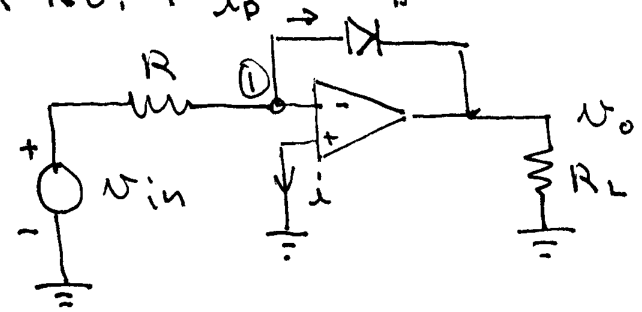
T.K. Gustafson Solutions Problem Set No 5 Oct 12, 2009

EECS 100/42

Problem No. 1



$$i_D = I_s e^{(v_D/nV_T)}$$

Ideal Op-Amp. $v_- = v_+ = 0$; $i = 0$

KCL at 1

$$\frac{v_{in}}{R} = i_D = I_s e^{v_D/nV_T}$$

$$= I_s e^{-v_o/nV_T} \quad \text{since}$$

$$v_D = -v_o$$

$$\therefore v_o = -\left\{\ln\left(\frac{i_D}{I_s}\right)\right\}(nV_T) = -\left(\ln \frac{v_{in}}{RI_s}\right) V_T n$$

Note v_o negative ($v_{in} > 0$)

$$= -(\ln v_{in})(V_T n) + (\ln RI_s) V_T$$

Thus $V_T n$ is the slope of the line

v_o versus $\ln v_{in}$

$R = 1k\Omega$ $\quad v_{in} = 60$ mV $\quad nV_T = 47.43$ mV

$v_o = -455$ mV

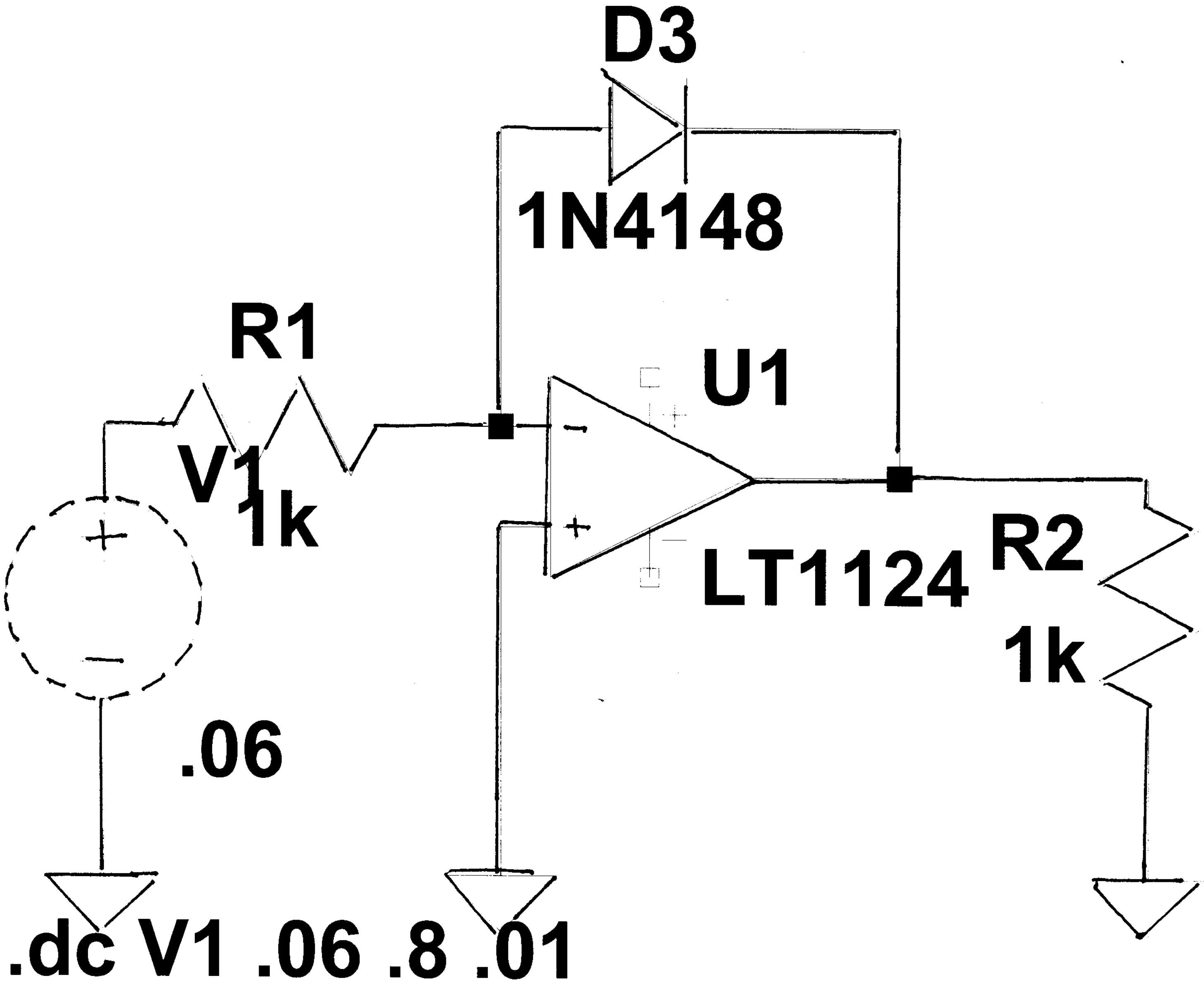
Thus $$-455 = -\left(\ln \frac{60}{10^3 I_s}\right) 47.43$$

