ENGR-4300

Electronic Instrumentation

Quiz 4

Fall 2010

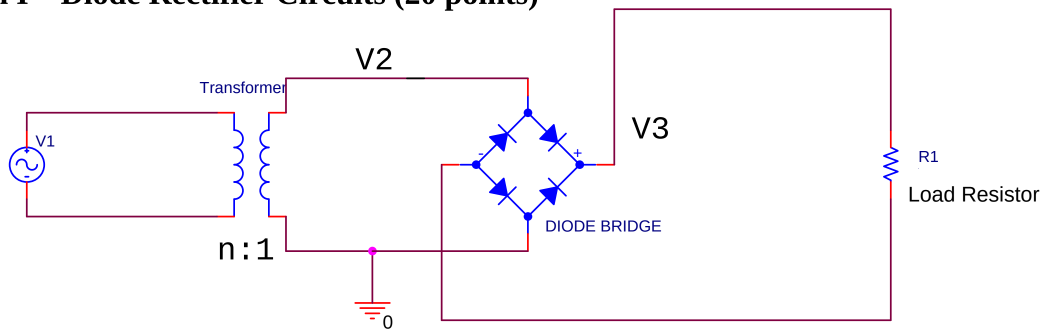
Name ____________________________ Section ____

Question	Value	Grade
I	20	
II	20	
III	20	
IV	20	
V	20	

Total (100 points) ________________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Provide as much explanation as possible so that partial credit can be given if appropriate.

Question I – Diode Rectifier Circuits (20 points)



The diagram above shows the application of a diode bridge for performing rectification of the voltage from the output of the transformer. The sinusoidal source voltage $V1 = 120V_{RMS}$ and $R1 = 5k\Omega$.

1. (3pt) Knowing that the voltage amplitude is $\sqrt{2}$ larger than the RMS voltage, what transformer turns ratio n:1 will give as close as possible to a 6V amplitude at V2? (n should be rounded to an integer.)

n = (120 x 1.414)/6 = 28.28 => 28 n:1 = 28:1

2. (3pt) What will the actual peak voltage be on the output of the full wave bridge (across R1). Let the idealized diodes have $V_{on} = 0.6V$ and V2 is the voltage from the turns ratio in question 1?

V = (120 x 1.414)/28 – 2x(0.6) = 4.86V

3. (3pt) Given R1 above, what is the peak current that will flow through any of the 4 diodes?

I = V/R = 4.86/5k = 0.972mA

Question I – Diode Rectifier Circuits (continued)

4. (3pt) For a 60Hz input voltage V1 a capacitor is added in parallel with R1 to reduce the ripple in the voltage across the load resistance so that the droop is less than 0.25V. Which of the following values is the minimum capacitance necessary to achieve this?

a) 1μF b) 17μF c) 33μF d) 100μF

Droop = 0.25/4.86 = 0.05

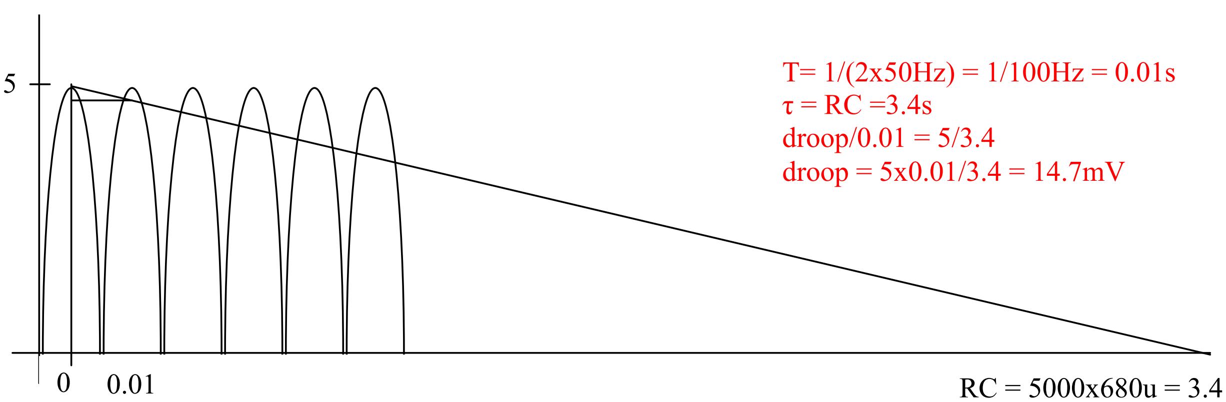
T = 1/120Hz = 8.3ms

τ = RC = 0.0083/0.05 = 0.166 C = 0.166/5000 = 33μF

5. (3pt) It is decided to use a 680μF capacitor to filter the supply voltage. What 3 digit code will be written on this capacitor to indicate its value?

