Quiz II ECSE 1010 Spring 2016

Draw circuit diagrams for all problems, especially as you simplify the circuits.

Be sure to fully annotate plots, even when the problem does not ask you to do this.

Show all of your work

Almost all problems can be solved using more than one method. Check your answers by using a second method.

At least skim through the entire quiz before you begin and then start with the problems you know best.

The proctor will only answer clarification questions where wording is unclear or where there may be errors/typos. No other questions will be responded to.

Extra Task for Free Points: This semester is the second pilot version of this course, so I am still trying some things to find out the best type of questions to ask in quizzes to address the desired learning outcomes. Note that every step in each question has a point total assigned to it. For any part of a question that you find very challenging, circle the point total. An example is shown below. Do this for *up to 20 points* worth of question parts and you will receive 15 free points. If you find none of the questions challenging, please indicate that at the bottom of this page and you will also receive the 15 points.

c. (4 Pts) What should we do to fix the presidential election process in the US?

Excerpts from Florida Job Postings *Examples of what you should be looking at.*

Lockheed-Martin: Experienced Electronics Engineer (Cape Canaveral) Perform electronics engineering support of the completion of development activities and support of production for three Fleet Ballistic Missile D5 Life Extension Avionics packages.

Basic Qualifications

1. Degree emphasis in Electrical, Electronics, or Computer Engineering from an accredited college or equivalent professional experience combined with experience and specialized training commensurate with the position. 2. Familiarity with Electrical Engineering Simulation Tools (such as *SPICE*). Experience using lab equipment *(oscilloscopes*, *logic analyzers*, *power supplies*). 3. .Excellent communication skills with the ability to articulate complex technical issues to subordinates, peers, management, subcontractors and customers. 4. .Experience working in team environments and must model excellent interpersonal, communication and organizational skills. 5. .Must be willing to travel 1-2 times per month.

Desired skills

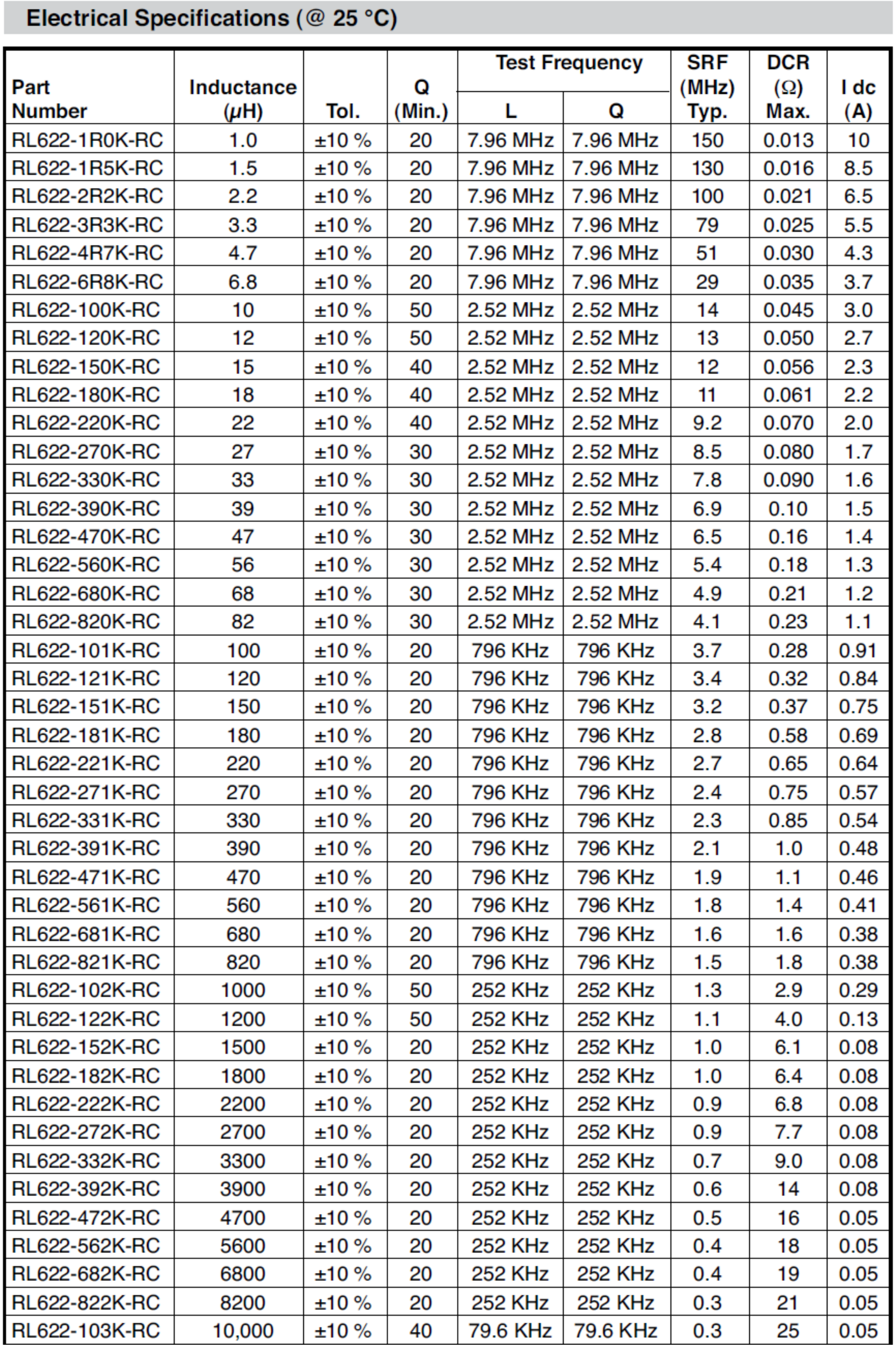
1..Automated test management software (such as Test Stand, Test Studio or *Matlab*)
2..Experience in the development of *analog, digital and/or mixed signal circuit design* for missile, spacecraft or aircraft avionics electronics 3.Mentor DxSim or Hyperlynx 4.C programming language proficiency 5.Experience as CPE or CPE delegate on avionics electronics package or component design 6.Experience in providing engineering support to electronics package production and the disposition of production hardware (E.g., Material Review Board or equivalent) and a long list of experiences not relevant to this course.

