ENGR4300 **Test 3** **Spring 2002**

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Solution -- (See quiz3_s02.PDF for figures and plots)

1) 555 Timer (20pts)

a) What is the Frequency of the 555 set at, What is T1, T2? 9pts

From plot: Period = (455us-300us) = 155us
Frequency = 1/period = .00645 MHz
Frequency = 6.5 KHz
From plot: T1 = 378us-300us
T1 = 78us
From plot: T2 = 455us - 378us
T2 = 77 us

b) Calculate R1, R2 8pts

T2 = 0.693(R2)(C2) = 0.693(R2)(0.1u) = 77u
R2 = 1111.1 ohms
T1 = 0.693(R1+R2)(C2) = 0.693(R1+1111.1)(0.1u) = 78u
R1 = 14.4 ohms

c) What are the two voltage thresholds at which the 555 switches? 3pts

From the circuit: The input voltage is 10 volts.
The 555 should switch at on at 1/3 Vcc and off at 2/3 Vcc.
Switch off at: 6.67 Volts
Switch on at: 3.33 Volts

2) Inductance Measurement (20 points)

a) Find the transfer function, H(j?), at point B. Determine the value of the function, the magnitude and the phase at hi and low frequencies.

(2 pts) H(j?) = [1/j? C1] / [R1+ j? L3 + 1/j? C1]
H(j?) = 1 / [j? R1C1 + 1-$?^2$L3C1]

(1 pt) H(j$?_{lo}$) = *1*

(1 pt) H(j$?_{hi}$) = *-1/$?^2$L3C1*

(1 pt) | H(j$?_{lo}$) | = *1*

(1 pt) | H(j$?_{hi}$) | = *0*

(1 pt) ? H(j$?_{lo}$) = *0* *(positive real)*

(1 pt) ? H(j$?_{hi}$) = ? *(negative real)*

b) Based on your results from part a), indicate on plot I the trace for the magnitude of the voltage at point B (2 pts).

The trace should be high at low frequencies and 0 at high frequencies.
The red upside down triangle trace from +200mV at 1KHz to 0 at 10MHz

c) Based on your results from part a), indicate on plot II the trace for the phase at point B (2 pts).

The trace should be 0 at low frequencies and 180 (or -180) at high frequencies.
The upside down triangle trace from 0d at 1KHz to -180d at 10MHz.

d) Find the resonance frequency f_0 from the plot. Notice that the x-axis has logarithmic scale. (ie. $10^{0.5} = 3.16$) (2 pts)

Look at the place on plot I where the resonance goes to zero.
Note: 10KHz = 10 x 10^4 and 100KHz = 10 x 10^5
(Note: the middle (dotted) line is at about 3.16 x 10^4 Hz)
The resonance is about 60% between 10 x 10^4 and 10 x 10^5
This means the resonance is at 10($^{0.60}$) x 10^4 or at 3.98 x 10^4 Hz
f_0 = 40KHz (Note that I rounded here because my ability to read the graph is limited and so I figure it is about here.)

e) Solve for the unknown inductance. (6 pts)

? $_0$ = 2 ? f_0 = 1/sqrt(L3C1) ✍ L3 = 1/[C1(2? f_0)^2]*
0.5u[2(3.14)(40K)]^2 = 1/L3*
L3 = 32u Henries

3) Zener Diodes (20 pts)

a) Which Plot matches this circuit diagram (7pt)

This question was particularly difficult and should not have appeared on the test.

At +10V make a loop equation:

Both diodes are above threshold, so D2 (forward bias) cuts off at the 0.6V and D3(reverse bias) at the zener voltage (about 4.7V)
+10V = 0.6 + 4.7 + V(R3)
V(R3) = 4.7 V

At 0 make a loop equation:

Both diodes are off, so D2 is open and D3 is open. R3 is attached to ground.
V(R3) = 0V

At -10V make a loop equation:

Both diodes are above threshold (but the current is running in reverse), so D2 cuts off at -4.7V and D3 cuts off at -0.6 volts.

-10V = -4.7 + -0.6 + V(R3)

V(R3) = -4.7V

At 10 volts, the voltage should be +4.7, at 0 V it should be 0, at -10V it should be -4.7. Only the fist plot satisfies these criteria.

B) The zener diode will turn into a short at +4.7 when the voltage is positive and -0.6 when the voltage is negative.