$$\frac{10^3 I_s}{60} = e^{-455/47.43}$$

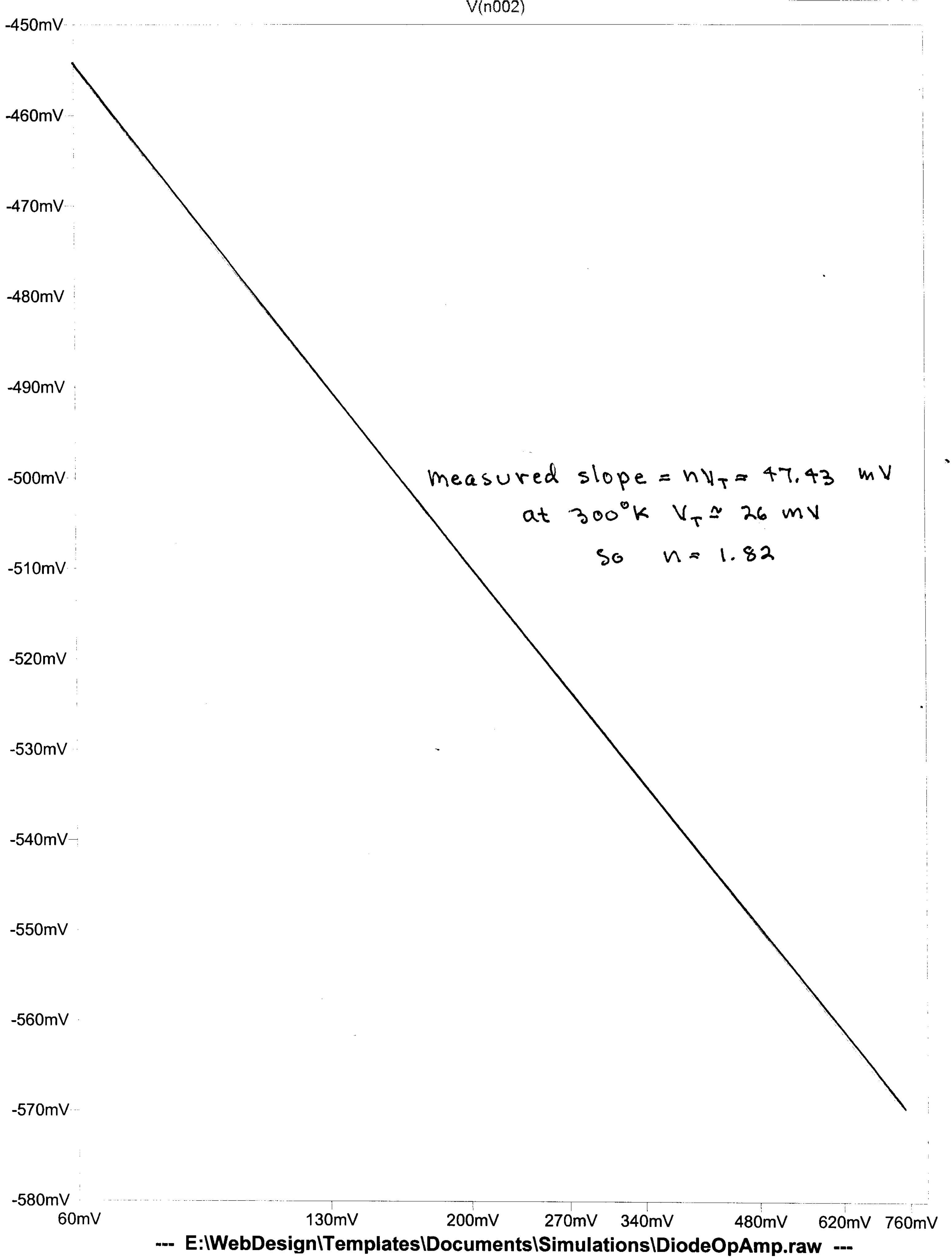
$$I_s = 6 \times 10^{-2} \times 6.8 \times 10^{-5} \text{ mA}$$