FARO: FPGA Electronics Engineer (Lake Mary) Focus on FPGA code development for image and video processing. In addition, the engineer will help design and develop circuit boards relating to the FPGA development, as well as troubleshooting boards to determine root cause of circuit and board failures.

HIRING PREFERENCES:

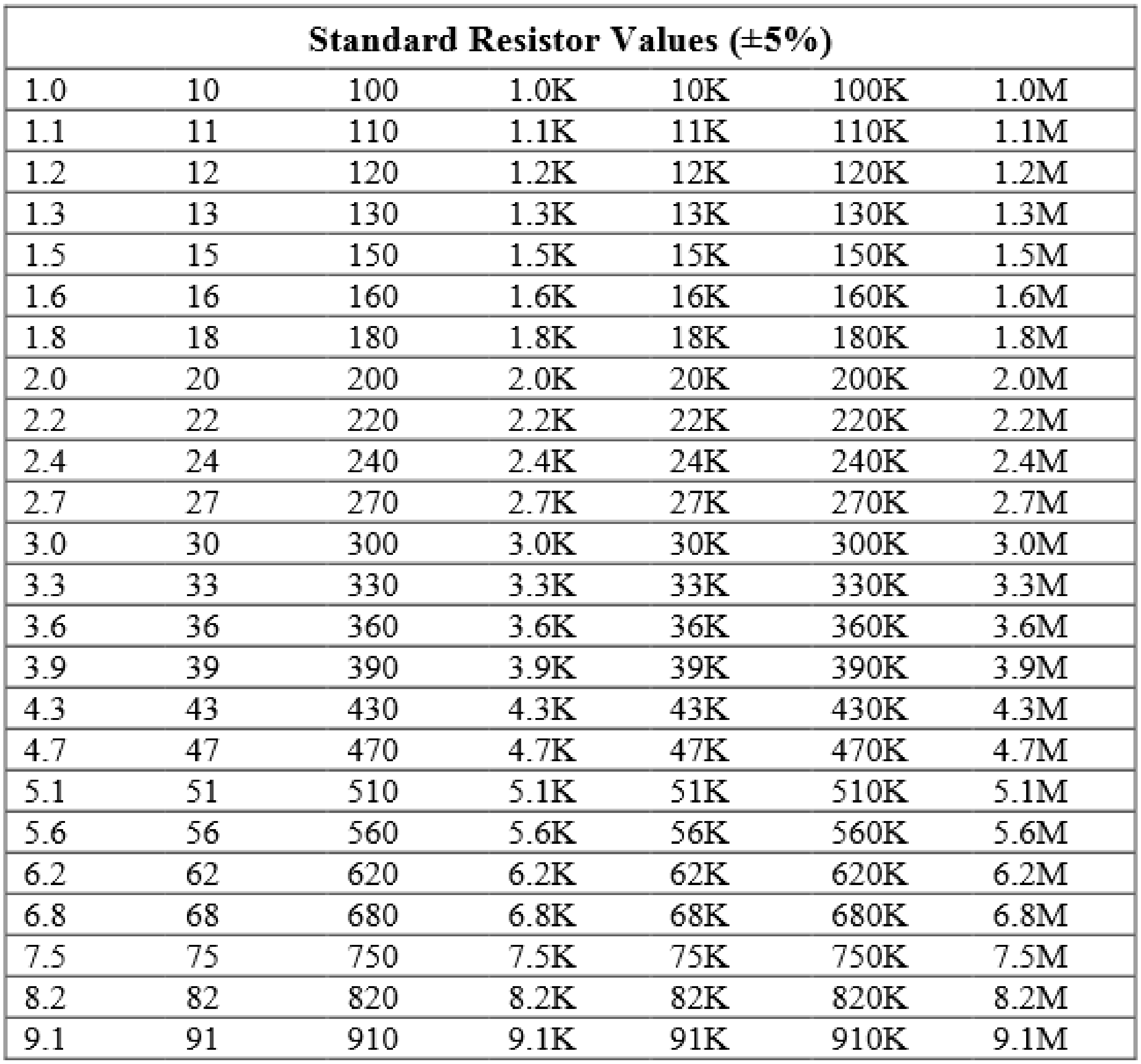
- Bachelor’s degree in Computer Engineering or Electrical Engineering
- 5+ years hands-on FPGA-based image processing development
- Experience with both Verilog and VHDL
- Experience creating image processing modules with *MATLAB*/Simulink
- Experience with Altera, Xilinx, and Modelsim development tools
- Outstanding debug/troubleshoot skills with *Oscilloscope*, *Logic Analyzer*, and on-chip analyzers such as Altera SignalTap or Xilinx ChipScope
- Embedded Microcontroller/Microprocessor/DSP and mixed signal circuit design experience
- Schematic capture tool experience: Cadence Allegro/OrCAD schematic capture preferred
- PCB Layout tool experience: Cadence PCB Editor layout preferred
- Embedded C/C++ desired

Inductance Specs – From Digilent Parts Kit Website



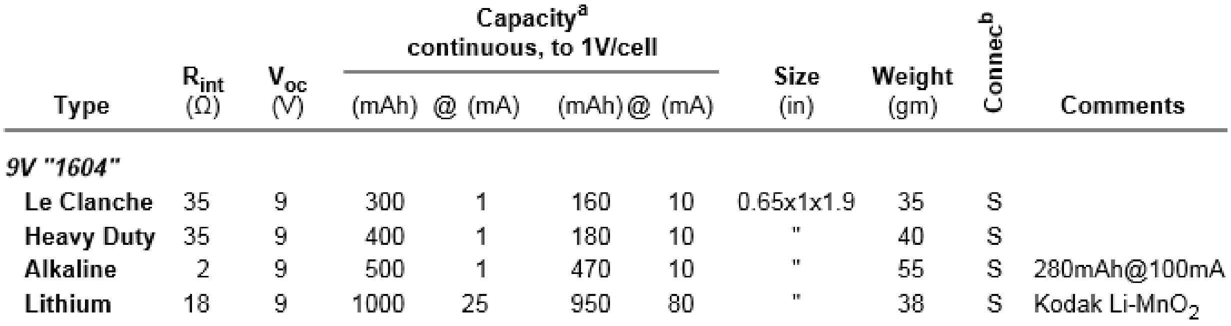
Electrical Specifications (@ 25 °C)