687 => 68 x 10^7pF = 68 x 10^7 x 10^{-12} = 68 x 10^{-5} = 0.00068F

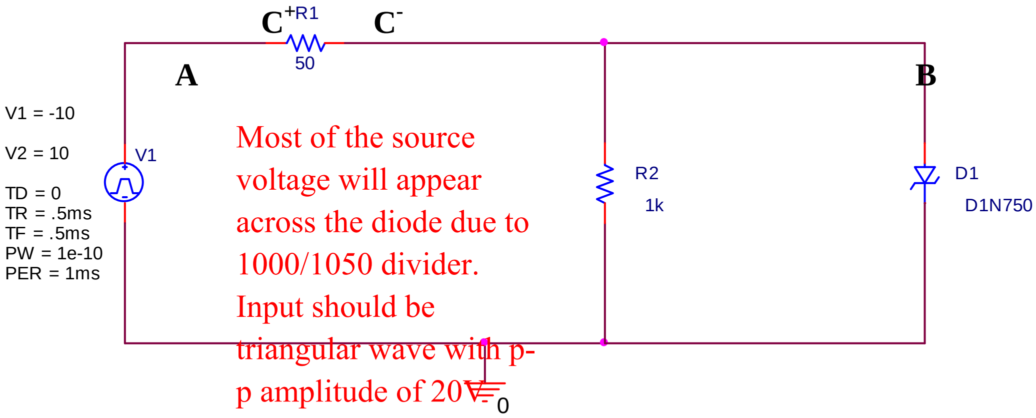
6. (5pt) For a quick calculation of the voltage droop with the 680μF capacitor and 5kΩ load resistance, assume a 5V amplitude 50Hz sine wave has been ideally full wave rectified (V_{on} = 0V). Use the period between adjacent peaks as the maximum droop time and assume the exponential decay can still be modeled as a straight line in this interval. With these simplifications, how much will the voltage droop from its 5V maximum value?



T= 1/(2x50Hz) = 1/100Hz = 0.01s
τ = RC =3.4s
droop/0.01 = 5/3.4
droop = 5x0.01/3.4 = 14.7mV

RC = 5000x680u = 3.4

Question II – Zener Diode Circuits (20 points)

