Mid-Term Exam, ECE-137B
May 14, 2002

Closed-Book Exam

There are 2 problems on this exam , and you have 75 minutes.

1) show all work. Full credit will not be given for correct answers if supporting work is not shown.
2) please write answers in provided blanks
3) Don't Panic !
4) 137a, 137b crib sheets, and 2 pages personal sheets permitted.

Do not turn over the cover page until requested to do so.

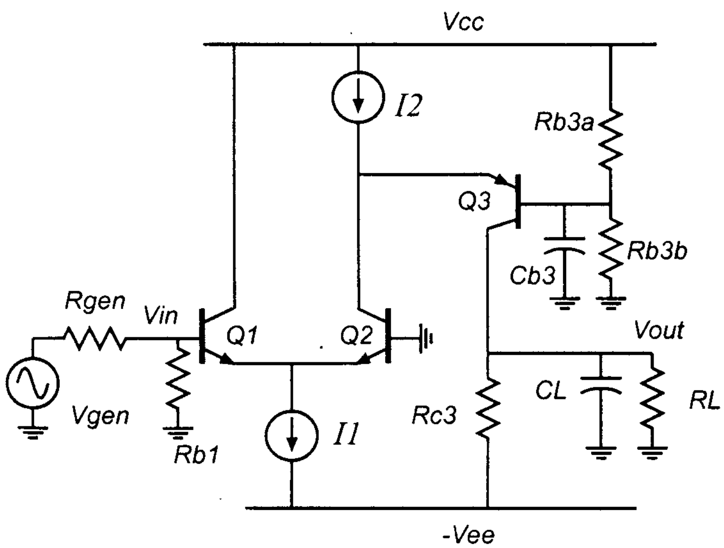
Name:

Solution

Use any and all reasonable approximations. 5% accuracy is OK if the method is correct.

Time function	LaPlace Transform
$\delta(t)$	1
U(t)	1/s
$e^{-\alpha t}U(t)$	$\frac{1}{s+\alpha}$
$e^{-\alpha t}\cos(\omega_d t)U(t)$	$\frac{s+\alpha}{(s+\alpha)^2+\omega_d^2}$
$e^{-\alpha t}\sin(\omega_d t)U(t)$	$\frac{\omega_d}{(s+\alpha)^2+\omega_d^2}$

Problem 1, 62 points



A very broadband DC-coupled amplifier.

Transistor parameters:
Ccb=2 pF, beta=infinity,
Va=infinity
τ_f =0.2 ns
$C_{be,depl}$=1 pF

RL= 100 Ohm
Rgen= 100 Ohms=Rb1
CL=5 pF.

Vcc= 7.5 Volts,
-Vee = -7.5 volts

a) 5 points

Q1 and Q2 are to each operate at 7.5 mA emitter current. Q3 is to operate at 10 mA. The emitter of Q3 is to be biased at +5 volts. The current through Rb3b is 3 mA. The DC output voltage is zero volts