Part Number	Inductance (μH)	Tol.	Q (Min.)	Test Frequency		SRF (MHz) Typ.	DCR (Ω) Max.	I dc (A)
				L	Q			
RL622-1R0K-RC	1.0	±10 %	20	7.96 MHz	7.96 MHz	150	0.013	10
RL622-1R5K-RC	1.5	±10 %	20	7.96 MHz	7.96 MHz	130	0.016	8.5
RL622-2R2K-RC	2.2	±10 %	20	7.96 MHz	7.96 MHz	100	0.021	6.5
RL622-3R3K-RC	3.3	±10 %	20	7.96 MHz	7.96 MHz	79	0.025	5.5
RL622-4R7K-RC	4.7	±10 %	20	7.96 MHz	7.96 MHz	51	0.030	4.3
RL622-6R8K-RC	6.8	±10 %	20	7.96 MHz	7.96 MHz	29	0.035	3.7
RL622-100K-RC	10	±10 %	50	2.52 MHz	2.52 MHz	14	0.045	3.0
RL622-120K-RC	12	±10 %	50	2.52 MHz	2.52 MHz	13	0.050	2.7
RL622-150K-RC	15	±10 %	40	2.52 MHz	2.52 MHz	12	0.056	2.3
RL622-180K-RC	18	±10 %	40	2.52 MHz	2.52 MHz	11	0.061	2.2
RL622-220K-RC	22	±10 %	40	2.52 MHz	2.52 MHz	9.2	0.070	2.0
RL622-270K-RC	27	±10 %	30	2.52 MHz	2.52 MHz	8.5	0.080	1.7
RL622-330K-RC	33	±10 %	30	2.52 MHz	2.52 MHz	7.8	0.090	1.6
RL622-390K-RC	39	±10 %	30	2.52 MHz	2.52 MHz	6.9	0.10	1.5
RL622-470K-RC	47	±10 %	30	2.52 MHz	2.52 MHz	6.5	0.16	1.4
RL622-560K-RC	56	±10 %	30	2.52 MHz	2.52 MHz	5.4	0.18	1.3
RL622-680K-RC	68	±10 %	30	2.52 MHz	2.52 MHz	4.9	0.21	1.2
RL622-820K-RC	82	±10 %	30	2.52 MHz	2.52 MHz	4.1	0.23	1.1
RL622-101K-RC	100	±10 %	20	796 KHz	796 KHz	3.7	0.28	0.91
RL622-121K-RC	120	±10 %	20	796 KHz	796 KHz	3.4	0.32	0.84
RL622-151K-RC	150	±10 %	20	796 KHz	796 KHz	3.2	0.37	0.75
RL622-181K-RC	180	±10 %	20	796 KHz	796 KHz	2.8	0.58	0.69
RL622-221K-RC	220	±10 %	20	796 KHz	796 KHz	2.7	0.65	0.64
RL622-271K-RC	270	±10 %	20	796 KHz	796 KHz	2.4	0.75	0.57
RL622-331K-RC	330	±10 %	20	796 KHz	796 KHz	2.3	0.85	0.54
RL622-391K-RC	390	±10 %	20	796 KHz	796 KHz	2.1	1.0	0.48
RL622-471K-RC	470	±10 %	20	796 KHz	796 KHz	1.9	1.1	0.46
RL622-561K-RC	560	±10 %	20	796 KHz	796 KHz	1.8	1.4	0.41
RL622-681K-RC	680	±10 %	20	796 KHz	796 KHz	1.6	1.6	0.38
RL622-821K-RC	820	±10 %	20	796 KHz	796 KHz	1.5	1.8	0.38
RL622-102K-RC	1000	±10 %	50	252 KHz	252 KHz	1.3	2.9	0.29
RL622-122K-RC	1200	±10 %	50	252 KHz	252 KHz	1.1	4.0	0.13
RL622-152K-RC	1500	±10 %	20	252 KHz	252 KHz	1.0	6.1	0.08
RL622-182K-RC	1800	±10 %	20	252 KHz	252 KHz	1.0	6.4	0.08
RL622-222K-RC	2200	±10 %	20	252 KHz	252 KHz	0.9	6.8	0.08
RL622-272K-RC	2700	±10 %	20	252 KHz	252 KHz	0.9	7.7	0.08
RL622-332K-RC	3300	±10 %	20	252 KHz	252 KHz	0.7	9.0	0.08
RL622-392K-RC	3900	±10 %	20	252 KHz	252 KHz	0.6	14	0.08
RL622-472K-RC	4700	±10 %	20	252 KHz	252 KHz	0.5	16	0.05
RL622-562K-RC	5600	±10 %	20	252 KHz	252 KHz	0.4	18	0.05
RL622-682K-RC	6800	±10 %	20	252 KHz	252 KHz	0.4	19	0.05
RL622-822K-RC	8200	±10 %	20	252 KHz	252 KHz	0.3	21	0.05
RL622-103K-RC	10,000	±10 %	40	79.6 KHz	79.6 KHz	0.3	25	0.05