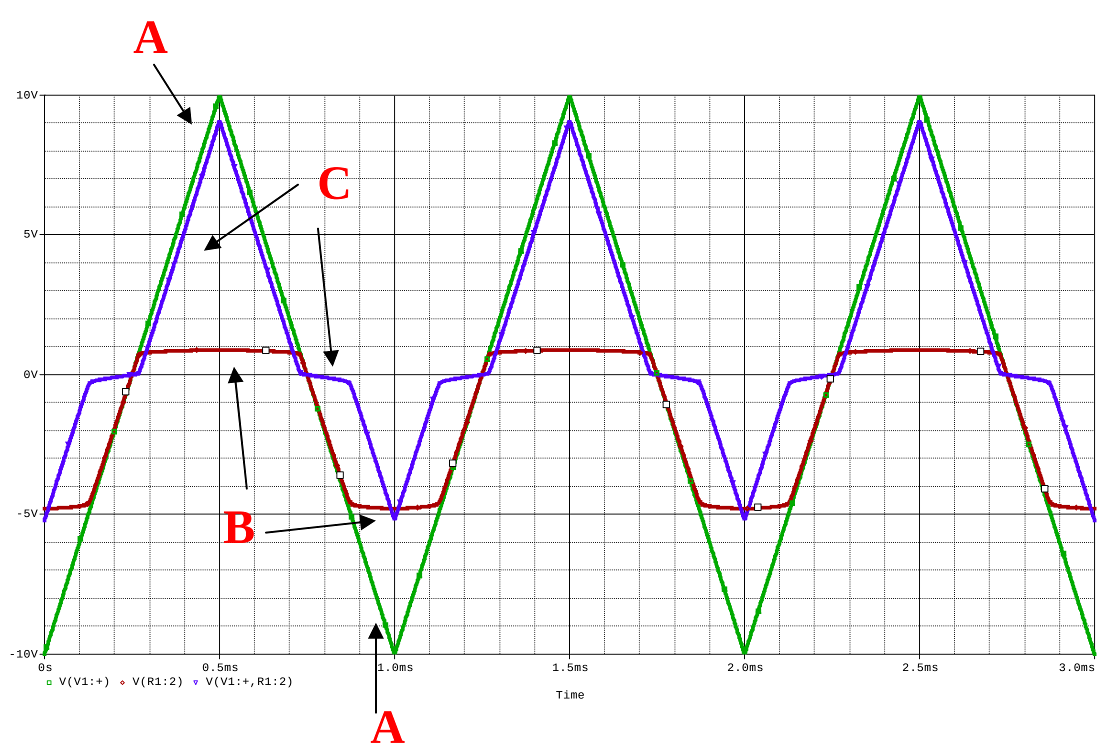


The circuit above is a Zener diode voltage regulator. A Zener diode is used to regulate the voltage across the load resistor R2 in the circuit. Shown below are two figures, one of which shows the correct voltages for this configuration.

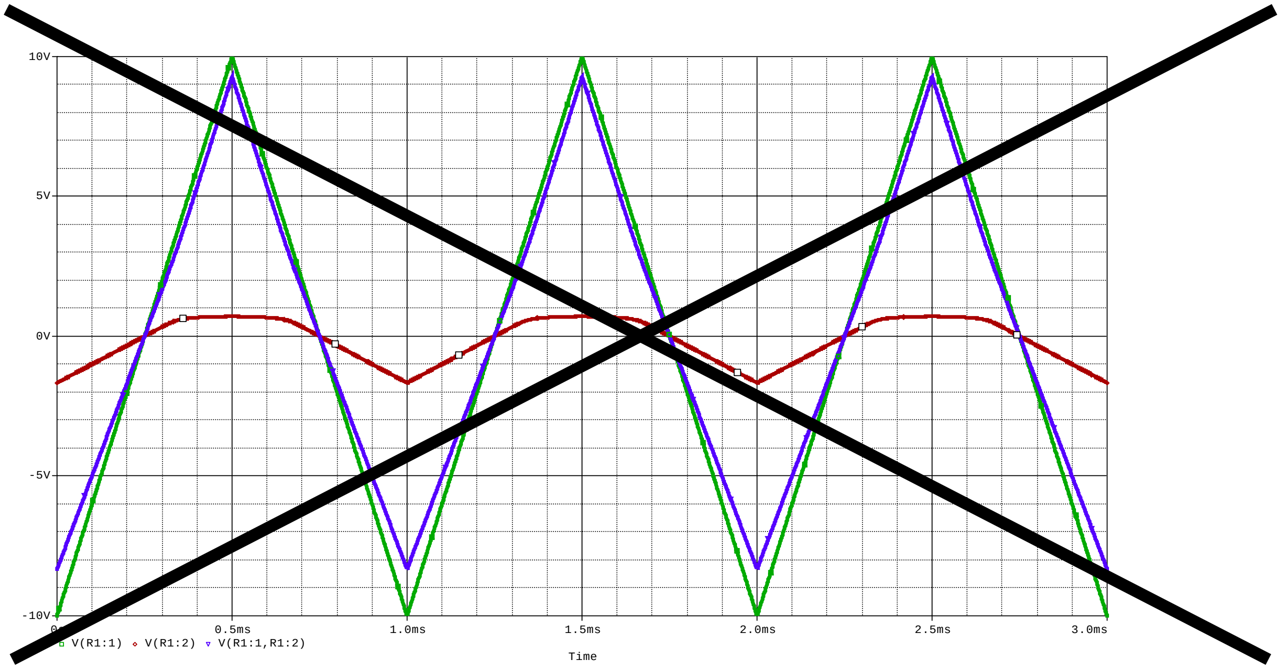
a) (5pts) Identify which of the two figures is correct by crossing out the one that is incorrect. Explain your answer.