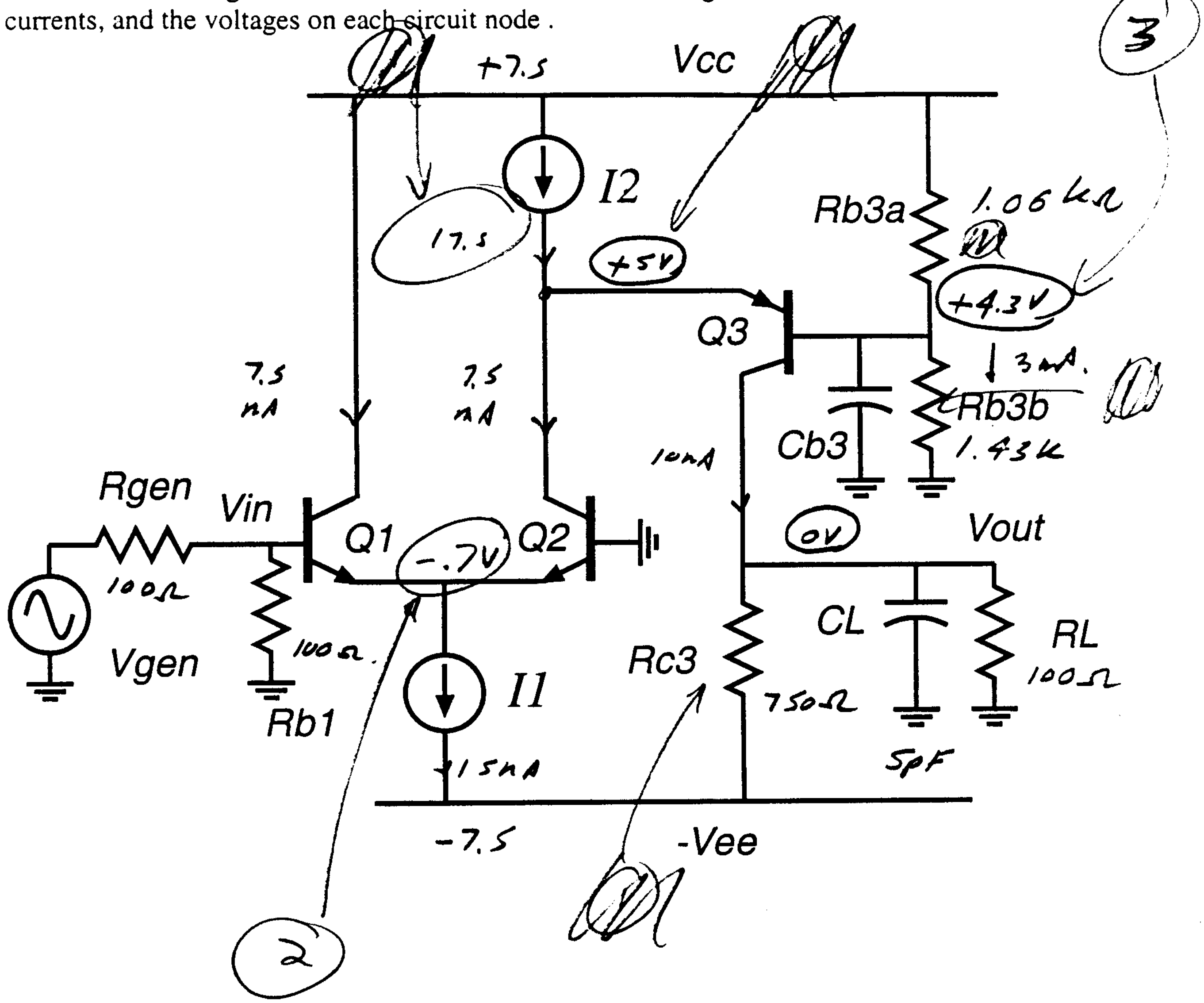
. Find I1, I2, Rb3a, Rb3b, Rc3

I1= 15mA (1) I2= 17.5mA (1)

Rb3a= 1.06kΩ (1) Rb3b= 1.43kΩ (1) Rc3= 750Ω (1)

b) 5 points

On the circuit diagram below indicate the currents through all resistors, all collector currents, and the voltages on each circuit node .



$V_A = \infty$

$\beta = \infty$

$\tau_f = 0.2ns$

$C_{je\,depl.} = 1pF$

$C_{cb} = 2pF$

b) 15 points

Find the mid-band amplifier parameters below

V_{out}/V_{in}= 12.73 (1) V_{out}/V_{gen}= 6.36 (1)

Rin,amplifier= 100Ω (1), Rout,amplifier = 750Ω (1)

voltage gain of Q1= 1/2 (1)

voltage gain of Q2= 0.75 (1)

voltage gain of Q3= 33.94 (1)

Input impedance of Q2= 3.47Ω (1)

Input impedance of Q3= 2.6Ω (1)

(1)

Q3 $R_{eq} = 100\Omega // 750\Omega = 88.24\Omega$

$r_{e3} = 26/10 = 2.6\Omega$

$A_{v3} = R_{eq}/r_{e3} = 33.94$ (1)

Q2 $R_{eq} = r_{e3} = 2.6\Omega$ (1)

$r_{e2} = 26/7.5 = 3.47\Omega$

$A_v =$ ~~3.47/2.6~~ $2.6/3.47 = 0.75$ (1)

Q1: $R_{eq} = r_{e2} = 3.47\Omega$ (1)

