

29:128 Homework Problems

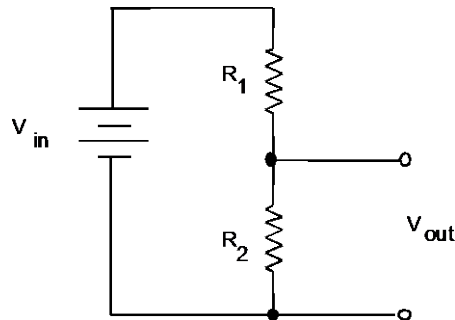
Revised 1 April 2016

29:128 Homework 1 (15 points)

references:

Sections 1.6-1.7 & 4.8, Meyer
Chapter 1 of Horowitz and Hill, 2nd Edition.

- (1) In the circuit shown below, $V_{in} = 9\text{ V}$, $R_1 = 1.5\text{ k}\Omega$, $R_2 = 5.6\text{ k}\Omega$,
- (a) Calculate V_{out}
 - (b) Calculate the power dissipated in R_1 and R_2 .
 - (c) Is a $\frac{1}{4}$ Watt resistor sufficient, or should you buy a resistor rated for a higher level of heat dissipation?



- (2) Repeat (1), but with $R_1 = 1.5\text{ }\Omega$, $R_2 = 5.6\text{ }\Omega$.
- (3) Suppose you have two ac signals, which we'll call signals A and B , which are sine waves that have *peak-to-peak* amplitudes of 30 mV and 600 mV, respectively.
- (a) What is the dB for signal A , as compared to signal B ?
 - (b) Your answer to (a) was either positive or negative. What is the significance of this sign?
 - (c) What are the *peak* voltages for signals A and B ?
 - (d) What are the *rms* voltages for signals A and B ?

29:128 Homework 2 (10 points)

references:

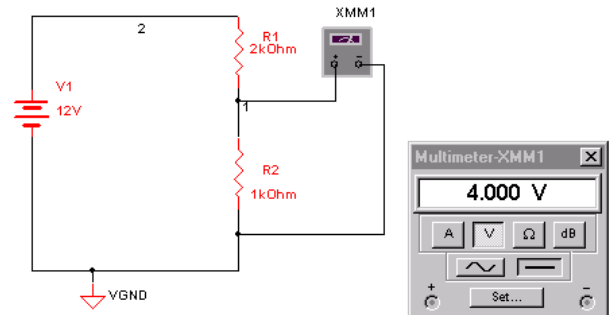
Sections 1.6-1.7 & 4.8, Meyer
Chapter 1 of Horowitz and Hill, 2nd Edition

notes:

- MultiSym is required for this homework set. Complete your work in 201 VAN, which closes at 5 PM. See Michael Ciha in 218 VAN for technical assistance with printers or PCs.
- If you have difficulty printing an image using Multisym, use the following Windows screen-shot trick:
 - Select the window you wish to print, type ALT-SHIFT-PRINT SCREEN to copy a bit-map image of that window
 - Paste into the Windows Accessory application called Paint, and then select and copy the rectangular portion of the image you want.
 - Open a blank Word document and perform a paste. You will now have a printable word document with a screenshot of what you saw on the monitor. You should hand in pages of hand-written solutions, pages printed from MultiSym.

(1)

(a) *Easy voltage divider problem.* Use Multi-sym to make a voltage divider circuit as shown in the screen shot to the right. For the resistors, use a “virtual” resistor, and add a multimeter as shown. Attach printouts of (i) the circuit and (ii) the multimeter display (it’s called an “instrument map” in Multisym’s print menu).



(b) Now change the component values to

the following: $V_1 = 9\text{ V}$, $R_1 = 1.4\text{ k}\Omega$ and choose a value for R_2 that will result in an output voltage of 5.0 V . Attach printouts of the circuit and multimeter display, and show a calculation of R_2 .

29:128 Homework 3 (30 points)

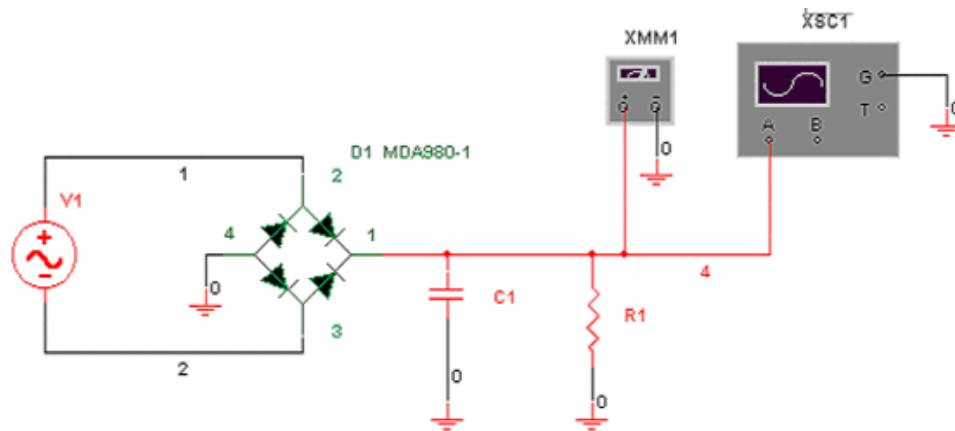
notes:

- Pages from Horowitz and Hill are needed to complete this assignment. They are available on ICON.
- MultiSym is required for this homework set.
- If you have difficulties making your circuit operate, try deleting nodes and then rewiring the circuit.
- You should hand in pages of hand-written solutions, pages printed from MultiSym, and the page of this question sheet that has the table for problem 2.

(1) Horowitz & Hill Exercise 1.27

Notes:

- This problem is related to a diode experiment in Laboratory 3, and you will find the problem easiest to do after you have done the lab.
 - Be careful not to confuse *peak* and *rms* amplitudes. Review these two concepts for ac signals, if you're not sure.
 - The electrical power in North America is 60 Hz.
 - Pay attention to diode drops – and to how many are experienced by the current as it makes a round trip from one side of the transformer secondary to the other
- (a) Solve the problem on paper. What you are supposed to do is choose the values of :
- (i) the *rms* voltage output of the transformer and
 - (ii) the value of the capacitor
- (b) What type of capacitor (ceramic, mylar, etc.) would you use (hint – see p. 22 Horowitz and Hill 2nd Edition)?
- (c) What is the value of the load resistance R_{load} , if the output current is $I_{\text{out}} \leq 10 \text{ mA}$. (Specify your result as either $R_{\text{load}} \leq X \Omega$ or $R_{\text{load}} \geq X \Omega$, whichever is appropriate.)



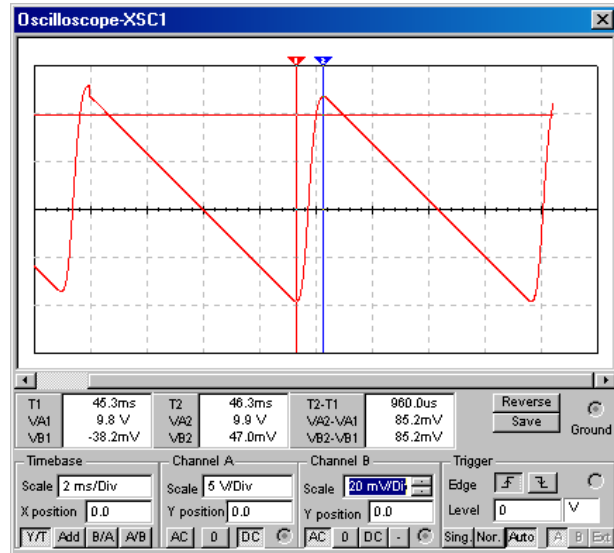
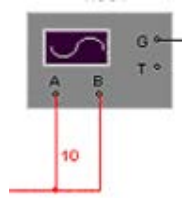
- (d) Set this circuit up as a simulation, using Multisym, as shown in the screenshot. The component values are hidden; you should use the values you found in part (a). Instead of using Multisym's transformer, use its ac voltage source, and specify the *peak* voltage corresponding to your result for 2 (a) (i).

(i) Choose the load resistor that you calculated for $I_{\text{out}} = 10 \text{ mA}$. Your circuit should begin with an ac voltage source that produces the ac voltage that you calculated in (a) as the desired output of the transformer. Be careful not to confuse rms with peak values of voltage. Use the MDA980-1 bridge rectifier. Attach a printout showing the circuit.

(ii) Set up an "oscilloscope" display. You will need to observe the waveform too ways, dc coupled to show the dc output level, and ac coupled to better show the ripple. You can connect the circuit's output to both the A and B channels to show both the dc and ac coupled signals at the same time, as shown in the screenshots.