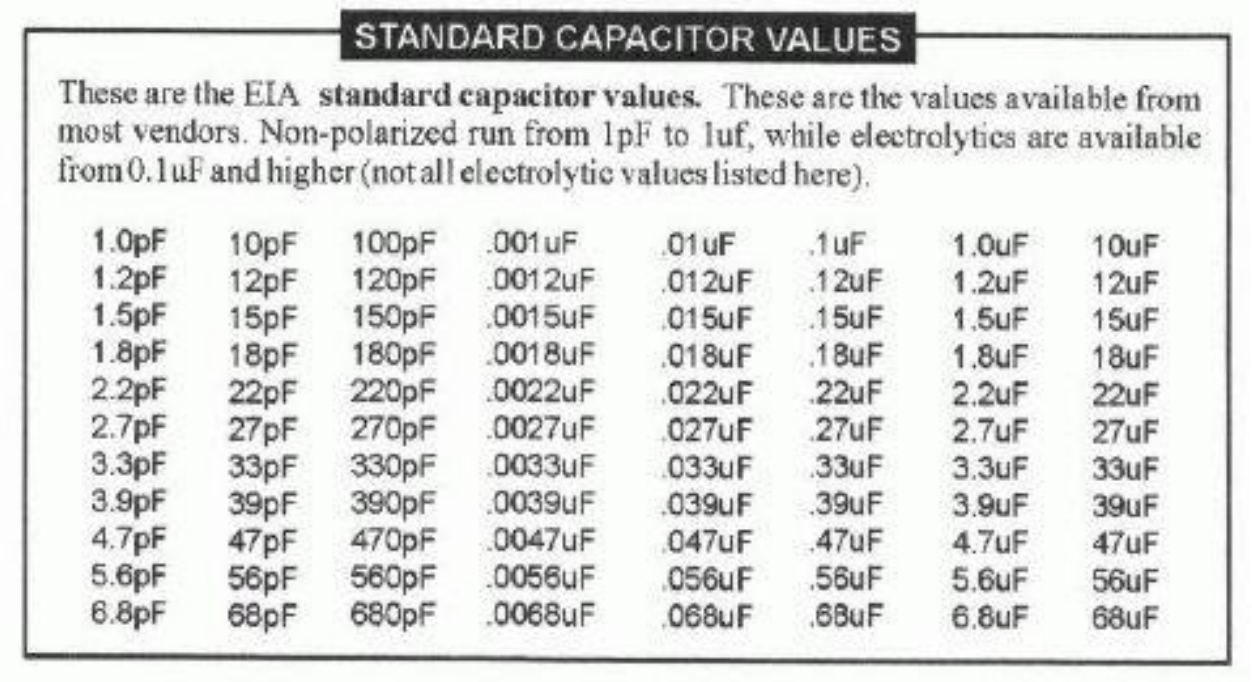
Standard Resistor Values (±5%)

1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M



			Capacity[a] continuous, to 1V/cell							
Type	R_{int} (Ω)	V_{oc} (V)	(mAh)	@ (mA)	(mAh)	@ (mA)	Size (in)	Weight (gm)	Connec[b]	Comments
9V "1604"										
Le Clanche	35	9	300	1	160	10	0.65x1x1.9	35	S	
Heavy Duty	35	9	400	1	180	10	"	40	S	
Alkaline	2	9	500	1	470	10	"	55	S	280mAh@100mA
Lithium	18	9	1000	25	950	80	"	38	S	Kodak Li-MnO_2

Standard Capacitor Values



STANDARD CAPACITOR VALUES

These are the EIA **standard capacitor values.** These are the values available from most vendors. Non-polarized run from 1pF to 1uf, while electrolytics are available from 0.1uF and higher (not all electrolytic values listed here).

1.0pF	10pF	100pF	.001uF	.01uF	.1uF	1.0uF	10uF
1.2pF	12pF	120pF	.0012uF	.012uF	.12uF	1.2uF	12uF
1.5pF	15pF	150pF	.0015uF	.015uF	.15uF	1.5uF	15uF
1.8pF	18pF	180pF	.0018uF	.018uF	.18uF	1.8uF	18uF
2.2pF	22pF	220pF	.0022uF	.022uF	.22uF	2.2uF	22uF
2.7pF	27pF	270pF	.0027uF	.027uF	.27uF	2.7uF	27uF
3.3pF	33pF	330pF	.0033uF	.033uF	.33uF	3.3uF	33uF
3.9pF	39pF	390pF	.0039uF	.039uF	.39uF	3.9uF	39uF
4.7pF	47pF	470pF	.0047uF	.047uF	.47uF	4.7uF	47uF
5.6pF	56pF	560pF	.0056uF	.056uF	.56uF	5.6uF	56uF
6.8pF	68pF	680pF	.0068uF	.068uF	.68uF	6.8uF	68uF

1N4148 Diode Characteristics

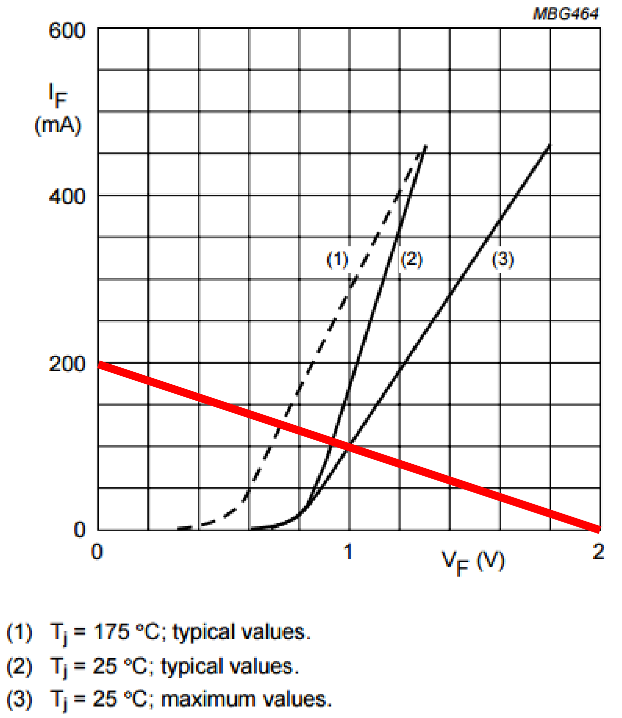


Fig.3 Forward current as a function of forward voltage.

High speed switching diode.