$r_{e1} = 3.47\Omega$

$A_v = 1/2$

A. $V_o/V_{in} = 12.73$

(1) [$V_o/V_{gen} = 12.73/2$

c) 5 points

Give the following transistor parameters

re1= 3.47 re2= 3.47 re3= 2.6

C_{be1}= 58.64 (1) C_{be2}= 58.64 (1) C_{be3}= 77.92 (1)

0.245 ✓ 1pF ✓

$C_{be} = g_m \tau_f + C_{be\,depl}$

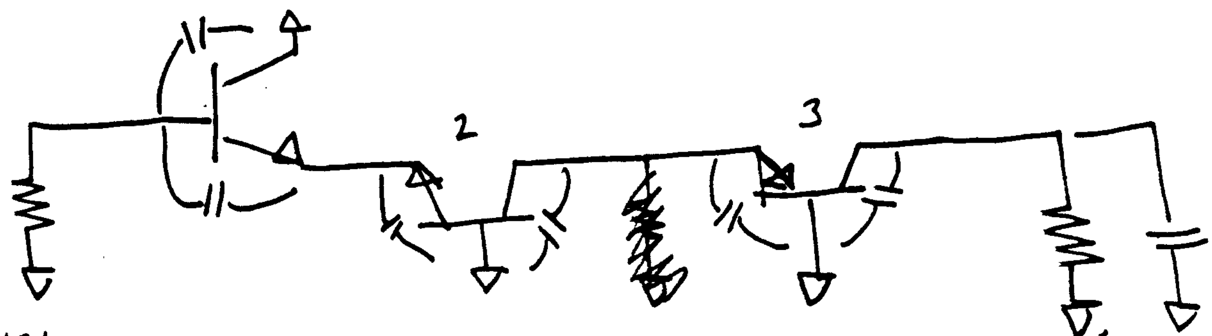
= (2)