ac voltage
source



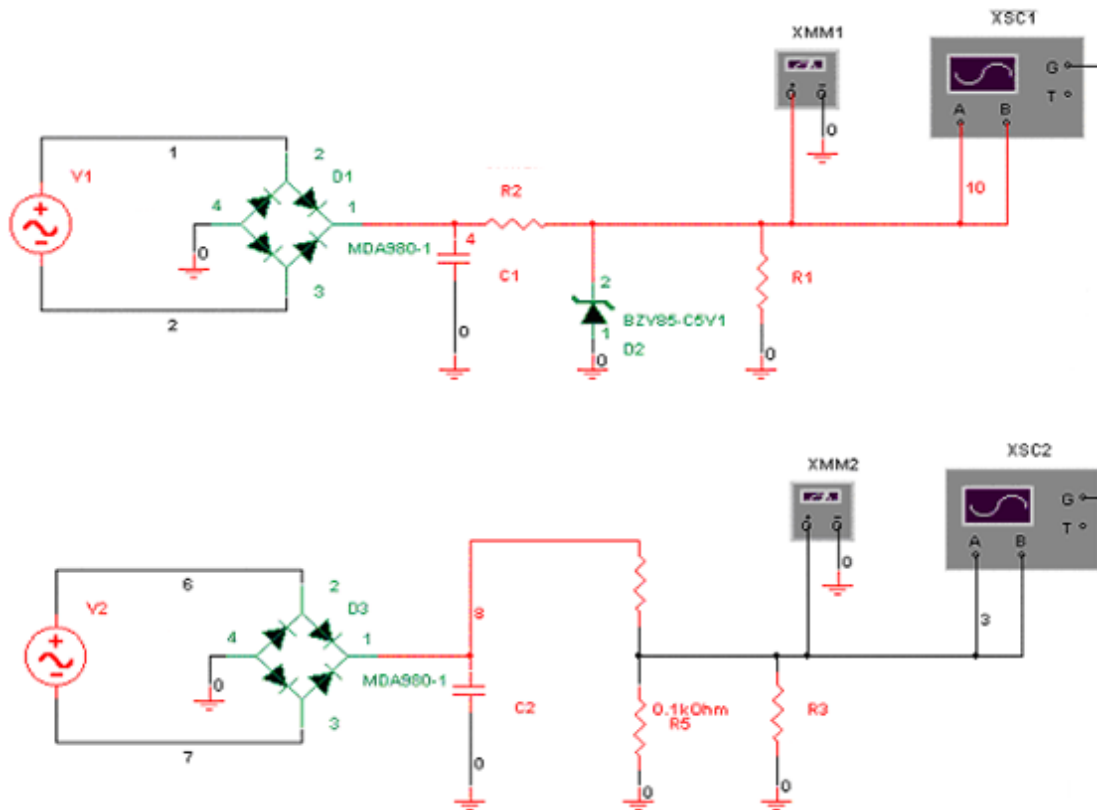
Be sure to choose vertical and horizontal scales that are suitable so that the signal with its peaks is easily seen and measured. Your results should look something like the screenshot presented here.

Use the two cursors to measure the voltage at the maximum and the minimum of the ripple; see the screenshot for an example.

Attach printouts of the oscilloscope display (it's called an "instrument map" in Multisym's print menu), showing both dc coupling, and ac coupling.¹

¹ For ac coupling, allow the oscilloscope trace to refresh itself twice before stopping and printing, otherwise you will only see an uninteresting transient at the beginning.

- (2) Suppose that you now decide that what you really want is a 5 V power supply. Here you will test two ways of adding components to your circuit above to achieve a 5 V output. The screenshot presented here shows both ways, with some component values hidden. When you are asked for a DC voltage, you must decide which “instrument” to use to make the best measurement.



- (a) After the filter capacitor, include a 5.1 V zener diode (for example, Philips BZV85-C5V1) with a series resistor. (i) Choose a value for the series resistor by testing two values, 100 Ω and then 1000 Ω , to see which gives you a smaller ripple. Report the corresponding peak-to-peak ripple values, as measured after the zener diode, and identify the value for the series resistor that gives the smaller ripple (Thereafter, always use that value for the series resistance.) (ii) Choose a value for the load resistor, which is located after the zener regulator; choose a value to achieve a load current of 10 mA (at 5 Volts). Attach a printout of your circuit. (iii) Set up an “oscilloscope” display first with dc coupling showing the peak dc output and then with ac coupling showing the peak-to-peak ripple. (Be sure to choose vertical and horizontal scales that are suitable so that the signal with its peaks is easily seen and measured.) Using the cursor measurements, measure the peak-to-peak ripple. Also measure the DC voltage (note that at the end, you will need to calculate a difference of this DC voltage and another

nearly equal DC voltage, so it is necessary to measure the DC voltage with sufficient digits.) Attach printouts of instrument maps.

(iv) Repeat (iii) with the load resistance increased to 1 G Ω (so that there is essentially zero output current through the load).

(b) Repeat parts ii-iv above, but instead of the zener diode and its series resistor, use a pair of resistors in series, to form a voltage divider. Use the same load resistor that you used above in part (a)(i). For the resistor in parallel with your load, use 100 Ohms. Calculate the value of the other resistor yourself, to achieve the desired output voltage (as measured with the load resistor, not as measured with a 1 G Ω load).