$$= 40.8 \times 10^{-11} \text{ Amps}$$

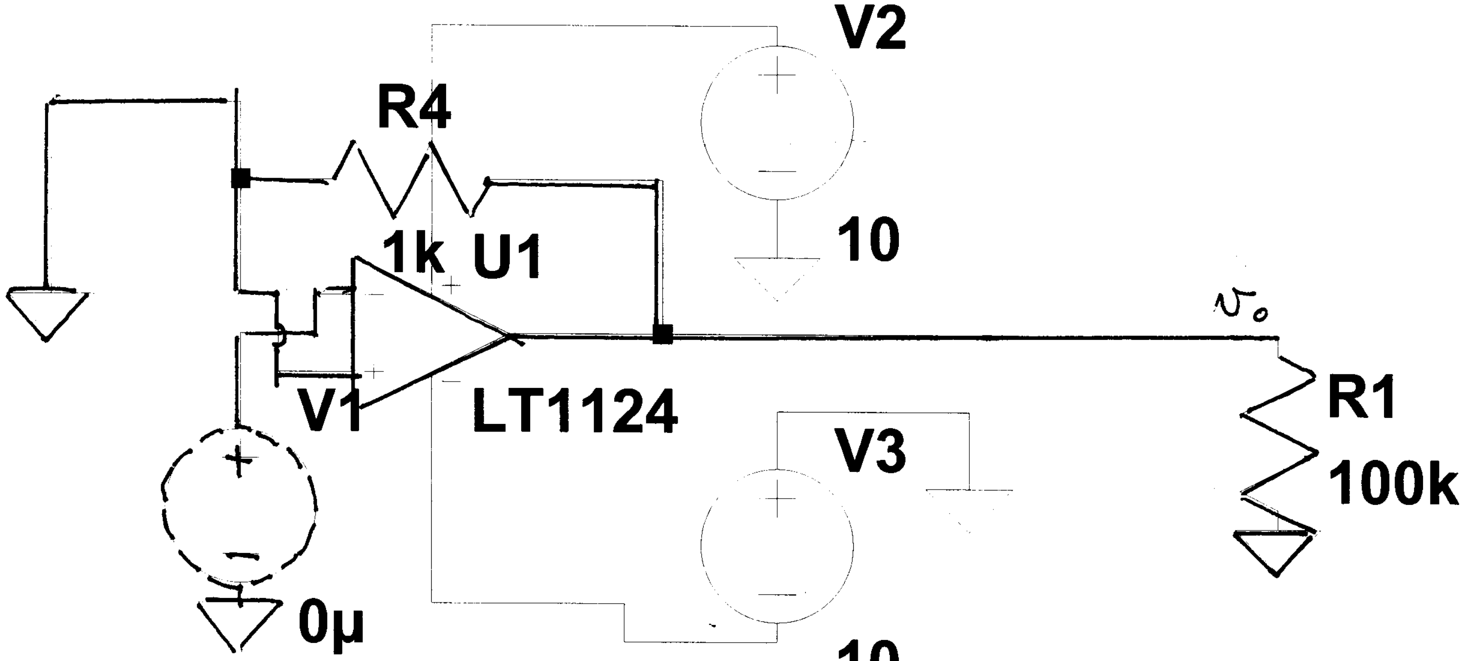
(1b) Logarithmic Amplifier