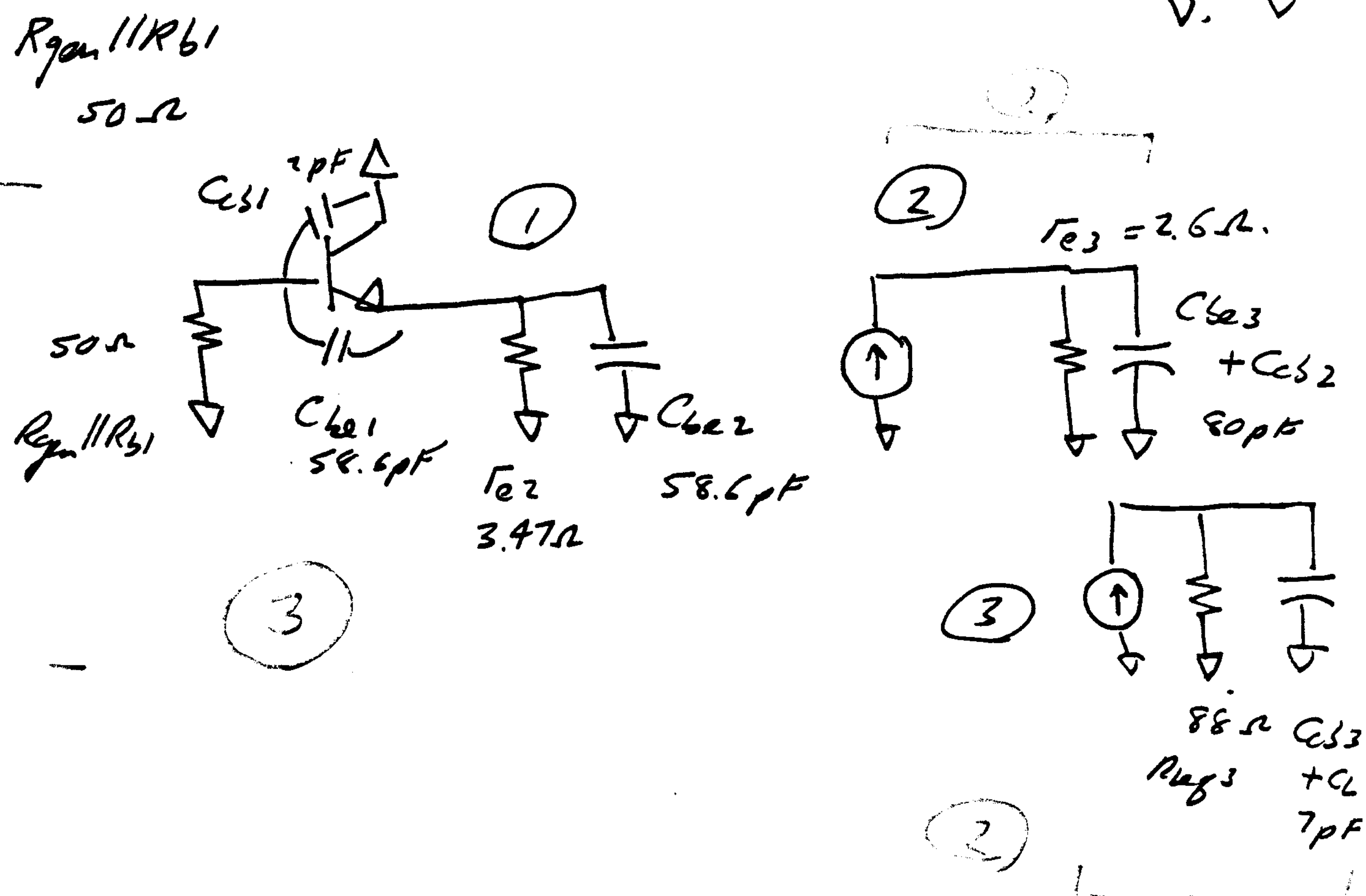
d) 20 points

High-frequency response. Calculate the gain-frequency characteristics of the amplifier: give an expression for Vout(s)/Vgen(s).

Give all pole frequencies and zero frequencies (in Hz).

Do NOT use the node-by node Miller Approximations. Use either MOTC or the results we have derived from Nodal analysis of single-stage amplifiers ***This part should not take an hour, so choose your analytic method sensibly. Please note that the circuit has separation points; this simplifies analysis considerably.***





FIRST PART   The emitter follower.

$$a_1 = C_{be1}\left[(R_{gen} \| R_{b1})(1 - A_{v1}) + r_{e1} \| r_{e2}\right] + C_{cs1} \cdot R_{gen} \| R_{b1} + C_{be2}\left[r_{e2} \| r_{e1}\right]$$

$$= 59pF(25\Omega + 1.73\Omega) + 2pF(50\Omega) + 59pF(1.73\Omega)$$

$$= 1.78\,ns$$

(2)

$$a_2 = 50\Omega \cdot C_{cs1} C_{be2} \cdot \underset{(r_{e1} \| r_{e2})}{1.73\Omega} + 50\Omega \cdot C_{cs1} \cdot C_{be1} (r_{e1} \| r_{e2}) + 1.73\Omega \cdot C_{be2} \cdot C_{be1} \cdot 50\Omega$$

$$= 50\Omega \cdot 1.73\Omega\left[C_{be1} C_{cs1} + C_{be1} C_{be2} + C_{be2} C_{cs1}\right]$$

$$= 3.17 (10^{-19})\ sec^2$$

(2)

Use SPA: $f_{p1} = \frac{0.159}{a_1} = \underline{89.3\,MHz}$.

(1) $f_{p2} \overset{?}{=} \frac{0.159}{a_2/a_1} = 892\,MHz$ $\underline{ok!}$

(2) $f_3 = \frac{0.159}{C_{be1} r_{e1}} = 782\,MHz$

Part 2 $f_p = \frac{0.159}{2.6\Omega (80pF)} = 764\,MHz.$ (1)