(c) Fill out this table, and hand it in with your solutions (you may make a handwritten version of the table if you wish, so that you can keep the original copy of this page):

<i>Method of reducing output voltage to 5 V.</i>	<i>dc output voltage (V)</i>	<i>ripple voltage peak-to-peak (mV)</i>
Zener regulator, with 10 mA output current through load		
Zener regulator, with 0 mA output current through load		
Difference in DC voltage		XXXXXXXXXX XXXXXXXXXX

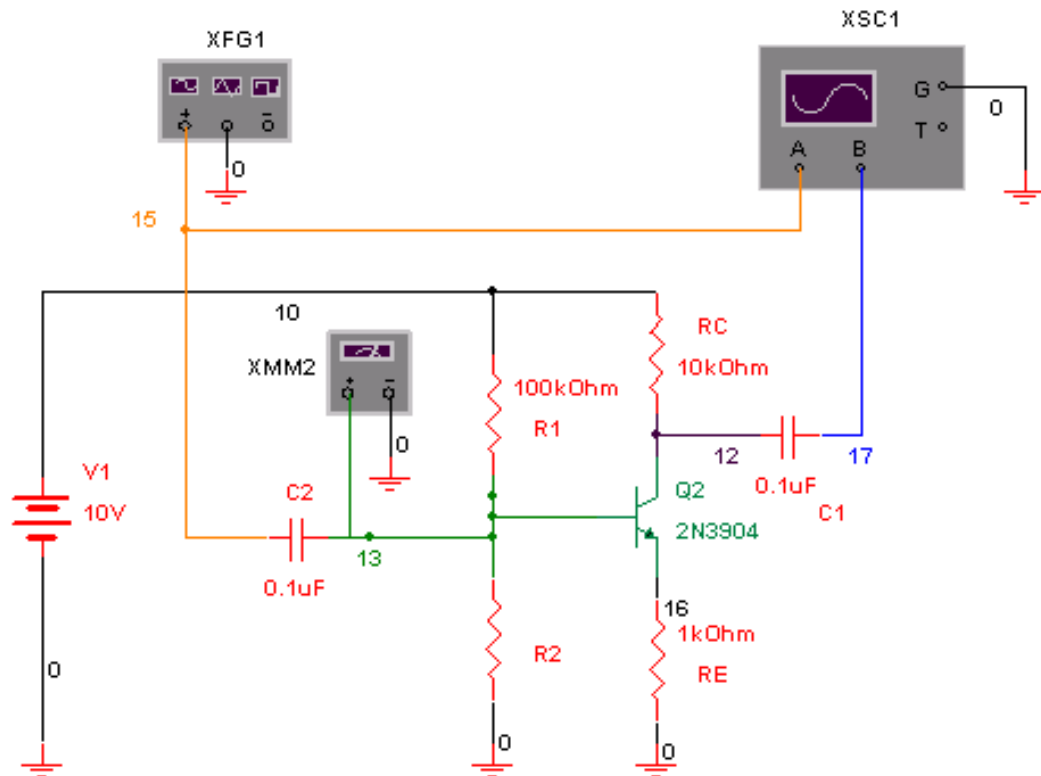
Voltage divider, with 10 mA output current		
Voltage divider, with 0 mA output current through load		XXXXXXXXXX XXXXXXXXXX
Difference in DC voltage		XXXXXXXXXX XXXXXXXXXX

(d) State which method of reducing the output voltage to 5 V is more desirable (voltage divider or zener)? Write down *two* reasons for your answer.

29:128 Homework 4 (20 points)

note: this homework assignment requires the use of MultiSym to simulate a circuit.

- (1) Common-emitter amplifier. Use Multisym to connect the circuit shown in the screen shot below. The value of R2 is not shown.
 - a. Choose a standard value for 5% resistors, as tabulated in Appendix C, to achieve a base bias that results in the most symmetric output waveform possible. Show your calculation, including a result for the base bias that you intend to achieve.
 - b. Before running the simulation, you need to choose reasonable values for the sine wave amplitude and frequency that you will use to test the circuit. Note that the circuit has capacitive coupling with $C2 = 0.2 \mu\text{F}$ and an unknown resistance that will be tens of kiloOhms. Estimate the corresponding RC time and roll-off frequency. Choose a frequency that is at least one or two orders of magnitude higher than the roll-off frequency (but less than radio frequency) so that your waveform will not suffer from the high-pass filtering effect of capacitive coupling.
 - c. Run the simulation with a sine wave amplitude of approximately 600 mV and observe the clipping.
 - d. Vary the value of R2 to test whether you chose the optimal value.



After you are certain that you have chosen the optimum value of a standard 5% resistor, attach a printout² of the circuit schematic diagram as shown below (but showing the value of R2), and a printout of the oscilloscope display showing the clipping of the output waveform. Be sure that the time scale for the oscilloscope appears in your printout. Also include a map of the function generator so that I can see the frequency you chose.