Most of 10V is enough to turn on the Zener.

b) (5pts) On the correct figure, label which plot corresponds to the voltages at points A and B and across resistor R1 (C^+ to C^-)



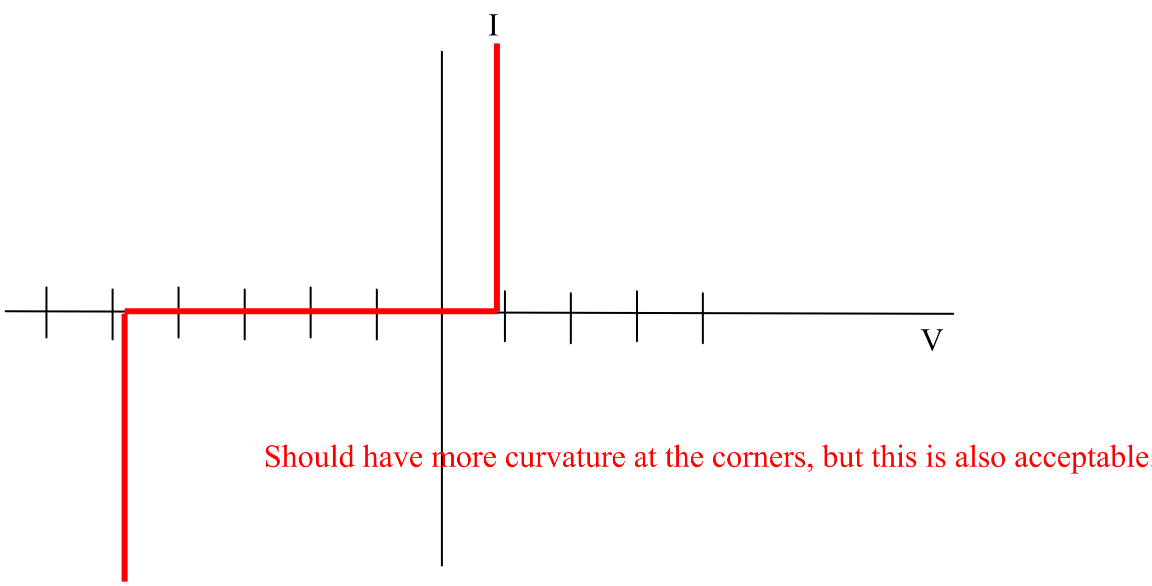
Zener clamps voltage at about 0.7V forward and about 5V reverse (Zener)



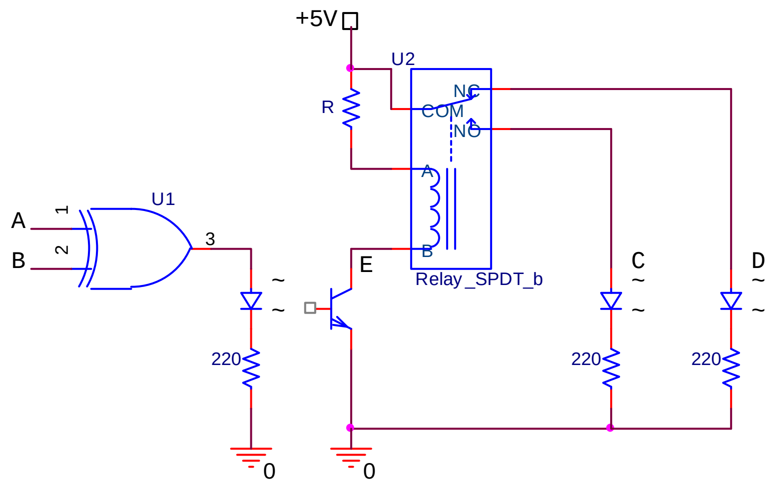
c) (6pts) From the given information, determine the Zener voltage for this diode V_Z and the forward bias voltage necessary to turn the diode on in the forward direction. Exact answers are not required.

V_Z is a little less than 5V, say about 4.7V, $V_{forward}$ is a little less than 1V, say about 0.8V with a range of answers accepted. It is not necessary to be able to read the graphs precisely but the answers should be reasonable.

d) (4pts) Sketch the V-I plot for this diode. Your sketch does not have to be perfect, but it should show the main characteristics of the diode.



Question III – LEDs and Phototransistor Circuits (20 points)



Above is a typical optical isolation circuit with an LED/phototransistor pair. The logic gate and inputs may be in a cage whose reference voltage is 5kV higher than the phototransistor and relay circuit, but the "optical isolation" removes the danger of high voltage getting through.

