130  0  1n  1u  10m)
L1   1   2   2      IC=0
R1   2   0   4
.TRAN   100   100   UIC
.END
```

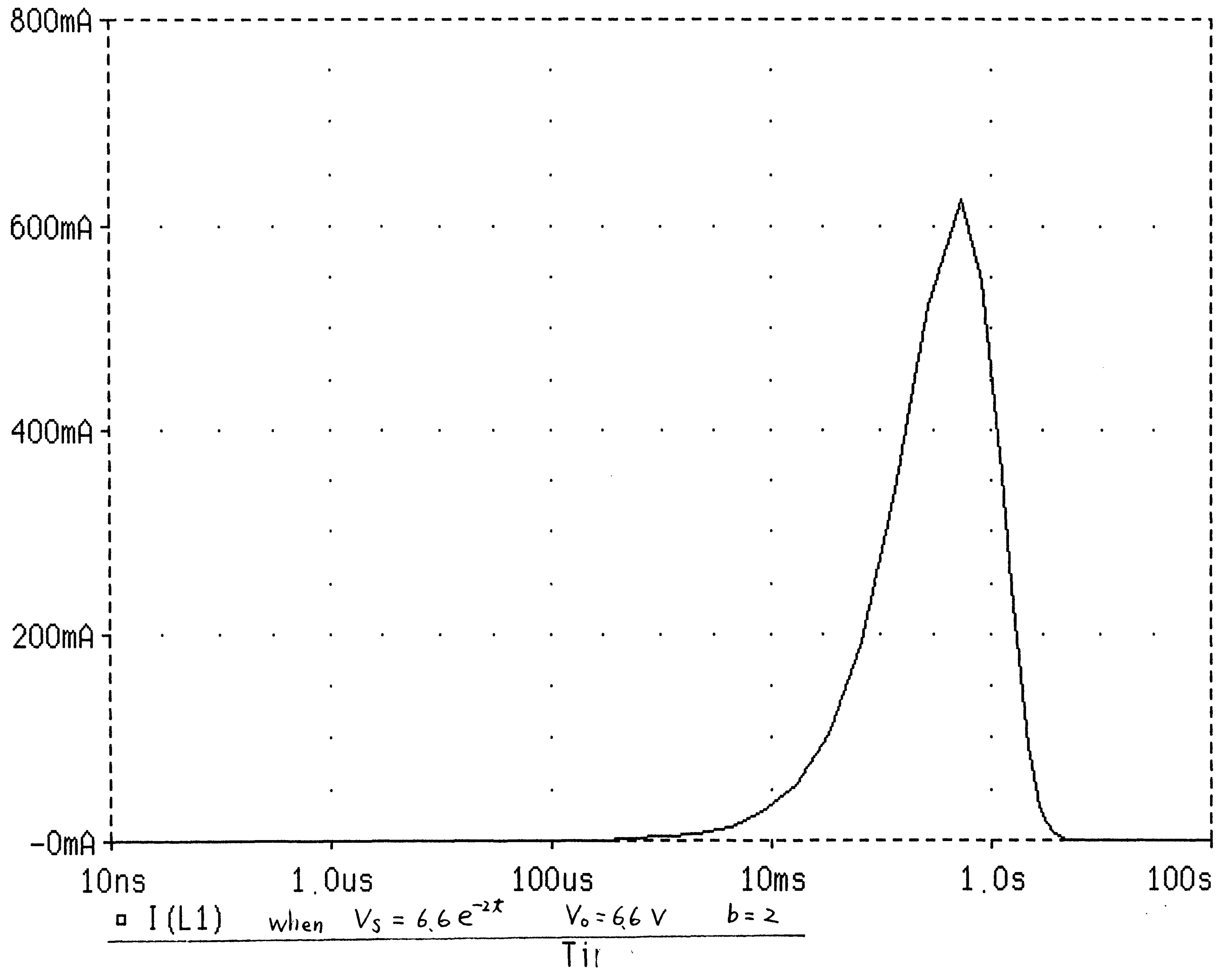
Trying different values of V_0 and b

	V_0(volts)	$b(S^{-1})$	b^{-1}(ms)	I_{max}(mA)
1	4.8	1	1000	≈ 600
2	6.6	2	500	≈ 600
3	18	10	100	≈ 600
4	130	100	10	≈ 600



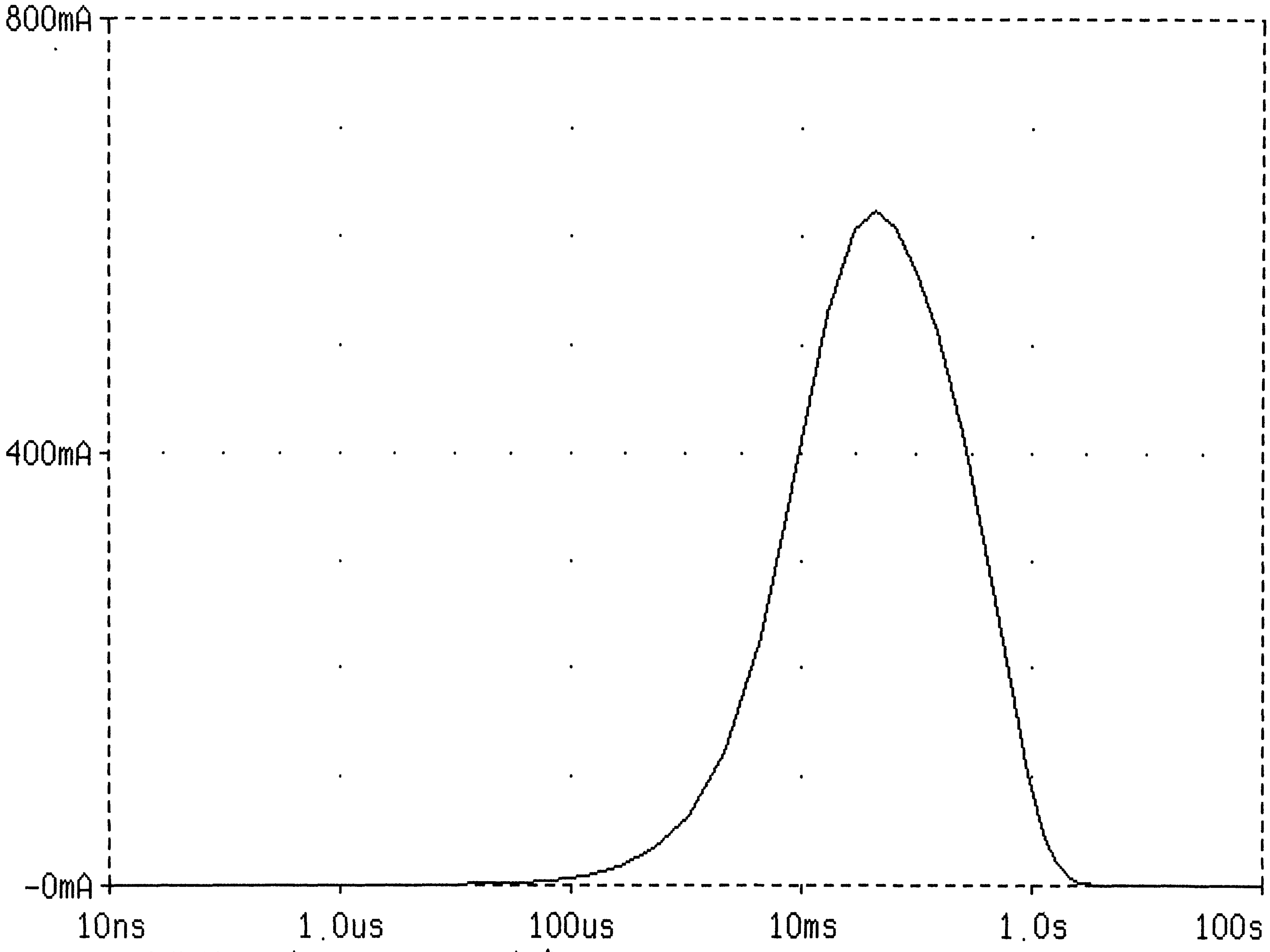
EXTRA CREDIT (4)

Date/Time run: 03/20/93 20:53:19 Temperature: 27.0



EXTRA CREDIT (4)

Date/Time run: 03/20/93 20:47:25 Temperature: 27.0

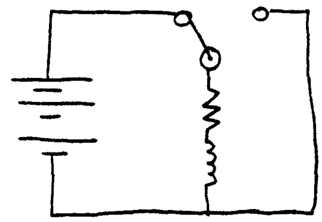


□ I(L1) when $V_s = 130\, e^{-100t}$ $V_0 = 130\, V$ $b = 100$

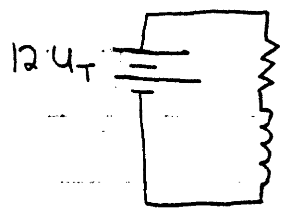
Tir

Jackson Harvey
EEAP 244
Extra Credit
3/31/93

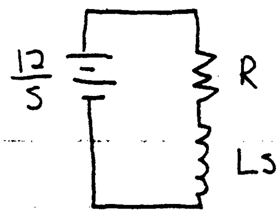
1)



A-



$\rightarrow$



$$\frac{12}{s} - IR - ILs = 0$$