- e. Use the multimeter to measure the dc voltage on the base, and report this value.
- (a) Reduce the input voltage amplitude to ~ 100 mV. Use the cursors to measure the input and output waveforms, at the maximum and minimum values. Reprot the peak-to-peak measurements. Calculate the ratio, including a minus sign if any, and report this as the gain. Repeat for $R_C = 2$ k and $R_C = 5$ k. Compare to the theoretical values. Report your results in a table, similar to this:

	Measured peak-to-peak input	Measured peak-to-peak output	Measured gain	Theoretical gain
$R_C = 2$ k				
$R_C = 5$ k				
$R_C = 10$ k				

² Note: be sure that *all* your attached printouts are labeled by question number, for example one of your plots will be labeled “question 2 (d) ii, ac coupling” Label this in the lower-right hand corner of your printout. It’s okay to label it by hand.

29:128 Homework 5 (20 points)

note:

- Pages from Horowitz and Hill 2nd Ed. are needed to complete this assignment. See ICON.
- This homework assignment DOES NOT require the use of MultiSym

(1) Exercise 4.2 in Horowitz and Hill. (10 points)

- Show that $I_{\text{load}} = -V_{\text{in}} / R_2$.
- Provide a consolidated list of the principles and/or rules that you invoke in your solution
- Notes:
 - Recall that an opamp output can source or sink current
 - Watch the polarity \pm when writing an expression for a voltage drop or a current. If you are inconsistent with this, you cannot get the correct result.

(2) Exercise 4.3 in Horowitz and Hill. (5 points)

- (a) For circuit A, show that gain = +1 with the switch in the follower position, and that gain = -1 with the switch in inverter position.
- (b) Repeat, for circuit B.

(3) Exercise 4.5 in Horowitz and Hill. (5 points)

29:128 Homework 6 (15 points)

note:

- Pages from Horowitz and Hill are needed to complete this assignment.
- This homework assignment DOES NOT require the use of MultiSym; it does require LabView software.

1. Digital Electronics: Do the following exercises in Horowitz and Hill 2nd Edition

exercise 8.7

exercise 8.9

exercise 8.12

2. Lab View exercise #1

3. Lab View exercise #2

29:128 Homework 7 (10 points)

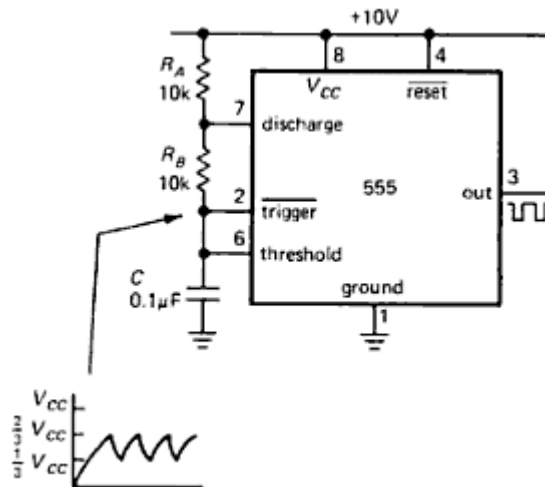
note:

- This homework assignment DOES NOT require the use of MultiSym. It does require the use of LabView.

(1) Consider the 555 timer circuit shown here. Show that the period is

$$T = 0.693 (R_A + 2 R_B) C.$$

Hint – review capacitor charging in the time domain (Meyer Sec. 2.7.1 or Horowitz & Hill pp. 23-24).



(2) Lab View Exercise #3 (some steps do not require any response in the paper you hand in – see instructions).

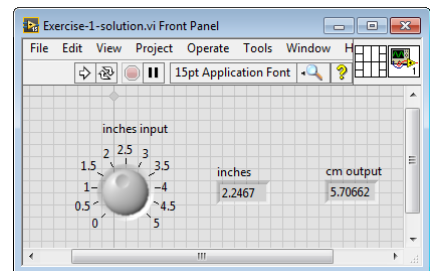
LabView Exercises

LabView Exercise #1: Environment: block diagram, front panel, indexing, graph

- If you don't already know how to start and run Labview, watch the first three training videos on the "LabVIEW Environment": (10 min total, you may need to watch more than once)

<http://www.ni.com/academic/students/learn-labview/>

- Create a blank VI. Then write a VI, i.e., program, that converts inches to centimeters, with a "knob" input for the input ranging from 0 to 5 inches, and numeric indicators for the input and output values. Label your panel parts.
- This simple VI does not need a loop. To operate it, you will just turn your input knob to the desired value, then click the run button to make it run once.
- Print out your and "block diagram", and "front panel." The front panel should look similar to the example here, with the knob turned close to the middle of its range.
- Save this VI; you will use it later for exercise #2