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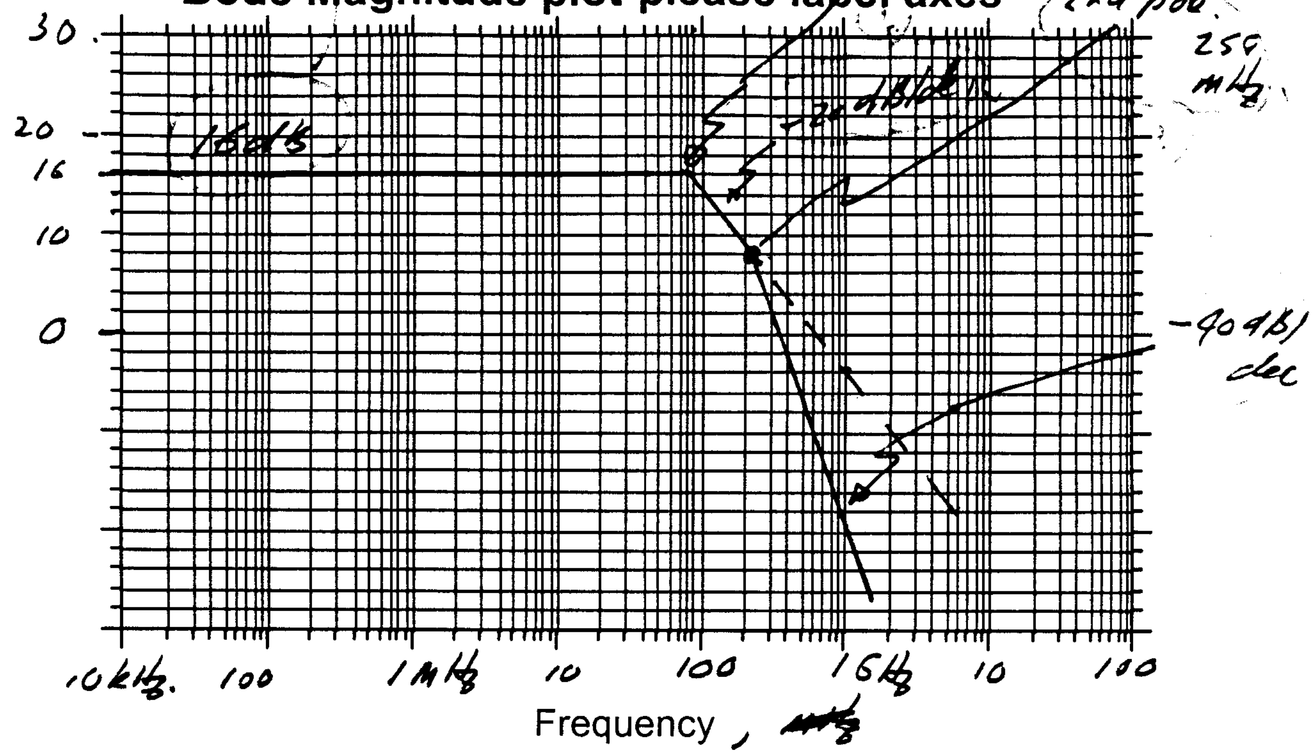
part 3: $f_p = \frac{0.159}{88\Omega (7pF)} = 258\,MHz.$ (2)

e) 12 points

(1) $V_o/V_{gen} = 6.36 = 16.1$ dB.

1st pole: 89 MHz

Bode Magnitude plot-please label axes



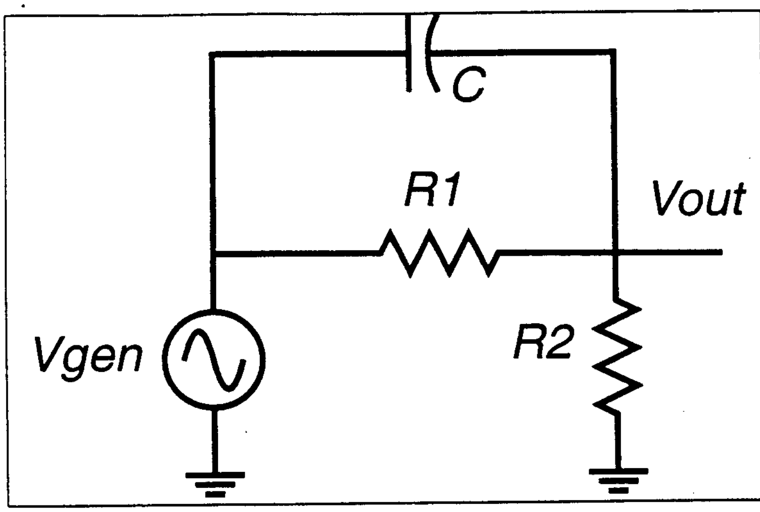
Draw a Bode Plot (Straight-line asymptotes) of the amplifier transfer function Vout/Vgen, labeling all pole and zero frequencies and labeling the slopes of all asymptotes. ***TO keep the plot managable, include only the 2 lowest-frequencypoles in the transfer function***

poles at 89.3, 892 MHz
258, 764

zero @ 782 MHz

Problem 2, 38 points

Part a 15 points



Derive an expression for Vout(s)/Vgen(s) in the form below...

$$\frac{V_{out}}{V_{in}} = K\frac{1+b_1 s+b_2 s^2+\ldots}{1+a_1 s+a_2 s^2+\ldots}$$

You must use nodal analysis .