1. (9pt) Fill in the following table:

A	B	Relay (on or off?)	LED C (on or off?)	LED D (on or off?)
0	0	OFF	OFF	ON
0	1	ON	ON	OFF
1	0	ON	ON	OFF
1	1	OFF	OFF	ON

2. (6pt) Assuming the resistance of the relay coil is negligible but 200mA is needed to turn it on, what is the maximum resistance value R can be if the on-resistance of the phototransistor is 15Ω?

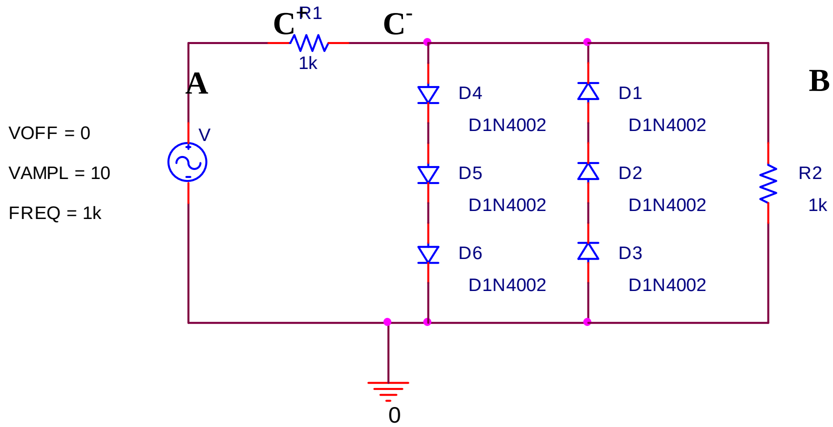
Answer: 5V/200mA = 15 + R *R = 5/0.2 – 15 = 10Ω*

3. (5pt) Using the phototransistor on-resistance of 15Ω, setting R = 5Ω and assuming the phototransistor behaves like an ideal switch when it is turned off, what are the minimum and maximum voltages at E, the collector of the transistor?

Answer: $Minimum = 5\frac{15}{15+5} = 5\frac{15}{20} = 3.75V$

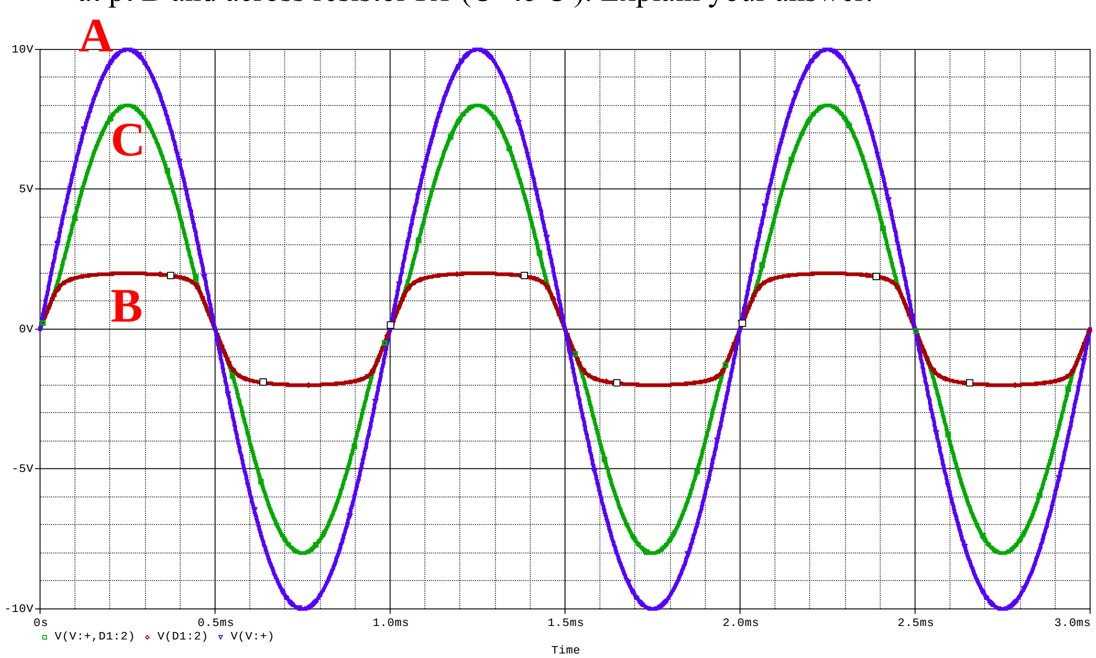
Maximum = 5V

Question IV - Diode Limiter Circuits (20 points)