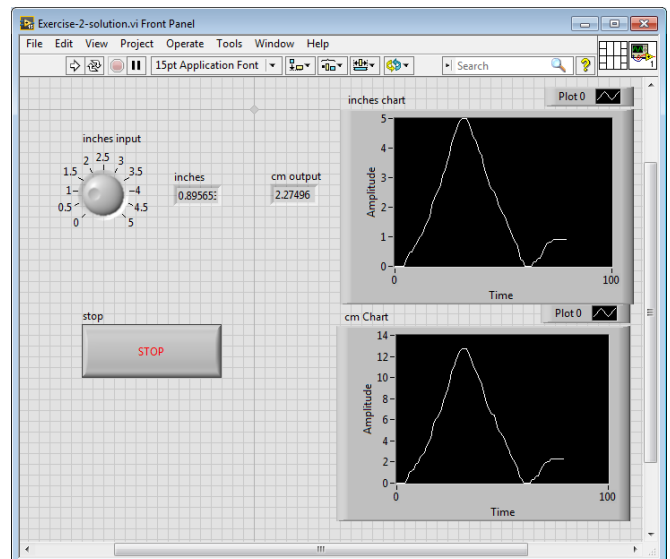


LabView Exercise #2: loops, charts

- View the videos for While Loops and For Loops on the LabVIEW "Loops and Execution Structures" (12 min total, you may need to watch more than once.)

<http://www.ni.com/academic/students/learn-labview/>

- Adapt the VI that you made in exercise #1, adding a "while" loop and "waveform charts" for both the inches input and cm output. Include a stop switch. Include a "wait" timer in the loop, set for 200 msec.
- Run the VI, turning the input gradually from 0 to its maximum, then to its minimum, then back up to about 1 before stopping it. Print the Block Diagram and the Front Panel, which should look similar to the example here.



Labview Exercise 3: Lab View DAQ using USB-6008

A. BASIC VI to output a DC voltage (this is a training step, no response is needed in the assignment that you hand in.).

A0. Check the cables on your analog-to-digital converter.

You will use the small white-colored device made by National Instruments, model number USB-6008. This device has several channels of inputs and outputs, with a 12 bit resolution and a maximum rate of 10 kilosamples/sec. The user manual and data sheet can be found on the NI website, or [here](#).



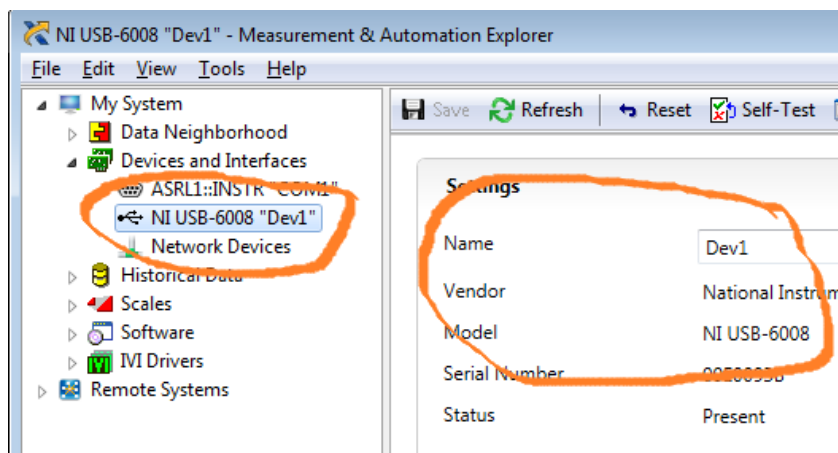
Examine your USB-6008 converter to verify that it has three cables:

- A red & black wire pair connected to analog output terminals A01 and GND. The other end of this cable should be terminated by a dual banana plug.
- A coaxial cable connected to analog input terminals A10 and GND. The other end of this cable should be terminated by a 3.5 mm coaxial headphone plug.
- A USB cable.

If any of these three cables are missing, your converter is not suitable for use.

A1. Test your computer for the required drivers:

- Connect to a multimeter set to measure DC voltage on a 20 Volt scale.
- Connect the USB-6008 to PC using USB cable.
- Launch NI-MAX to confirm that device is connected as shown in the screenshot:



If the device does not appear immediately, press <F5> to refresh the view in NI-MAX.

Verify also that the green LED light is blinking. This completes the test for drivers and functionality of the converter. Quit NI-MAX, Launch LabView.