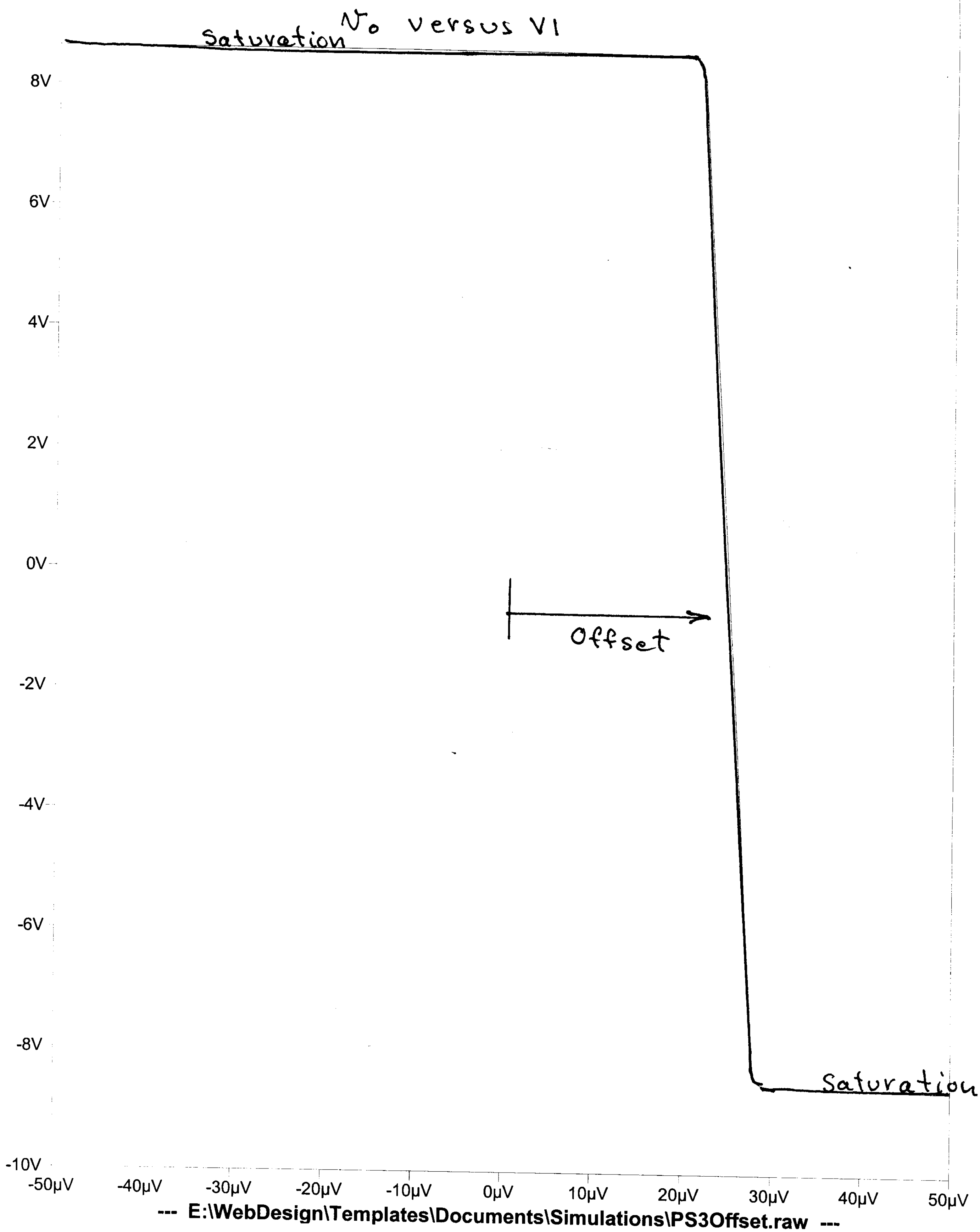
--- E:\WebDesign\Templates\Documents\Simulations\DiodeOpAmp.asc ---