Continuous forward current I_F = 200mA

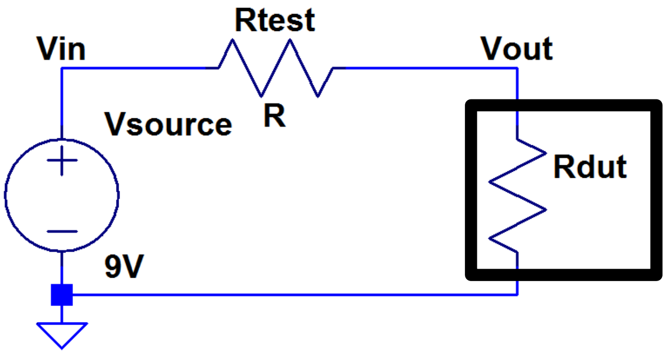
Total power dissipation P_{TOT} = 500mW

Forward voltage V_F from 0.6V to 1V

Note that 25 degrees Celsius is room temperature. When using the plot at the left, choose the curve for typical values at room temperature.

Load line passes through curve 2 at a little more than 100mA so about 110mA at a voltage a little more than .9 so about .92

Problem 1 (10 Pts) – Experimentally Determining an Input Impedance



Nearly all loads can be characterized by some kind of simple input impedance. For example, the two analog input channels on the Analog Discovery board have an input resistance of 1MΩ and an input capacitance of 24pF. The circuit at the right is set up to study a black box resistive load. It could be, for example, the resistance of a photocell. Six different test resistors are connected between the voltage source and the unknown Device Under Test (dut) and the voltage Vout is measured using a voltmeter that can only measure to 1 significant digit. The results of the six trials are listed in the table below. *Note that there is more information than you need and the resistance is a standard value.*

Trial	**Rtest**	**V(OUT)**
1	**1kΩ**	**8V**
2	**10kΩ**	**4V**
3	**50kΩ**	**1V**
4	**500Ω**	**8V**
5	**3kΩ**	**6V**
6	**30kΩ**	**2V**

a. (7 Pts) Determine the unknown resistance Rdut as accurately as you can. *Hing: the resistor has a standard value (see page 4).*

Take any trial number (trial 1). $Vout = 9\frac{Rtest}{1000 + Rtest} = 8$ or $1.125Rtest = 1000 + Rtest$ or Rdut = 8k. Closest is 8.2k. Trial 2: $Vout = 9\frac{Rtest}{10000 + Rtest} = 4$ or $2.25Rtest = 10000 + Rtest$ or Rdut = 8k

Trial 4: $Vout = 9\frac{Rtest}{500 + Rtest} = 8$ or $1.125Rtest = 500 + Rtest$ or Rdut = 4k

Trial 5: $Vout = 9\frac{Rtest}{3000 + Rtest} = 6$ or $1.5Rtest = 3000 + Rtest$ or Rdut = 6k

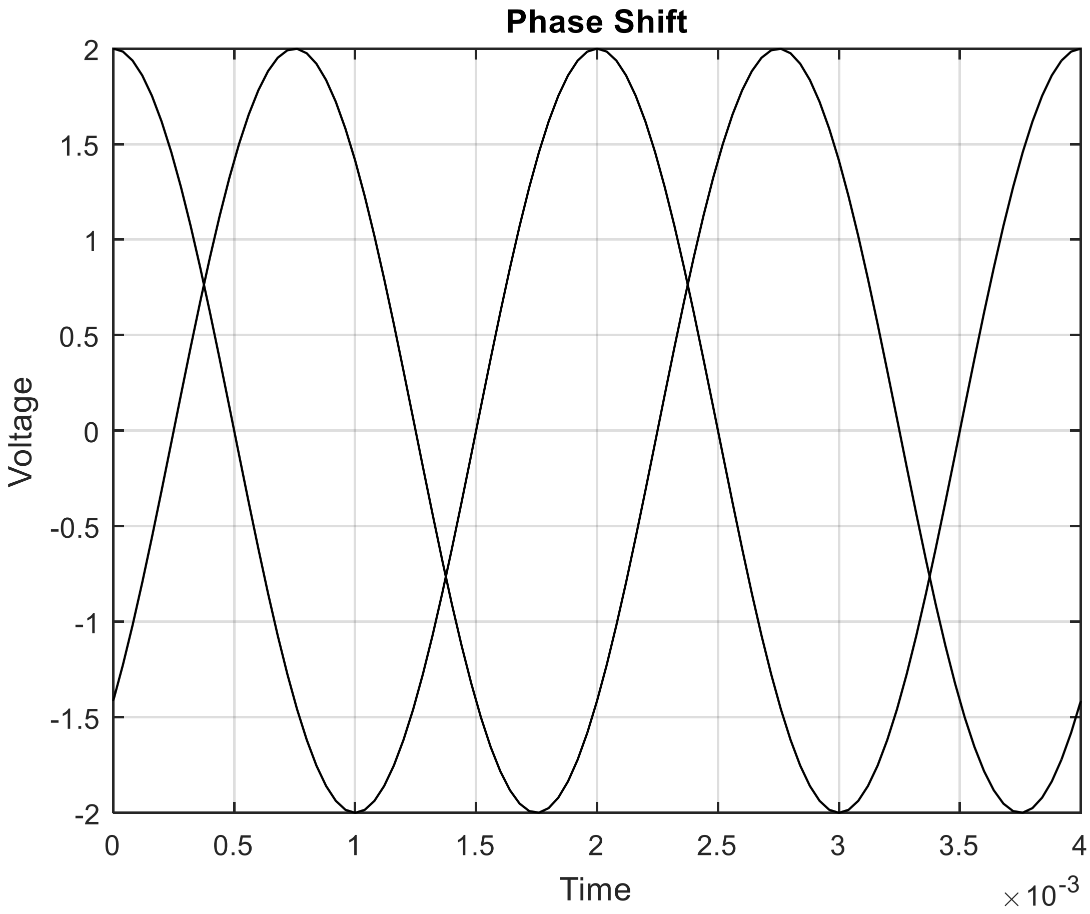
It should be between 6k and 8k, however, 8.2k and 5.6k are acceptable. The answer is 7.5k or 6.8k. With enough time to check all trials, the best answer is 7.5k. The average of all 6 is 7.3k.

b. (3 Pts) Which of the 6 measurements is the most accurate (the closest, in percentage error) to the actual value?