$$I(s) = 12/Ls^2 + Rs = \frac{A}{s} + \frac{B}{Ls+R}$$

$$AL + B = 0$$

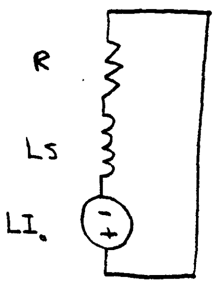
$$RA = 12 \qquad A = \frac{12}{R} \qquad B = \frac{-12L}{R}$$

$$I(s) = \frac{12/R}{s} - \frac{12L/R}{Ls+R} = \frac{12/R}{s} - \frac{12/R}{s+(R/L)}$$

$$i(t) = \frac{12}{R} - \frac{12}{R}e^{-R/Lt} = \frac{12}{R}\left(1 - e^{-R/Lt}\right)$$

$$.3 \leq \frac{12}{R}\left(1 - e^{-.33R}\right)$$

$$R < 40$$



$$LI_0 - ILs - IR = 0$$

$$I = LI_0/Ls+R = I_0 \frac{1}{s+R/L}$$

$$i(t) = I_0 e^{-R/Lt}$$

$$.225 \geq I_0 e^{-.067R}$$

$$R \geq (\ln(.225/I_0))/-.067$$

$$R \geq 4.32\ \Omega$$

I am assuming that the switch switches when the solenoid reaches it's definite on current. Both this assumption and the assumption that the switch is thrown at some later unname time are equally well supported by the assignment wording.