V(n002)
-450mV
-460mV
-470mV
-480mV
-490mV
-500mV
-510mV
-520mV
-530mV
-540mV
-550mV
-560mV
-570mV
-580mV
60mV
130mV
200mV
270mV
340mV
480mV
620mV
760mV
--- E:\WebDesign\Templates\Documents\Simulations\DiodeOpAmp.raw ---
measured slope = nV_T = 47.43 mV
at 300°K $V_T \simeq$ 26 mV
so n = 1.82

Measuring Voltage Offset
With Comparator



.dc V1 -50u 50u 1u



v_o versus VI
Saturation
Offset
Saturation
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
-50µV
-40µV
-30µV
-20µV
-10µV
0µV
10µV
20µV
30µV
40µV
50µV
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Problem No 2

AC Analysis

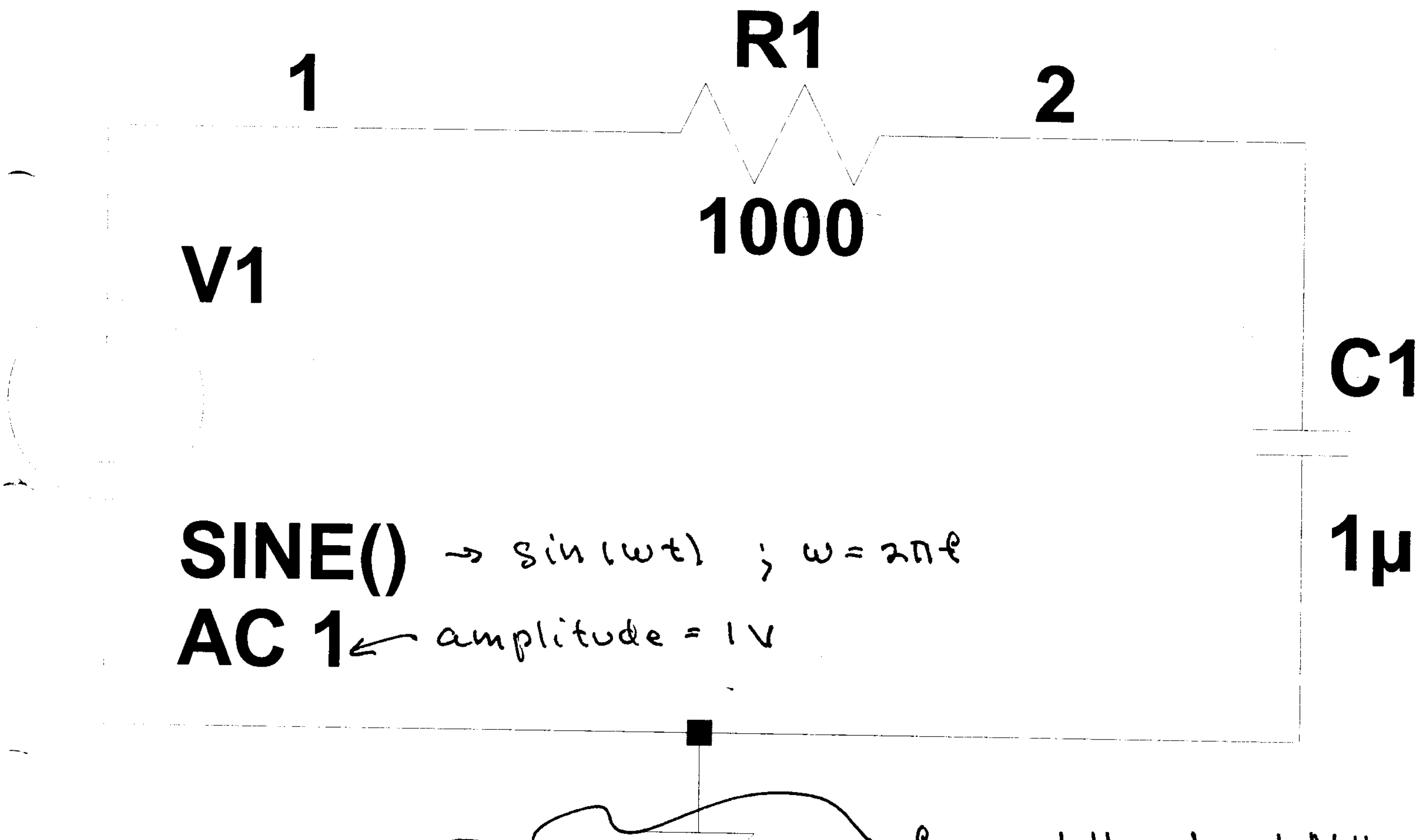
AC Amplitude 1 volt

Octave Sweep from 1 to 10^6 Hz

No of points / octave 100

Stop frequency 10^6 Hz

<u>Note Only asked to Plot Results.</u> and compare with $\tan^{-1}\omega RC$ and $1/(1+(\omega RC)^2)^{1/2}$