Vout(s)/Vgen(s) = $\left(\frac{R_2}{R_1+R_2}\right)\left(\frac{1+sR_1C}{1+s[R_1 \| R_2]C}\right)$

8

$$\frac{V_o}{R_2}+\frac{V_o-V_g}{R_1}+\frac{V_o-V_g}{\frac{1}{sC}}=0 \qquad \frac{V_{gen}-V_o}{R_1}+\frac{V_{gen}-V_o}{\frac{1}{sC}}=0$$

$$V_o R_1\cdot\frac{1}{sC}+(V_o-V_g)(R_2\cdot\tfrac{1}{sC})+(V_o-V_g)(R_1R_2)=0$$

$$V_o R_1\frac{1}{sC}+V_oR_2\frac{1}{sC}-V_gR_2\frac{1}{sC}+V_oR_1R_2-V_gR_1R_2=0$$

$$V_o\left(R_1\frac{1}{sC}+R_2\frac{1}{sC}+R_1R_2\right)=V_g\left(R_2\frac{1}{sC}+R_1R_2\right)$$

2

$$\frac{V_o}{V_g}=\frac{R_2\frac{1}{sC}+R_1R_2}{R_1\frac{1}{sC}+R_2\frac{1}{sC}+R_1R_2}=\frac{R_2+R_1R_2sC}{R_1+R_2+sCR_1R_2}=\frac{R_2(1+sR_1C)}{(R_1+R_2)(1+s[R_1\|R_2]C)}$$

5

Part b) 10 points

We have the following values: R1=R2=7 kΩ , C= 0.3 μF

Give all the pole frequencies and all the zero frequencies, using units of Hz.

pole frequencies = 151 Hz

zero frequencies = 75.7 Hz

$R_1 \| R_2 = 3500\ \Omega$

$$\frac{V_o}{V_g} = \left(\frac{R_2}{R_1+R_2}\right)\left(\frac{1+sR_1C}{1+s[R_1\|R_2]C}\right)$$

$$= .5\left(\frac{1+.0021s}{1+.00105s}\right) \quad (2)\ (2)$$

$$\tau_{pole} = .00105\text{sec} \Rightarrow \frac{1}{2\pi\tau_p} = \boxed{151\text{ Hz}} \quad (3)$$

$$\tau_{zero} = .0021\text{sec} \Rightarrow \frac{1}{2\pi\tau_z} = \boxed{75.7\text{ Hz}} \quad (3)$$

Part c) 13 points

Now calculate Vout(t) for

Vgen(t)=5 Volts*U(t),

where U(t) is the unit step-function.

Graph on the chart below, giving units and labeling axes. Clearly label initial and final values, and charging time-constants.

Vout(t)= ______________________

(3)

$$\frac{V_o}{\text{[redacted]}} = \frac{5(.5)}{s}\left(\frac{1+.0021s}{1+.00105s}\right) = \frac{2.5}{s}\left(\frac{1+.0021s}{1+.00105s}\right)$$

$$= \frac{952\cdot 2.5}{476\,s}\,\frac{(476+s)}{(952+s)} = \frac{5}{s}\left(\frac{s+476}{s+952}\right)$$