The maximum resistance is therefore $40\,\Omega$.

The maximum current is $.3A = \frac{12}{40}$

Average current is $.075A$ — Please show ~~[illegible]~~ solution in. ~~[illegible]~~ it Integrate $i(t)$, and divide by period

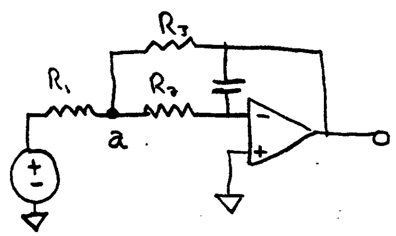
Average Power $= i^2R = (.075)^2\,40 = .225\,W$

The assumptions were that charge and discharge times are so short that the power dissipated during them is negligible.

Note: Results show that the assumption made earlier makes no difference, either circuit operation yields the same answer.

The reason that the inductor should not be open circuited is that the current cannot be changed instantaneously, or the voltage will increase drastically across the inductor, possibly causing much damage to the circuit.

2)



$$\frac{V_o - V_a}{R_3} - \frac{V_a}{R_2} - \frac{V_a - V_s}{R_1} = 0$$

$$V_o C s = -V_a / R_2$$

$$V_a = -V_o C R_2 s$$

$$\frac{V_o + V_o C R_2 s}{R_3} + \frac{V_o C R_2 s}{R_2} + \frac{V_o C R_2 s + V_s}{R_1} = 0$$

$$R_1 R_2 (V_o + V_o C R_2 s) + R_1 R_3 (V_o C R_2 s) + R_2 R_3 (V_o C R_2 s + V_s) = 0$$

$$R_1 R_2 V_o + C R_1 R_2^2 s\, V_o + R_1 R_2 R_3 C s\, V_o + R_2^2 R_3 C s\, V_o + R_2 R_3 V_s = 0$$

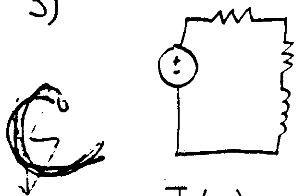
$$V_o (R_1 R_2 + C R_1 R_2^2 s + R_1 R_2 R_3 C s + R_2^2 R_3 C s) = -R_2 R_3 V_s$$

$$\frac{V_o(s)}{V(s)} = -\frac{R_3}{R_1 + C R_1 R_2 s + R_1 R_3 C s + R_2 R_3 C s} = -\frac{R_3}{R_1 + Cs(R_1 R_2 + R_1 R_3 + R_2 R_3}$$

2) cont.) Could Not Get AD847 Model to Run in PSPICE. I don't Know how to go about solving this problem with no values for R_1, R_2, R_3, and C_2. It seems to me that by choosing the correct values for these components any desired input impedance could be achieved. I am officially choosing the AD847 because a model that was so sure to cause problems would not have been included in the assignment for no reason. Also, it is at least possible that the AD stands for Analog - Digital, which bears some relation to our problem

Select them such that the desired impedance is achieved

3)



$$\frac{A}{s} - \frac{Ae^{-.75s}}{s} - I - 2I - .2sI = 0$$

$$I(3 + .2s) = A\left(\frac{1 - e^{-.75s}}{s}\right)$$

$$I(s) = A\,\frac{1 - e^{-.75s}}{s(3+.2s)} = A\,\frac{5}{s(s+15)} - \frac{5e^{-.75s}}{s(s+15)}$$

$$\frac{5}{s(s+15)} = \frac{A}{s} + \frac{B}{s+15} \qquad A = -B \qquad 15A = 5 \qquad A = \tfrac{1}{3} \quad B = -\tfrac{1}{3}$$

$$\mathcal{L}^{-1}\left\{\frac{1}{s(3+.2s)}\right\} = \frac{1}{3} - \frac{1}{3}e^{-15t}$$

$$i(t) = \frac{A}{3}\left(\left(1 - e^{-15t}\right)u_T - \left(1 - e^{-15(t-.75)}\right)u_{.75}\right)$$

There are two points at which $i(t) = 10$, one charging and one discharging.

~~First~~ Not a reasonable approach Think about it.