The trial at 1k is the most accurate, but the answer may change based on the solution to part a. The best way to check is to see what the voltage divider produces with different values for Rtest and Rdut. 7.5k will work the best, but others nearby will be close. Any reasonable answer will be accepted.

Problem 2 (10 Points) – Phase

In the Matlab generated plot below, two cosinusoidal voltages are shown vs time. $V(t) = \cos(\omega t)$ and $U(t) = \cos(\omega t + \theta)$. The magnitude of both voltages is 2V. The vertical scale is 0.5V/Div and the horizontal scale is 0.5ms/Div



a. (4 Pts) Determine the frequency *f in Hertz* and *ω in Radians.*

f = 1/T = 0.5k or 500Hz   ω = 1000π

b. (2 Pts) Determine the phase of *U* in degrees. *Be sure to specify its sign and remember it can have any value from -360 degrees to +360 degrees.*

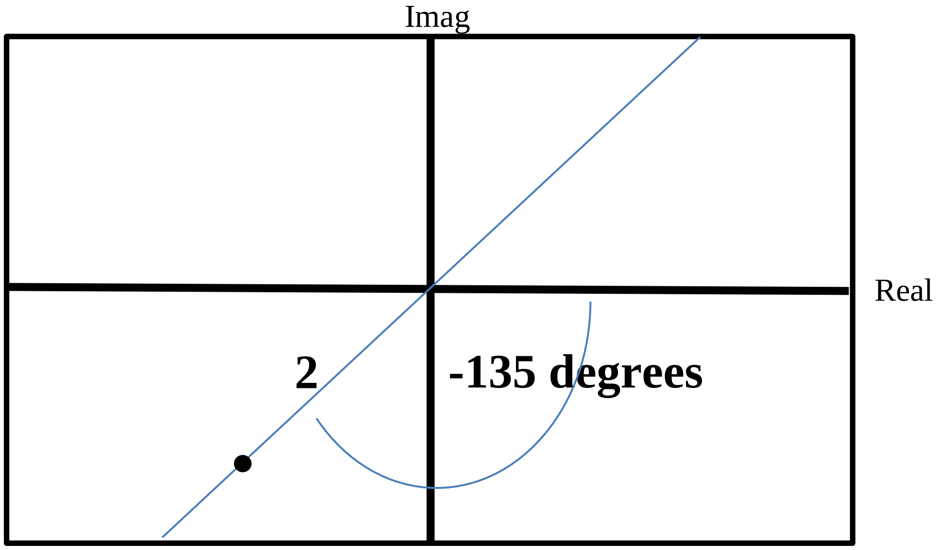
Phase is negative because U is to the right of V. Time shift is 0.75ms which is .75/2 times 2π. Thus phase shift is -0.75π or -135 degrees.

c. (2 Pts) What is the phasor form of $\tilde{U} = ?$

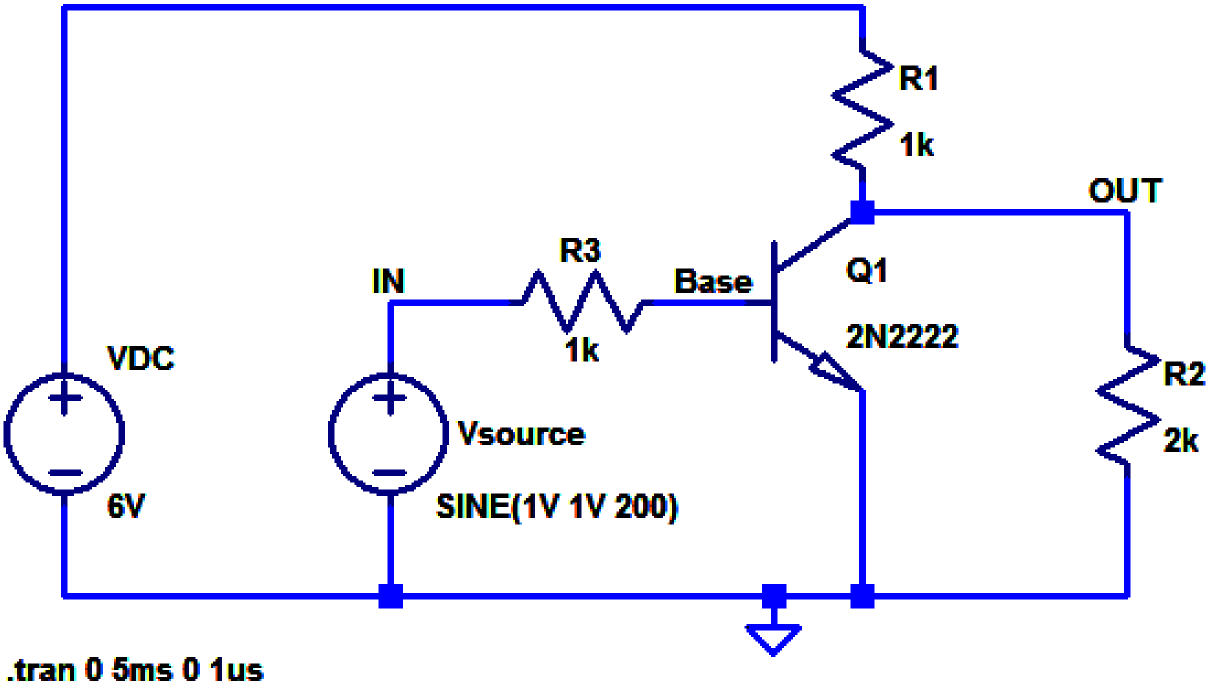
$$\tilde{U} = 2e^{-j\frac{3\pi}{4}}$$

d. (2 Pts) Plot the point for the phasor voltage on the complex plane. *Plot the point that represents its value as a complex number. Be sure to fully label the plot.*

Can also label the negative x and negative y values as square root of 2



Problem 3 (10 Pts) – Transistor as a Switch



In the circuit above, the 2N2222 NPN transistor is being used as a switch. The sinusoidal source voltage has a 1V amplitude and a 1V offset.

a. (4 Pts) Determine the voltage across resistor R2 when the source voltage Vsource is at or near its maximum value. Is the switch ON or OFF?