from 1 Hz to 1 MHz

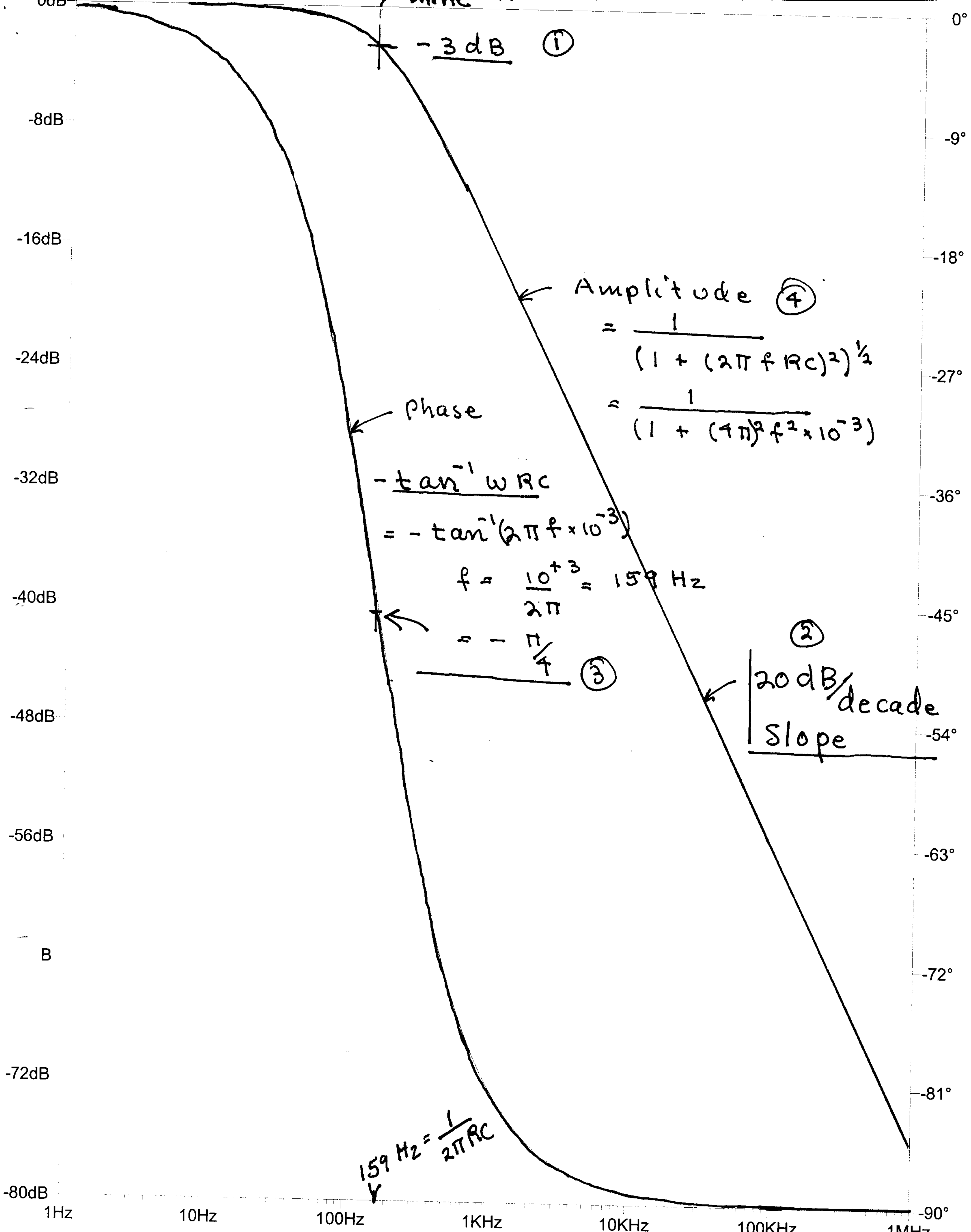
.ac oct 100 1 1e06

ac analysis

octave sweep

100 points / octave

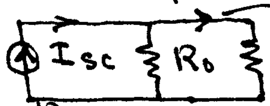
--- C:\Program Files\LTC\LTspiceIV\RC_Circuit_Vc.asc ---



--- C:\Program Files\LTC\LTspiceIV\RC_Circuit_Vc.raw ---

Note: On problem 14.32 Hambley states "since i_o/i_{in} is independent of R_L the output R is ∞

This is seen for Norton Equiv.



If $i_{RL} = I_{sc}$ for all R_L, then R_o must be ∞

Problem 4 Problem 14-34 of Hambley

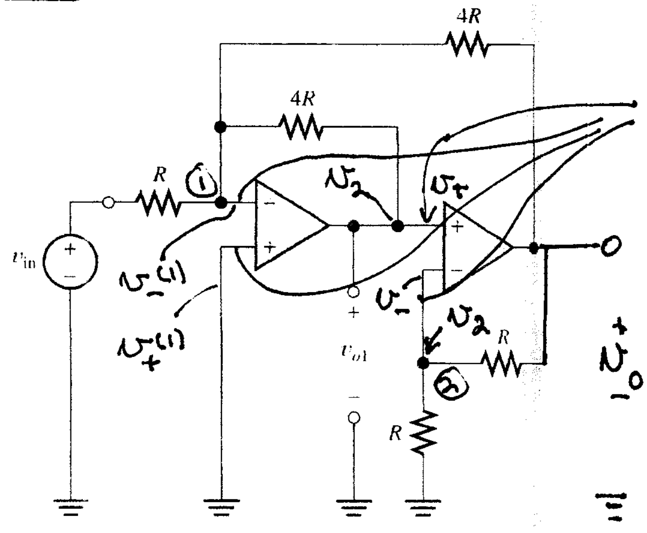


Figure P14.34

currents are all zero

$+$
v_{o2}
$-$