$$\frac{30}{A} = 1 - e^{-15t} \qquad\qquad \frac{30}{A} = e^{-15(t-.75)} - e^{-15t}$$

$$-\ln\left(1 - \frac{30}{A}\right)/15 = t_1 \qquad\qquad \frac{30}{A} = e^{-15t}\left(e^{11.25} - 1\right)$$

$$\frac{30}{A(e^{11.25}-1)} = e^{-15t}$$

$$t_2 = -\ln\left(\frac{30}{A(e^{11.25}-1)}\right)/15$$

Not consistent with this equation

We require that $t_2 - t_1 = .5$

$$\ln\left(\frac{30}{A(e^{11.25}-1)}\right) - \ln\left(1 - \frac{30}{A}\right) = -7.5$$

$$\ln\left(\frac{1 - \frac{30}{A}}{\frac{30}{A(e^{11.25}-1)}}\right) = 7.5 = \ln\left(\frac{A(e^{11.25}-1) - 30(e^{11.25}-1)}{30}\right) =$$

You can justify this approximation if you try, though

$$\ln\left(\left(\frac{A}{30} - 1\right)\left(e^{11.25} - 1\right)\right) = \ln\left(\frac{A}{30} - 1\right) + \ln\left(e^{11.25} - 1\right) = 7.5$$

$$\ln\left(\frac{A}{30} - 1\right) = -3.75$$

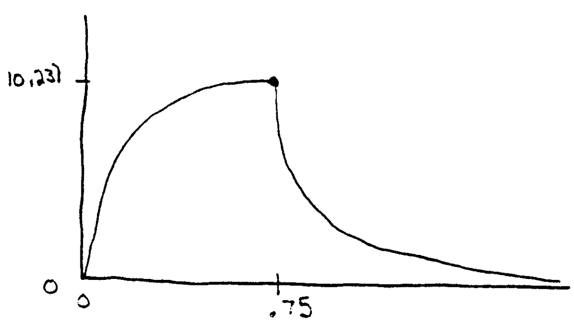
$$\frac{A}{30} - 1 = e^{-3.75}$$

$$A = 30\left(e^{-3.75} + 1\right) = 30.71$$

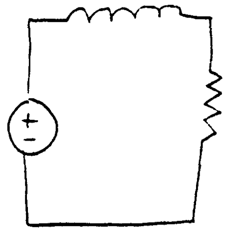
9.5 Nice try.

$t_1 = .2511s \qquad t_2 = .7516s \qquad t_2 - t_1 = .5005s \approx .5s$

$$i(t) = 10.237\left(1 - e^{-15t}\right)u_T - 10.237\left(1 - e^{-15(t-.75)}\right)u_{.75}$$



4)



$$\frac{V_0}{s+b} - 2Is - 4I = 0$$

$$I(s) = \left(\frac{V_0}{(s+b)(s+2)}\right)\frac{1}{2} = \left(\frac{A}{s+b} + \frac{B}{s+2}\right)\frac{1}{2}$$

$$A(s+2) + B(s+b) = \frac{V_0}{2} \qquad A + B = 0 \qquad A = -B$$

A

$$2A + Bb = \frac{V_0}{2} \qquad B = \frac{V_0}{2(b-2)} \qquad A = -\frac{V_0}{2(b-2)}$$

$$-\frac{2V_0}{2(b-2)} + \frac{bV_0}{2(b-2)} = \frac{V_0}{2}$$

$$i(t) = \frac{V_0}{2(b-2)}e^{-2t} - \frac{V_0}{2(b-2)}e^{-bt} = \frac{V_0}{2(b-2)}\left(e^{-2t} - e^{-bt}\right)$$

$$\frac{di}{dt} = -\frac{V_0}{b-2}e^{-2t} + \frac{V_0 b}{2(b-2)}e^{-bt} = \frac{V_0}{2(b-2)}\left(be^{-bt} - 2e^{-2t}\right)$$

$$\frac{di}{dt} = 0 = \frac{V_0}{2(b-2)}\left(be^{-bt} - 2e^{-2t}\right) \qquad be^{-bt} = 2e^{-2t}$$

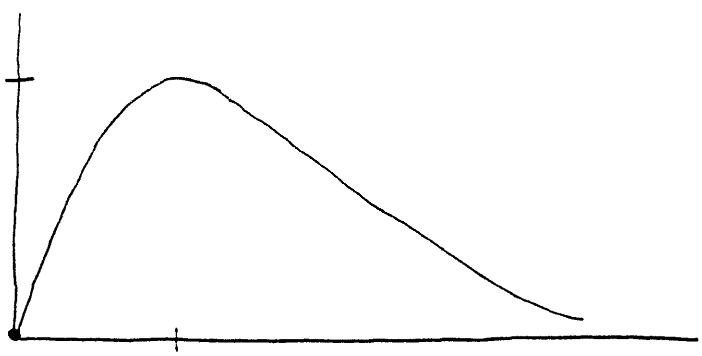
$$\ln\left(be^{-bt}\right) = \ln\left(2e^{-2t}\right) \qquad \ln b - bt = \ln 2 - 2t$$