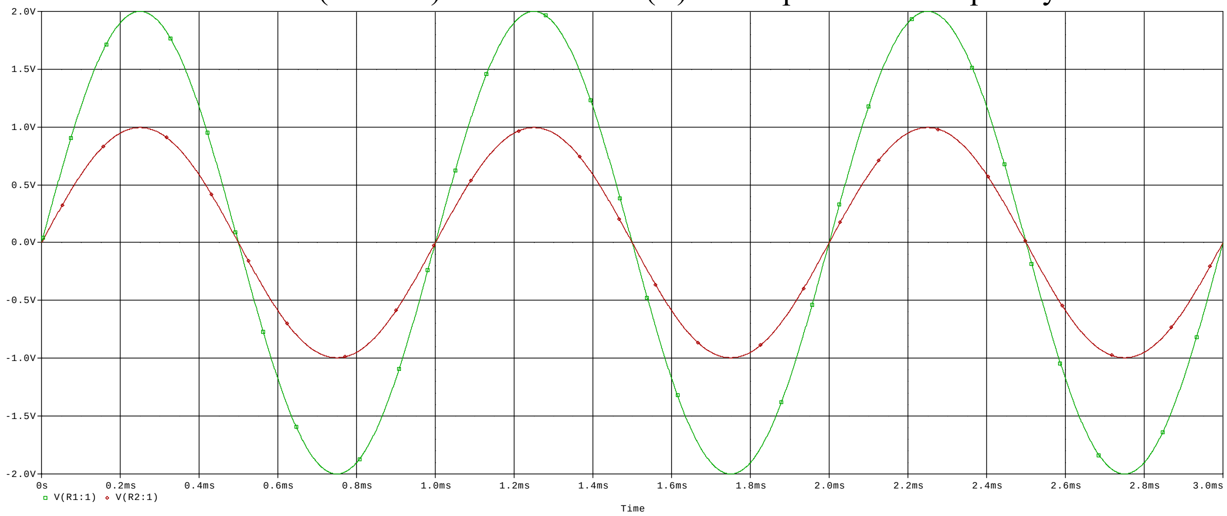
Six 1N4002 diodes are used to protect a load (in this case R2) from having too large a voltage across it. The 4002 diode has somewhat different properties than the 4148 diode we have studied in class.

a) (9pts) This configuration is tested with the sinusoidal voltage source shown in the circuit above. The voltages measured are shown below. Label which plot is the voltage at pt A, at pt B and across resistor R1 (C^+ to C^-). Explain your answer.



A is 10V sinusoid at the input, B cannot be larger than the forward bias of three diodes which is about 2V, C is what is left.

b) (6 pts) The source voltage amplitude is changed to 2V. Sketch the resulting voltage across resistor R1 (C^+ to C^-) and at the load (B) on the plot below. Explain your answer.



At 2V, the input voltage is not sufficient to turn on the diodes so they remain open and out of the circuit. All that remains is a voltage divider with two 1k resistors, so the voltage observed is a sinusoid at half the input.

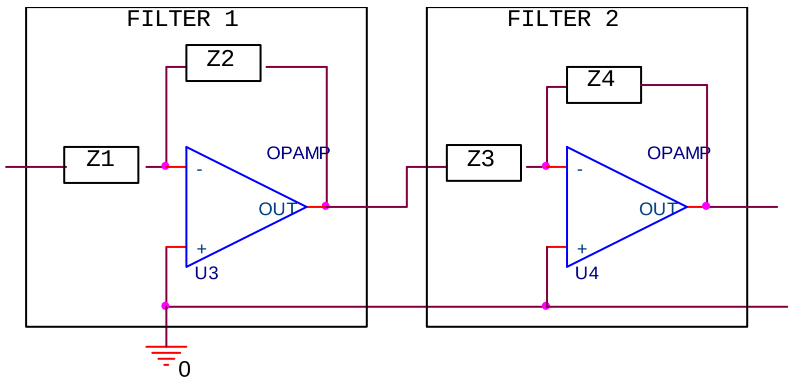
c) (5pts) Using the given information, determine the forward voltage necessary to turn the 1N4002 diode on. Explain your answer.