voltage divider

$$v_2 = \frac{R}{R+R} v_{o2}$$

$$= v_{o2}/2$$

$$= v_- = v_+$$

Consider Node Equation at 1

$$v_+^{(1)} = v_-^{(1)} = 0$$

Thus
$$\frac{v_{in}}{R} + \frac{v_2}{4R} + \frac{v_{o2}}{4R} = 0$$

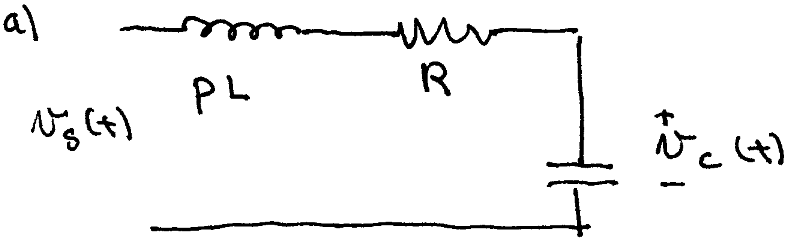
$$\frac{v_{in}}{\cancel{R}} + \frac{v_{o2}}{2} \cdot \frac{1}{4\cancel{R}} + \frac{v_{o2}}{4\cancel{R}} = 0$$

$$\therefore v_{o2} = \frac{4}{3} v_{in}$$

$$v_{o1} = v_2 = \frac{v_{o2}}{2} = \frac{2}{3} v_{in}$$

Problem No 5)

a)



$$v_c(t) = \frac{1/pC}{1/pC + pL + R}\, v_s(t)$$

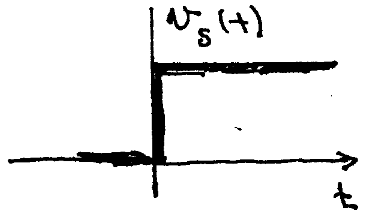
$$= \frac{1}{1 + p^2 LC + pCR}\, v_s(t)$$