When the source is near its max, the switch is ON so the output voltage is zero.

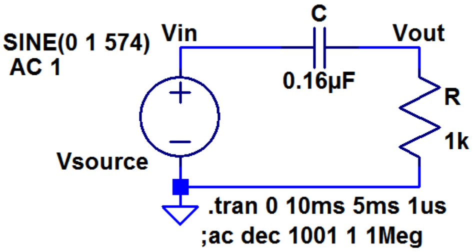
b. (4 Pts) Determine the voltage across the resistor R2 when the source voltage Vsource is at or near its minimum value. Is the switch ON or OFF?

When the voltage is near its min, the switch is OFF and the output is determined by the voltage divider. (2/3)6 = 4V

c. (2 Pts) Which of the following is true?
   [✓ a.] The transistor is ON more than half the time
   b. The transistor is OFF more than half the time
   c. The transistor is ON half the time and OFF half the time
   d. There is not enough information to select an answer from the choices above

The voltage is above 0.7V more than it is below, so the switch is ON more time than it is OFF.

Problem 4 (30 Points) – Phasor Analysis of Filters
A simple filter is configured with a capacitor and a resistor, as shown. For parts a-d of this problem, you are asked for the general functional form of expressions (i.e. in terms of ω, R, C, V_{source}, V_{in}). Do not plug in numbers until you are asked to do so.

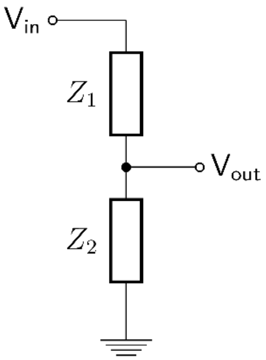


a. (2 Pts) Is this a high pass or a low pass filter?
High pass filter. C becomes short circuit at high f.

b. (2 Pts) What are the general forms for the impedances of a capacitor and a resistor as functions of frequency?

$$Z_C = \frac{1}{j\omega C} \qquad\qquad Z_R = R$$

c. (2 Pts) This circuit is of the general form shown at the right which is a voltage divider built with two general impedances rather than resistors. Write the general expression for V_{out} in terms of V_{in}, Z_1 and Z_2.



$$V_{out} = V_{in}\frac{Z_2}{Z_1 + Z_2}$$

d. (3 Pts) Find the general form of the filter transfer function $H(j\omega) = \dfrac{\tilde{V}_{OUT}}{\tilde{V}_{IN}} = ?$

$$H(j\omega) = \frac{j\omega RC}{1 + j\omega RC}$$

For the remainder of this problem, plug in actual numbers for components, voltages, etc.

e. (3 Pts) Evaluate your expression from part d for the given frequency (574Hz) and component values. *Your answer should be complex, but you do not need to simplify it yet.*

Find ωRC first, then plug in

$$\omega RC = 2\pi 574(1000)(.16x10^{-6}) = 0.577 \qquad \omega = 2\pi 574 = 3607$$

$$H(j\omega) = \frac{j0.577}{1 + j0.577}$$ For part f: $$H(j\omega) = \frac{j0.577}{1 + j0.577}\,\frac{1 - j0.577}{1 - j0.577} = \frac{0.333 + j0.577}{1.333}$$

f. (4 pts) Find the real and imaginary parts of your answer to part e.

$\mathrm{Re}\{H(j\omega)\} = ? = 0.25$ $\mathrm{Im}\{H(j\omega)\} = ? = 0.433$

For part g, convert to magnitude and phase.

g. (4 Pts) Using your answers to part f, write the transfer function in polar form. That is find the magnitude and phase (in radians and degrees). *Hint: The phase should be near π/n where n is some integer from 2 to 6.*

$$H(j\omega) = |H(j\omega)|e^{j\theta_H} = ? = 0.5e^{j\pi/3}$$

$$|H(j\omega)| = \sqrt{0.25^2 + 0.433^2} = 0.5 \qquad \theta_H = \tan^{-1}\left(\frac{0.433}{0.25}\right) = 1.05 = 60\,\mathrm{deg}$$

h. (2 Pts) For reference, find the corner frequency in radians and Hertz. $\omega_C = ?$ $f_C = ?$

Corner frequency $\omega_C = ? = 6.25k$ $f_C = ? = 0.994k \approx 1k$ Note that this is consistent with the magnitude being less than 0.707 because the filter is high pass and 574 is below f_c.

i. (2 Pts) The input voltage is given as $V_{IN}(t) = \cos\omega t$. That is, it has a magnitude of 1V, no phase and is at the given frequency. Write the input voltage in phasor form $\tilde{V}_{IN} = ?$

Input voltage $\tilde{V}_{IN} = ? = 1e^{j0} = 1$

j. (3 Pts) Solve for the output voltage in phasor form $\tilde{V}_{OUT} = ?$.