A2 Training for using DAQ Assistant in Labview

Create a blank VI

On the block diagram:

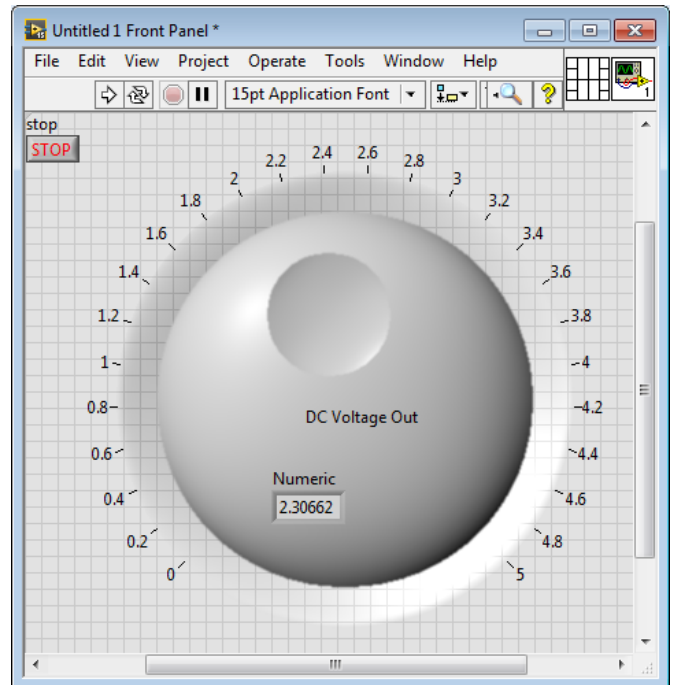
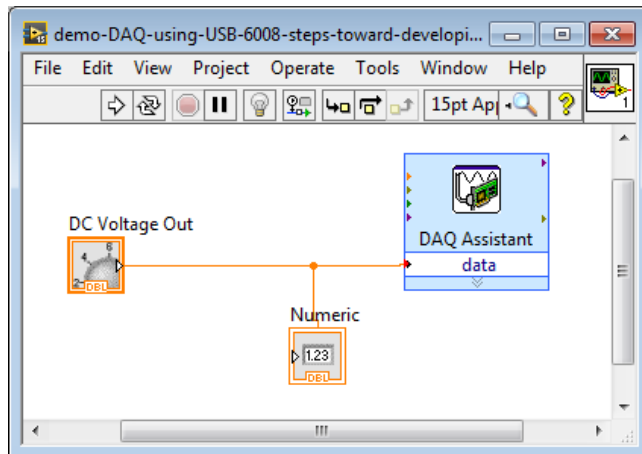
- right click, Measurement I/O > NI-DAQmx > DAQ Assist
- In the DAQ Assistant dialog that opens, choose Generate Signals > Analog Output > Voltage > Dev 1 a01 > Finish. Then leave all default settings and click OK to exist DAQ Assistant. You should now have a Block Diagram with one item, the DAQ assistant.

In the Front Panel:

- right click, numeric, knob. Left click to deposit on front panel.
- Change upper value on knob to 5. Rename knob "dc voltage out"
- Add a numeric indicator to the front panel.

In the block diagram:

- connect the knob to the data input on the DAQ Assistant
- connect the numeric indicator so that it displays the DC Voltage Out from the "knob"



Run the VI several times, and observe that the voltage displayed on your multimeter changes to respond to a changing position of the front-panel knob.

At this point, you have made a DAC that outputs a single voltage once and then leaves that voltage on its output indefinitely.