DE $\left(1 + LC\, d^2/dt^2 + RC\, d/dt\right) v_c(t) = v_s(t)$

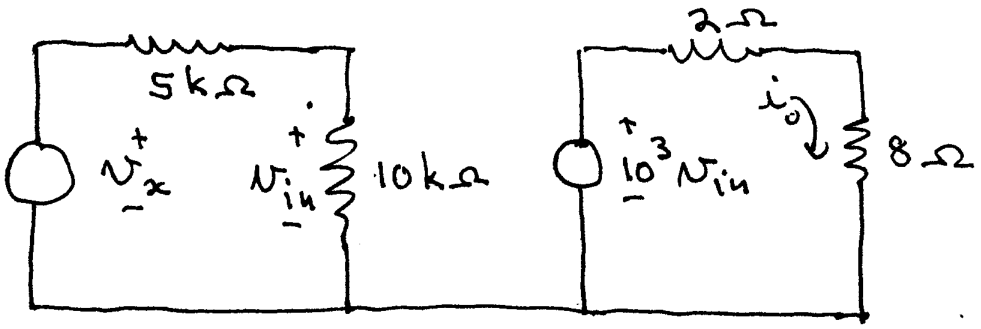
b) $v_c(t) = v_s(t)$ since $p \to 0$

c) $v_c(t) = 0$ since $p \to \infty$

An excitation with a sharp jump



Problem No. 6



Power delivered $= i_o^2 R_L = i_o^2 \, 8 = 8$

$\therefore i_o = 1$ Amp.

KVL $\quad i_o = \dfrac{10^3 v_{in}}{2+8} = \dfrac{10^3}{10} v_{in} = 1$

$\therefore v_{in} = 10^{-2}$ Volts.

Voltage divider

$v_{in} = \dfrac{10}{10+5} \times v_x = 10^{-2}$ Volts

$\therefore v_x = \dfrac{15}{10} \times 10^{-2}$ Volts

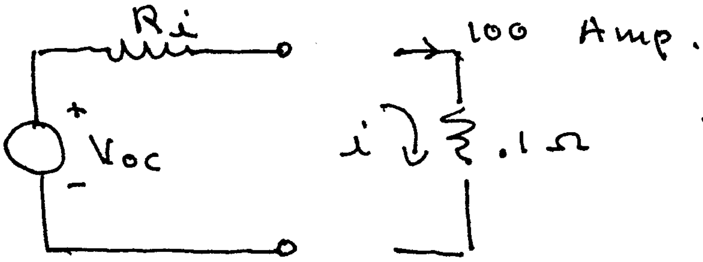
$= 15$ mV.

Problem No. 7

$V_{oc} = 12.6\,V$

supplies 100 Amp for a .1 Ω resistance

Equivalent Circuit



$$i = \frac{V_{oc}}{R_i + .1} = 100$$

Thevenin Equivalent

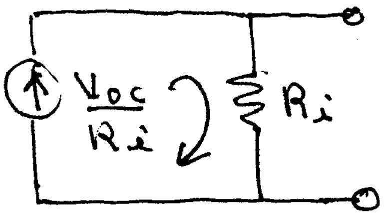
$$\therefore V_{oc} = 100 R_i + 10$$

$$R_i = \frac{2.6}{100} = .026\,\Omega$$

(Very Small!)

$$I_{sc} = \frac{V_{oc}}{R_i} = \frac{12.6}{.026} =$$

Norton Equivalent



From the terminal point of view they are equivalent. However the book suggests that the Thevenin is more realistic because the Norton would imply dissipation in R_i by a circulating current!