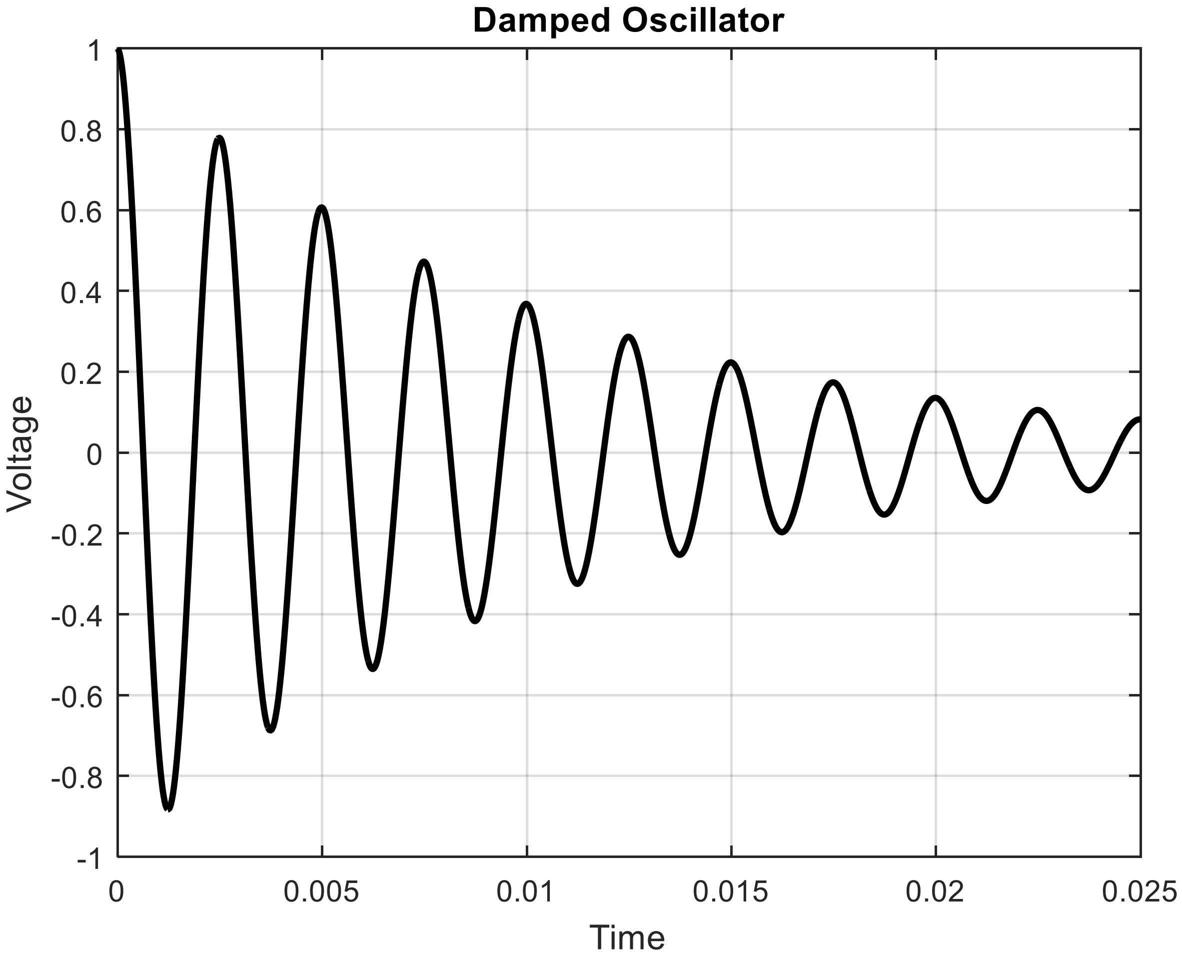
Output voltage $\tilde{V}_{OUT} = ? = 0.5e^{j\pi/3}$

k. (3 Pts) Convert the output voltage back to time varying form $V_{OUT}(t) = ?$

$$V_{OUT}(t) = 0.5\cos\left(3607t + \pi/3\right)$$

Problem 5 (10 Pts) – Damped Harmonic Oscillator

The voltage shown below is for a typical damped harmonic oscillator. The vertical scale is 0.2V/Div and the horizontal scale is 0.005s/Div.



a. (3 Pts) Determine the frequency of the oscillation *f*.

Two periods = 5ms so T = 2.5ms and f = 400Hz

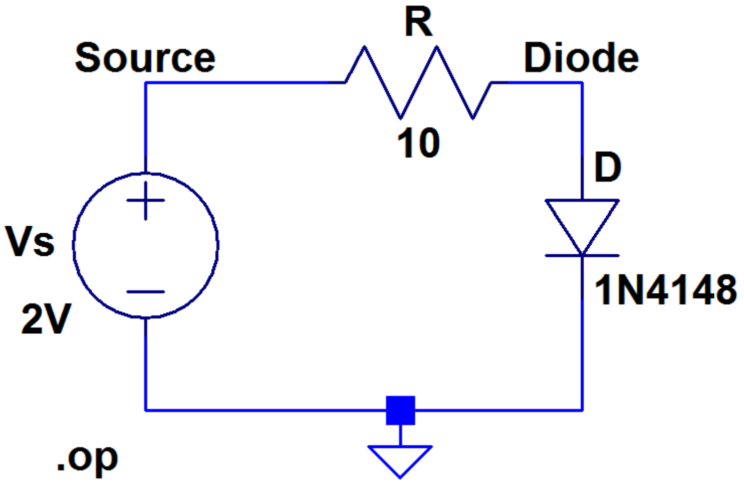
b. (3 Pts) Determine the damping constant of the oscillation $\alpha = {}^{1}\!/_{\tau}$

Evaluate at t = 0 (V = 10) and t = 5ms (V = 6) $10e^{-100(0.005)} = 6$ so $\alpha = 100$

c. (4 Pts) Write the mathematical expression for the voltage as a function of time in the form $V(t) = V_o e^{-\alpha t} \cos \omega t = 10e^{-100t} \cos 800\pi t$.

Problem 6 (10 Pts) – Diodes, Current, Voltage and Power

In the diode circuit shown, a 1N4148 high speed signal diode is used. This is similar to the 1N914 we have in the standard parts kit. The voltage source is DC. Information on the 1N4148 is found on page 5 above.



a. (4 Pts) Draw the load line on the current voltage plot found on page 5 and then determine the approximate operating point of the circuit. That is, find the diode current I_D and diode voltage V_D for this circuit. *These values will be approximate because you are reading them off of a plot.*

   From page 5 $I_D \approx$ 110mA and $V_D \approx$ 0.92V (anything reasonably close accepted)

b. (4 Pts) By applying Ohm's Law to your answer to part a, find the voltage across the resistor.

   Voltage across resistor is 10 time .11 or 1.1V.

c. (2 Pts) Verify that your answers to part a and part b are consistent by showing that the sum of the voltages across the resistor and the diode equal the voltage from the source.

   Add the voltage across the resistor to the voltage across the diode = 1.1 +.92 = 2.02V which is very close to the 2V of the source. Certainly, within our ability to read the numbers off of the plot on page 5.