3 diodes at about 2V means about 0.67V. A good range for the answer would be

0.6V < 0.67V < 0.7V or the usual range for simple diodes.

Question V – Signal Modulation and Filtering (20 points)

A modulated signal is to be filtered to remove the effects of the modulation and other noise. The desired signal is from 100Hz – 8kHz. The undesired parts of the signal are below 50Hz and above 10kHz. Design a combination of filter types (low pass and/or high pass) that will remove everything except the desired signal. It has been decided that the filters should be in series (cascaded) as shown below. The Zs in the op-amp circuits represent complex impedances and may be combinations of resistors and capacitors. (Hint: one of these filters was used in Project 4.)



1. (4pt) For each filter determine the appropriate type.

Filter 1: ___LOW PASS__________ Filter 2: ___HIGH PASS__________

Order of filters may be switched around

2. (4pt) For each filter determine the corner frequency.

Filter 1 f_c: ___~9kHz__________ Filter 2 f_c: ___~70Hz______________

8kHz – 10kHz OK 50Hz – 100Hz OK

(5pts?) For one of the first four problems on this quiz, you can choose one of the following options.

- Write 'do not grade' on it in really huge and clear letters and you will receive the full 20 points, regardless of your actual answer, or
- Solve the problem and, if your answer is completely correct, you will receive 25 points

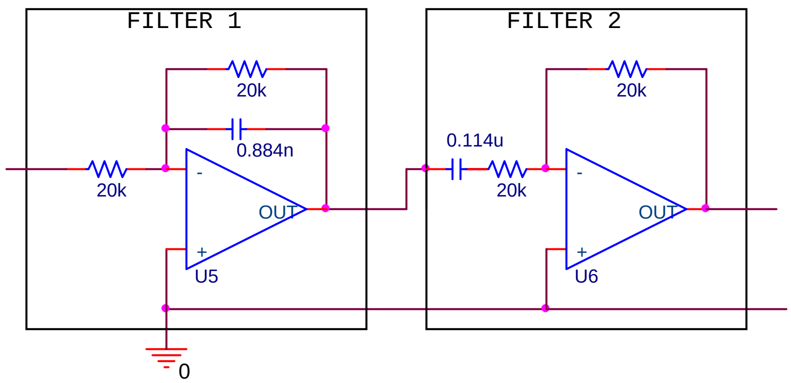
Note that you have this option for only one of the first four problems. You must solve the other three.

Question V – Signal Modulation and Filtering (continued)

3. (6pt) Using 20kΩ resistors and whatever capacitor values are necessary, draw the circuits for Filter 1 and Filter 2 with the correct components replacing the Zs above.

LPF Filter 1: $\omega = 2\pi f = \frac{1}{R_f C_f} \Rightarrow C_f = \frac{1}{R_f 2\pi f} = \frac{1}{20{,}000 \cdot 2\pi 9k} = .884nF$

HPF Filter 2: $\omega = 2\pi f = \frac{1}{R_i C_i} \Rightarrow C_i = \frac{1}{R_i 2\pi f} = \frac{1}{20{,}000 \cdot 2\pi 70} = 0.114\mu F$



4. (4pt) Write down the transfer function, H(jω), for each filter with numerical values for the coefficients.

LPF Filter 1:

$$H(j\omega) = -\frac{R_f}{R_i(1 + j\omega R_f C_f)}$$
$$= -\frac{1}{1 + j\omega 17.7x10^{-6}}$$

HPF Filter 2:

$$H(j\omega) = -\frac{j\omega R_f C_i}{1 + j\omega R_i C_i}$$
$$= -\frac{j\omega 2.27x10^{-3}}{1 + j\omega 2.27x10^{-3}}$$

5. (2pt) Which type of filters, Miller integrators or practical differentiators, have problems due to inherent noise in signals?

Practical Differentiators: they greatly amplify high frequency noise

They are also inherently unstable and some noise at the input can cause them to oscillate. Practically speaking, it is best to filter out this part of the response so the differentiator can do its job.

Either description is fine for this question.