$$\ln b - \ln 2 = (b-2)t \qquad t = \ln\tfrac{b}{2}/b-2 \qquad b = 3 \qquad t = \ln\tfrac{3}{2}$$

$$i(t) = \frac{V_0}{2(b-2)}\left(e^{-2t} - e^{-3t}\right) = \frac{V_0}{2}\left(e^{-2t} - e^{-3t}\right)$$

$$i\left(\ln\tfrac{3}{2}\right) = \frac{V_0}{2}\left(e^{-2\ln\frac{3}{2}} - e^{-3\ln\frac{3}{2}}\right) \geq 0.6$$

$$V_0(.44 - .2963) \geq 1.2 \qquad V_0 \geq 8.1$$



$$i(t) = 4.05\left(e^{-2t} - e^{-3t}\right)$$

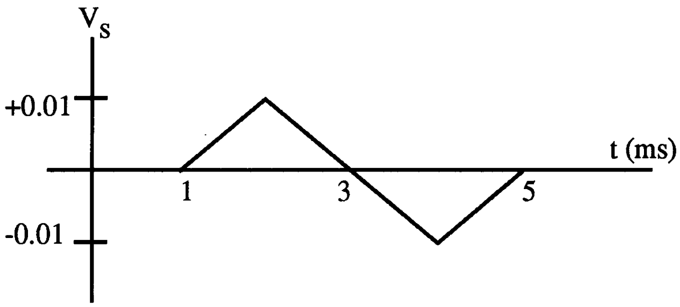
INS TCP/IP PrintServer 20

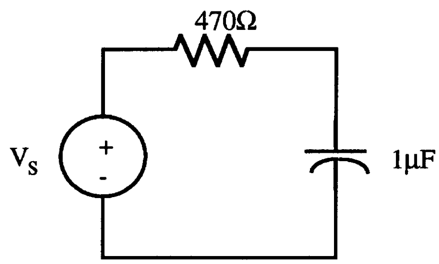
Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	101
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	Xcred_3.ps.733769471
Submitted at:	Fri Apr 2 11:59:57 19931993X
Printed at:	Fri Apr 2 11:59:59 1993

flm@util
Xcred_3.ps.733769471

Extra credit #3:   Due: April 2

4.6. Calculate by hand what the derivative of the sawtooth voltage source shown is (Hint: a pulsed source). Calculate the current response of the circuit to the pulsed source. Then use PSpice and Probe to demonstrate that the response to the derivative of the sawtooth source is equal to the derivative of the response to the sawtooth source. Use a small enough end_time in the .tran statement to show the matter clearly.





Solution:

```
Problem 4-6: sawtooth source
V10 1 0 pwl 1m,0 2m,10m 4m,-10m 5m,0
R12 1 2 470
C20 2 0 1u
.tran 10m 10m 0 100u
.probe
.end
Problem 4-6: pulse source
V10 1 0 pwl 1m,0 1.001m,10 2m,10 2.001m,-10 4m,-10 4.001m,10
5m,10 5.001m,0
R12 1 2 470
C20 2 0 1u
.tran 10m 10m 0 100u
.probe
.end
```

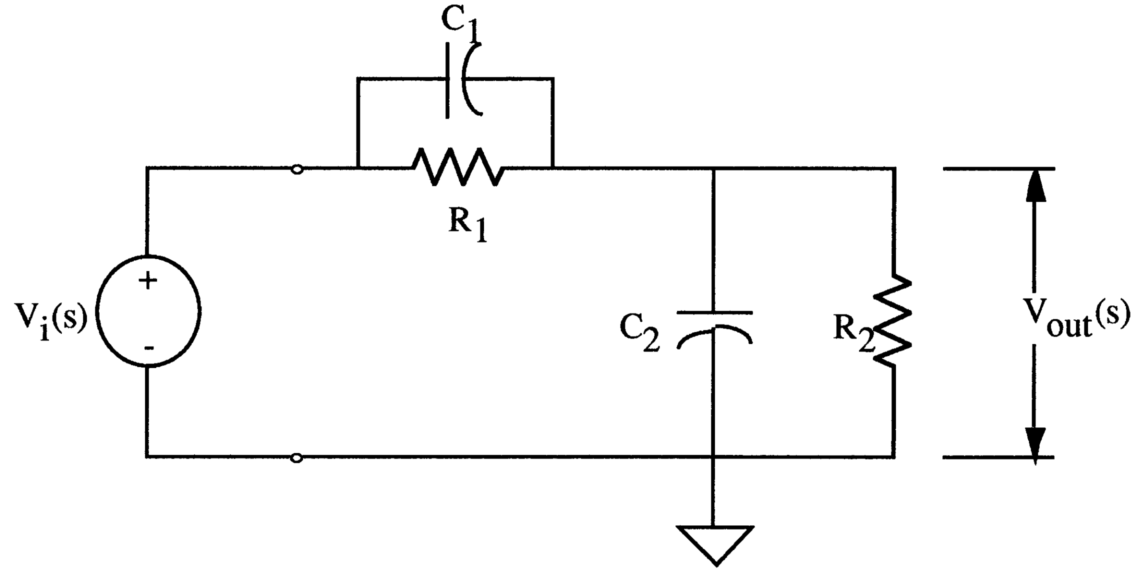
INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	86
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	xcred_4.ps.735168758
Submitted at:	Sun Apr 18 18:09:15 19939933X
Printed at:	Sun Apr 18 18:09:15 1993

flm@util
xcred_4.ps.735168758

Extra credit #4: Due: April 19th

1. The circuit shown below represents an oscilloscope probe connected to an oscilloscope. Components R_2 and C_2 represent the input circuitry of the oscilloscope, and R_1 and C_1 represent the probe. Use R_2=10MΩ and C_2=8pF for your analysis.