(3)

$$= \frac{A}{s} + \frac{B}{s+952}$$

$s=0$ $\quad A = 5\left(\frac{s+476}{s+952}\right)$

$A=2.5$

$s=-952$ $\quad B = \frac{5}{s}(s+476)$

$B=2.5$

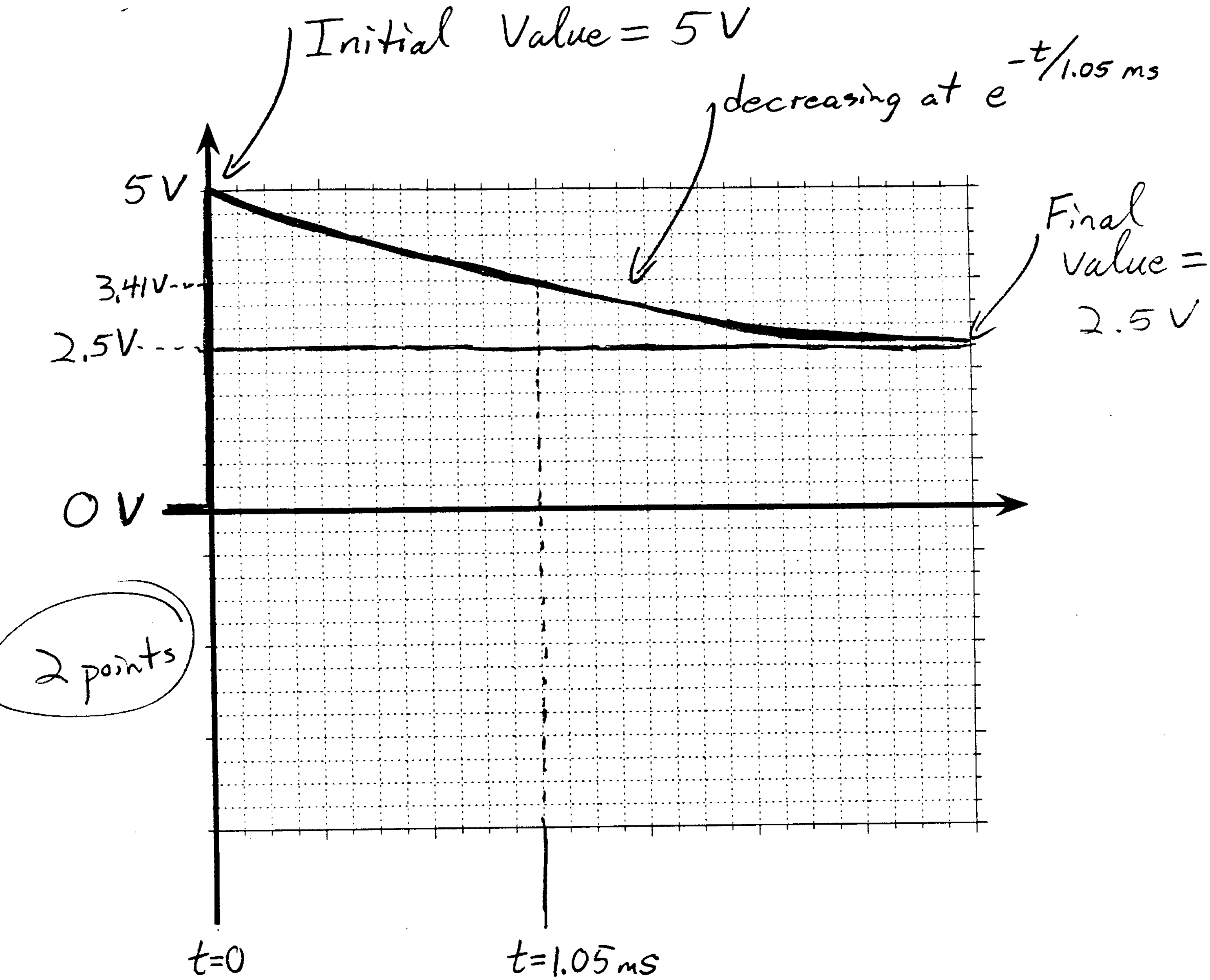
(2)

$$\frac{V_o}{\text{[redacted]}} = \frac{2.5}{s} + \frac{2.5}{s+952}$$

Inverse LaPlace $\Longrightarrow$ $\boxed{2.5u(t) + 2.5e^{-952t}u(t)}$

(3)

$$= \boxed{\left[2.5 + 2.5e^{-t/1.05\,ms}\right]u(t)}$$


Initial Value = 5 V
decreasing at $e^{-t/1.05\,ms}$
Final Value = 2.5 V
5 V
3.41V
2.5V
0 V
2 points
t=0
t=1.05ms