Note that in general, the voltage at R4 can be found using the voltage divider rule:

*V(R4) = V1 * (R4)/(R4+R6)*

*At 50 ohms, V(R4) = V1*50/1050 = 0.05 V1*

*At 5000 ohms, V(R4) = V1*5000/6000 = 0.83 V1*

*At 50000 ohms, V(R4) = V1*50000/51000 = 0.98 V1*

*At 50 ohms, the theoretical maximum voltage across the diode is 0.05 * 10V = 0.5 V. This never exceeds the 0.6V or 4.7V thresholds, so the diode is off. The output is determined only by the voltage divider. This is the second graph (50 ohms).*
*At 5000 ohms, the theoretical maximum voltage across the diode is 0.83*10V = 8.3 V. This exceeds the 0.6V (negative) and 4.7V (positive) voltages across both diodes. Therefore, the first graph which cuts off at -0.6 and +4.7 is correct. (5000 ohms)*
*At 50000 ohms, the theoretical maximum voltage across the diode is 0.98*10V = 9.8V. This exceeds the 0.6V (negative) and 4.7V (positive) voltages across both diodes. Therefore, the first graph which cuts off at -0.6 and +4.7 is correct. (50000 ohms)*
*Note that if R4 was about 500 ohms, V(R4) = 10 * 500/1500 = 3.33 V. This is like the third graph where the -0.6 cuts off, but the 4.7 does not.*

C) What is the main difference between standard diode, and a zener diode?? (7pt)

A standard diode has a reverse bias threshold which is very large. It is designed to only work in one direction (the forward bias) at a threshold of about 0.6. A zener diode is designed to work in the reverse bias direction and has a cutoff threshold which is much lower and known. Zener diodes are rated in terms of the voltage at which they cutoff in the reverse bias.

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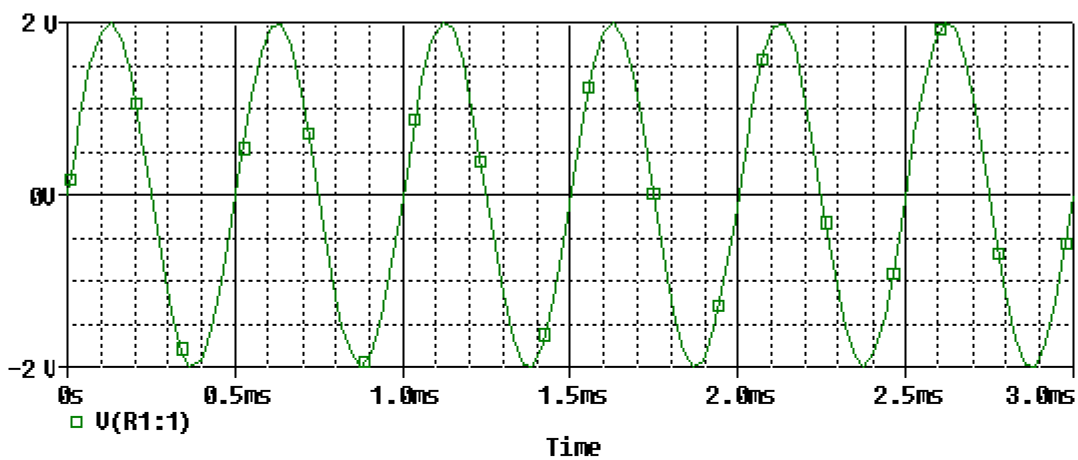
4) Op-Amp Configurations (20 points)

a) Seven circuits are shown below. (Connections to the power supply are not displayed but assumed). For each circuit, identify the function (1 pnt each) and give the mathematical relationship that relates the input and output voltages (1 pnt each).

1. *ideal differentiator Vout/Vin = -j? R1C1*
2. *voltage follower Vout/Vin = 1*
3. *non-inverting op-amp Vout/Vin = (1+R2/R1)*
4. *inverting op-amp Vout/Vin = -R2/R1*
5. *differential amplifier Vout/(V1-V2) = -R3/R1 (iff R1=R2, R3=R4)*
6. *weighted adder Vout = -R4(V1/R1 + V2/R2)*
   -or-
   adder Vout/(V1+V2) = -R4/R1 (iff R1=R2)
7. *ideal integrator Vout/Vin = -1/(j? R1C1)*

b) Consider the following input plot:



If this was used as the input to the circuit in 1 of this question, sketch what the graph of the output would be. Make sure the frequency and the amplitude and the value at 0 seconds are clearly indicated. Assume C1=1 nF and R1=1 K ohms. Show your work.

The circuit in 1 is an ideal differentiator. H(j?) = -j? RC
? = 2? f = 2(3.14)(1/0.5m) = 12.566 K rad/sec
The plot would have an amplitude of (2V)(?)(R)(C) = (2)(12.566K)(1K)($1x10^{-9}$)
amplitude = 0.025 V = 25 mV
The plot would have a phase shift of -90 degrees (negative j).
The frequency would not change.

Therefore, it would look like a negative cosine with an amplitude of 25 mV and the same frequency. At 0, 0.5ms, 1.0ms …, the amplitude would be -25 mV. At .25ms, .75ms, 1.25ms…., the amplitude would be +25 mV. You can sketch it.

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5) Circuit Functionality (20 pts)

List the functionality of each block, A,B,C,D and E. (4 pt each)

A = bypass capacitors (filter out high frequency noise from power supply)
B = buffer or voltage follower
C= inverting amplifier
D = approximate integrator or low pass filter
(capacitor is open at low frequencies and short at high frequencies)
E = high pass filter
(inductor is short at low frequencies and open at high frequencies)