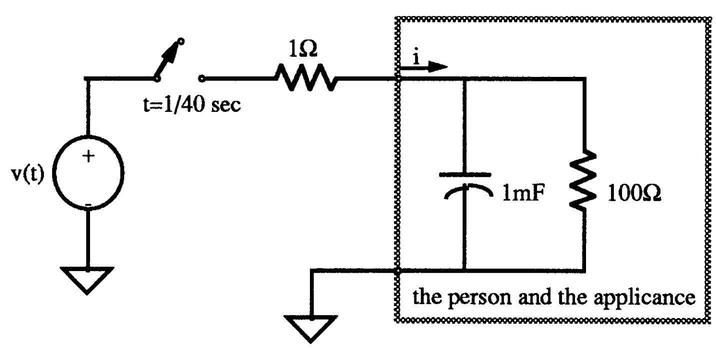


(a) Determine the transfer function $H(s)=V_{out}(s)/V_i(s)$.

(b) Determine $V_{out}(t)$ if R_1=2.5MΩ and C_1=2pF.

(c) Determine the required relationship (i.e., the values of R_1 and C_1) so that the step response (the output $V_{out}(t)$) is equal to the step input to within a gain constant. Is this physically possible?

2. All new homes are required to install a device called a ground fault circuit interrupter (GFCI) that will provide protection from shock. By monitoring the current going to and returning from a receptacle, a GFCI senses when normal flow is interrupted and switches off the power is 1/40-th of a second. This is particularly important if you are holding an applicance shorted through your body to ground. A circuit model of the GFCI acting to interrupt a short is shown below. Find the current flowing through the person, i(t), for t≥0 when the short is initiated at t=0. Assume v(t)=160cos400t and the capacitor is initially uncharged.



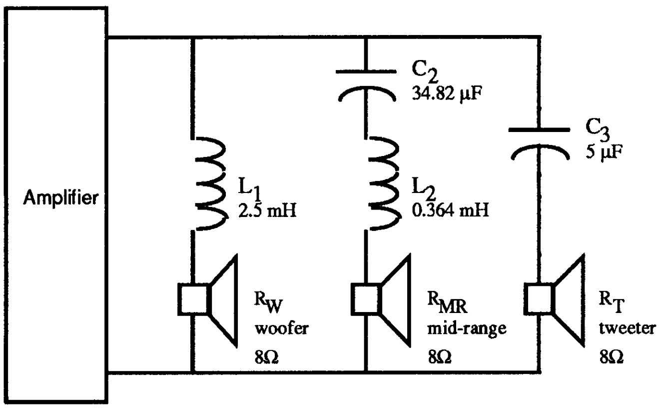
Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	86
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	xcred_5.ps.735168768
Submitted at:	Sun Apr 18 18:10:29 19939933X
Printed at:	Sun Apr 18 18:10:29 1993

flm@util
xcred_5.ps.735168768

Extra credit #5: Due: April 26

1. Frequently, audio systems contain two or more loudspeakers that are intended to handle different parts of the audio-frequency spectrum. In a three-way setup, one speaker, called a woofer, handles low frequencies. A second, the tweeter, handles high frequencies, while a third, the midrange, handles the middle range of the audio spectrum.

A three-way filter, called a crossover network, is used to split the audio signal into three bands of frequencies suitable for each speaker. There are many and varied designs. A simple one is based on series LR, CR, and resonant RLC circuits as shown in the Figure below. All speaker impedances are assumed to be resistive. The conditions are (1) woofer, at the crossover frequency: $X_{L1}=R_W$; (2) tweeter, at the crossover frequency $X_{C3}=R_T$; (3) midrange, components C_2, L_2 and R_{MR} form a series resonant circuit with upper and lower cutoff frequencies f_U and f_L, respectively. The resonant frequency = $(f_U f_L)^{1/2}$.

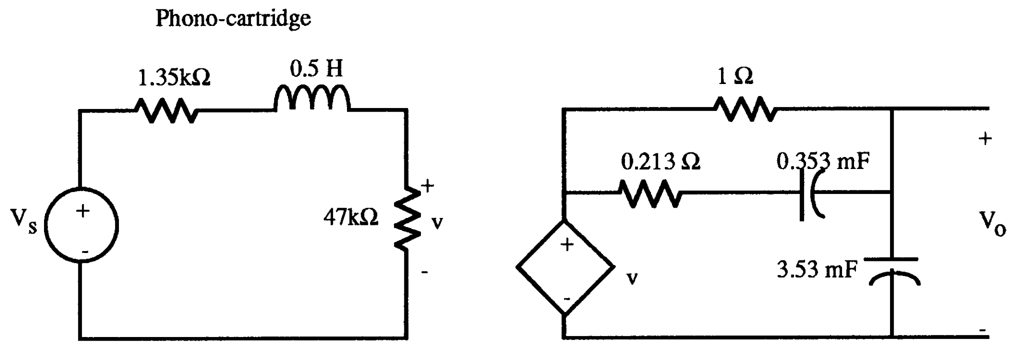


When all speaker resistances are 8Ω, determine the frequency response and determine the cutoff frequencies. Plot the Bode diagram for the three speakers. Determine the bandwidth of the midrange speaker section.

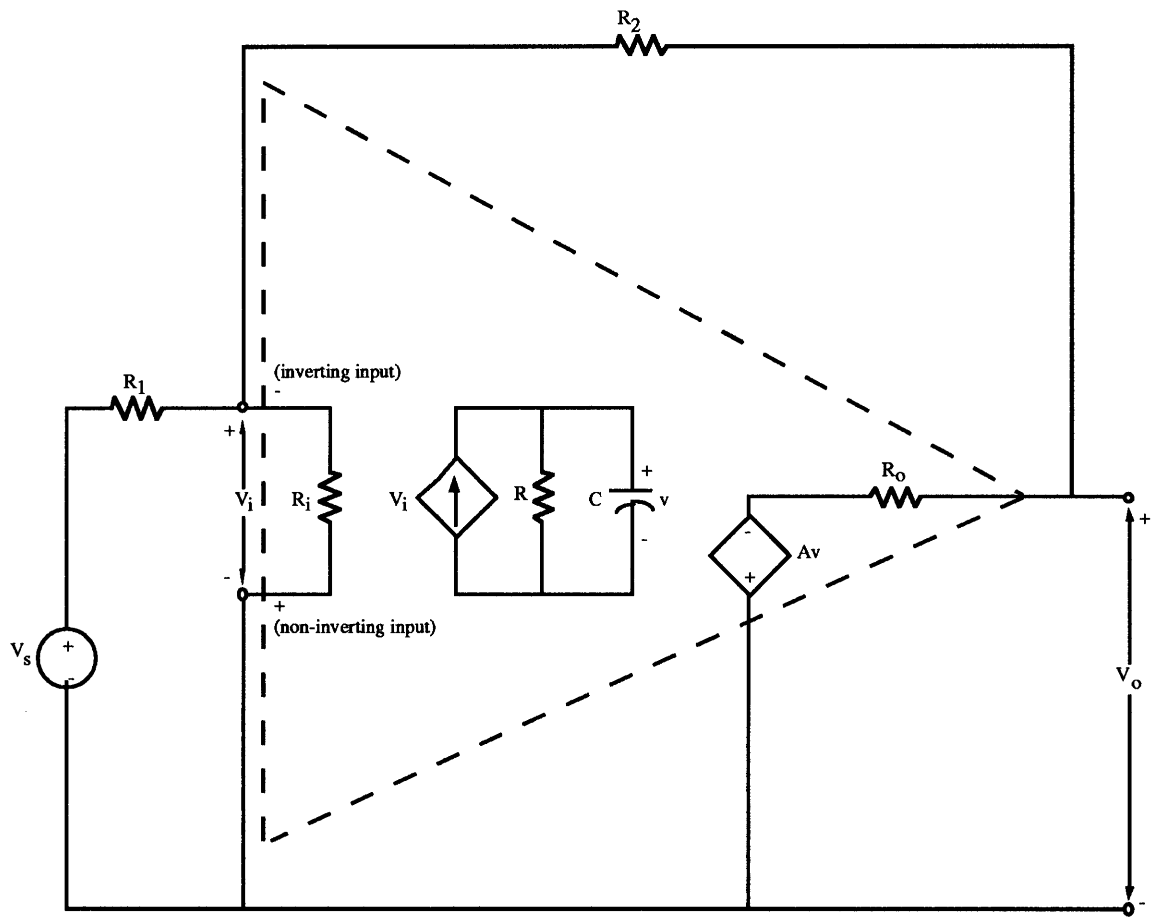
Notes: (1) X means reactance, i.e. an impedance that is entirely imaginary.
(2) You should do a Bode diagram for the voltage output across each speaker.
(3) This problem does not have to be done using PSpice.

2. Use PSpice to obtain the frequency response of the crossover network of problem 1 when all the speaker impedances are 8Ω, L_1=2.5mH, L_2=364µH, C_2=13.76µF, and C_3=5µF. Verify that the three speakers handle different parts of the audio-spectrum bandwidth. NOTE: This problem is almost the same as problem 1 but MUST be done with PSpice.

3. The model of an amplifier for a phonograph (an obsolete mode for stereo recordings) stereo is shown below. Plot the dB magnitude portion of the Bode diagram for V_o/V_s for 20 Hz to 20 kHz.

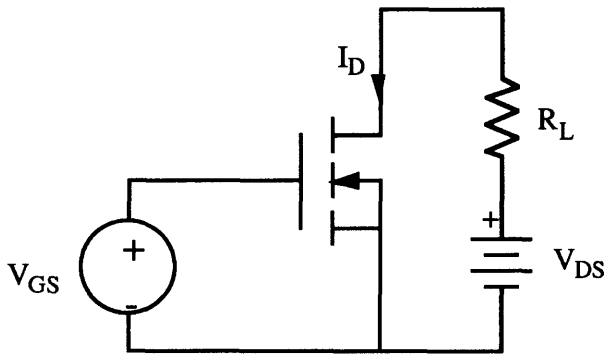


4. The frequency response of an actual op amp is dependent upon a gain A(jω) which is a function of frequency. One model of a frequency dependent op amp circuit is shown in the figure below, where R_1 and R_2 are used to establish an inverting amplifier with $R_2=10R_1$. Assume that the op amp has $R_i=1M\Omega$, $R_o=100\Omega$, and $A=10^6$ with R and C establishing the bandwidth of the op amp itself. The op-amp has a gain bandwidth product equal to $Af=10^9$ where f is the 3-dB bandwidth in Hz. Select the appropriate R and C to fit the model and use PSpice to obtain the Bode diagram for the circuit. Use a param statement to vary R2 to plot your results as shown below.



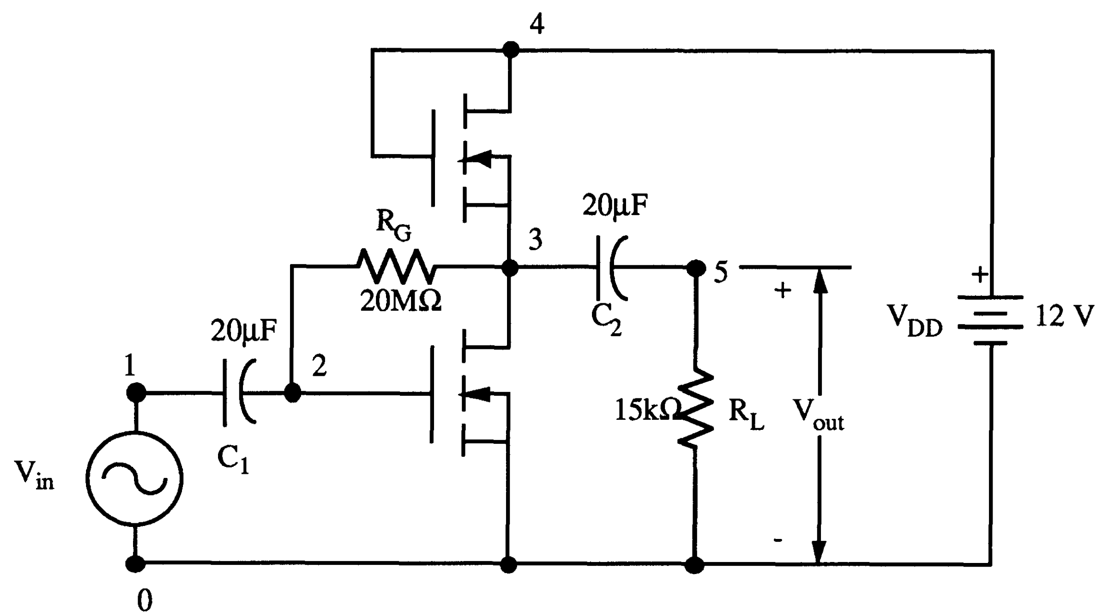
Extra credit #6: PSpice Due: May 4

1. For the 2N244 N-channel enhancement MOSFET in the circuit shown below plot the output characteristics if V_{DS} is varied from 0 to 15 volts in steps of 0.1 volt and V_{GS} is varied from 0 to 6 volts in steps of 1 volt. Use R_L=0 for this analysis so that you obtain the characteristics of the MOSFET only. You may change the plotting parameters, i.e. larger step sizes if you have difficulty plotting your results on a single graph.



Using your characteristic curves for the MOSFET, do a load line analysis to dtermine an appropriate R_L for using the above circuit as an amplifier. Plot the transfer characteristics of the circuit, i.e. I_D vs V_{GS} and V_{DS} vs. V_{GS}, for this value of R_L.

2. A MOSFET amplifier using the 2N245 N-channel enhancement MOSFET is shown below. Plot the magnitudes of the output voltage and the input current. The frequency is varied from 10 Hz to 100 MHz with a decade increment and 10 points per decade. The peak input voltage is 200 mV. Print the details of the bias point and the small-signal parameters of the MOSFET.



NOTES:

1. Do not use a .LIB command to reference your transistors. These are dummy transistors defined especially for this problem. Add the command

```
.MODEL M2N244  NMOS (L=10u W=20U VTO=2.5 KP=6.5E-3 RD=5
+ RS=2 RB=0 RG=0 RDS=1MEG)
```

to your program and refer to the transistor as M2N244

2. Similarily, for problem 2 add the following command and use the M2N245 in your PSpice commands.

```
.MODEL M2N245 NMOS (VTO=2.5 KP=4.5E-2 CBD=5PF CBS=2PF
+ RD=5 RS=2 RB=0 RG=0 RDS=1MEG CGSO=1PF CGDO=1PF
+ CGBO=1PF).
```

3. See your EVAL.LIB file for details. A MOSFET PSpice model has four electrical connections which are in order:

DRAIN GATE SOURCE BULK (SUBSTRATE)

4. A simple example of a MOSFET feedback amplifier analysis is:

```
*      Input voltage of 100 mV peak for frequency response
VIN    1      7      AC     100mV
VDD    8      0      15V
RS     1      2      250
C1     2      3      1UF
R1     8      3      1.4MEG
R2     3      0      1MEG
RD     8      4      15K
RS1    5      9      100
RS2    9      0      15K
CS     9      0      20uF
C2     4      6      0.1UF
R3     6      7      15K
R4     7      0      5K
RL     6      0      10K
*      MOSFET M1 with model MQ is connected to 4 (drain),
*      3 (gate), 5 (source) and 5 (substrate)
M1     4      3      5      5      MQ
*      MODEL FOR MQ
 .MODEL MQ NMOS (VTO=1 KP=6.5E-2 CBD=5PF CBS=2PF
+ RD=5 RS=2 RB=0 RG=0 RDS=1MEG CGSO=1PF CGDO=1PF
+ CGBO=1PF).
*      AC analysis for 10Hz to 100 MHz with a decade increment
*      and 10 points per decade
.AC    DEC    10     10HZ   100MHZ
*      Plot the results of ac analysis: voltage at node 6
.PLOT AC     VM(6)
*      DC Transfer characteristics
.TF    V(6)   VIN
*      Plot the details of DC operating point
.OP
.PROBE
.END
```