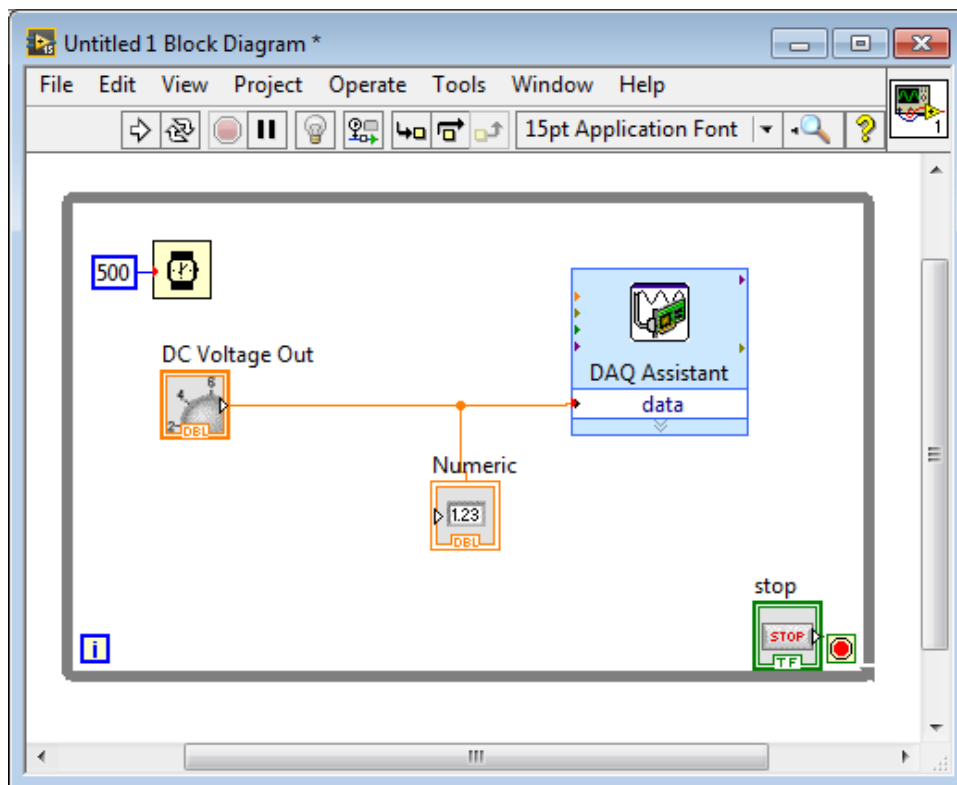
A3. Training step: add a While Loop

In the Block diagram:

- right click > Structures > while loop.
- right click stop sign to add a control
- right click > timing > wait (ms)
- right click > numeric > numeric constant . Change value to 500 (milliseconds).

Run the VI:

- adjust the knob up and down slowly while watching the multimeter display.
- Click stop button, and verify that further adjustment of the knob do not cause the voltage to change.



Exercise 3, part A. Do the following to hand in as part of your HW assignment.

On the front panel:

delete the knob, and add a numeric constant which you should rename "Vout_max". Change its value to 4.

On the block diagram

replace the While loop with a FOR loop; specify $N = 8$ iterations; change the wait time to 3000 millisec; insert a mathematical division to compute i/N , where i is the iteration; insert a mathematical multiplication to compute $(i/N) * V_{out_max}$. The latter is the quantity that you wish to be produced as an output voltage, so connect it to the data input of the DAQ Assistant; also connect the Numeric display on the front panel to this value.

Run the VI, while watching your multimeter. You should see the analog voltage increase in increments of 0.5 volts, at intervals of 3 seconds, until it reaches its final value, which should be approximately 3.5 V.

After running the VI, with the front panel indicating the condition after running it, print the front panel and block diagram, mark them as: assignment 3, part A, and hand these in.

Exercise 3, part B. Do the following to hand in as part of your HW assignment.

Sine wave generation:

- Use a computer, tablet, or smart phone. Open a web browser to open a webpage such as <http://onlinetonegenerator.com/>. Try producing a sine wave of 440 Hz (middle C). If you have headphones or earbuds, verify that an audible signal is coming out. Repeat for several frequencies from 300 to 600 Hz, to verify that the pitch of the sound varies with the expected trend.
- Now change the output of the sinewave to 50 Hz. This frequency might be too low for your headphones to work well, but it is suitable for the measurement that you are about to do.
- Examine your A to D device: it should have a cable connected to input AI0 and GND at one end, and a 3.5 mm coaxial headphone plug on the other end. Insert the 3.5 mm plug into the computer/tablet/smart phone headphone jack.
- Adjust the volume of the app on the webpage to approximately 50%, and the volume of the PC to about 50%. Your PC should now output a 50 Hz sine wave of approximately 0.25 V peak-peak on the 3.5 mm plug.

Create a blank VI

On block diagram:

- right click, Measurement I/O > NI-DAQmx > DAQ Assist

In the DAQ Assistant dialog that opens:

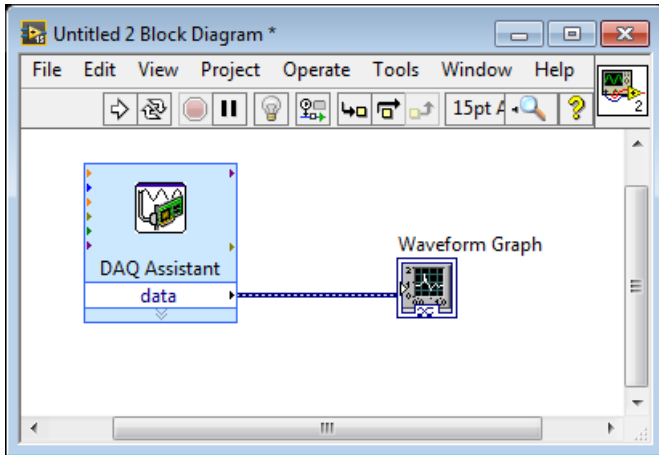
choose Acquire Signals > Analog Input > Voltage > Dev 1 ai0 > Finish. In the box that appears for configuration, change the max and min signal input range to 3 and -3 volts, respectively. Leave all default settings, including:

- “samples to read” of 1k
- sampling “rate” of 1k, meaning 1000 samples per second are recorded.
- Note that the combination of these two settings corresponds to a data-recording time of 1k samples / 1k samples per sec = 1 sec).

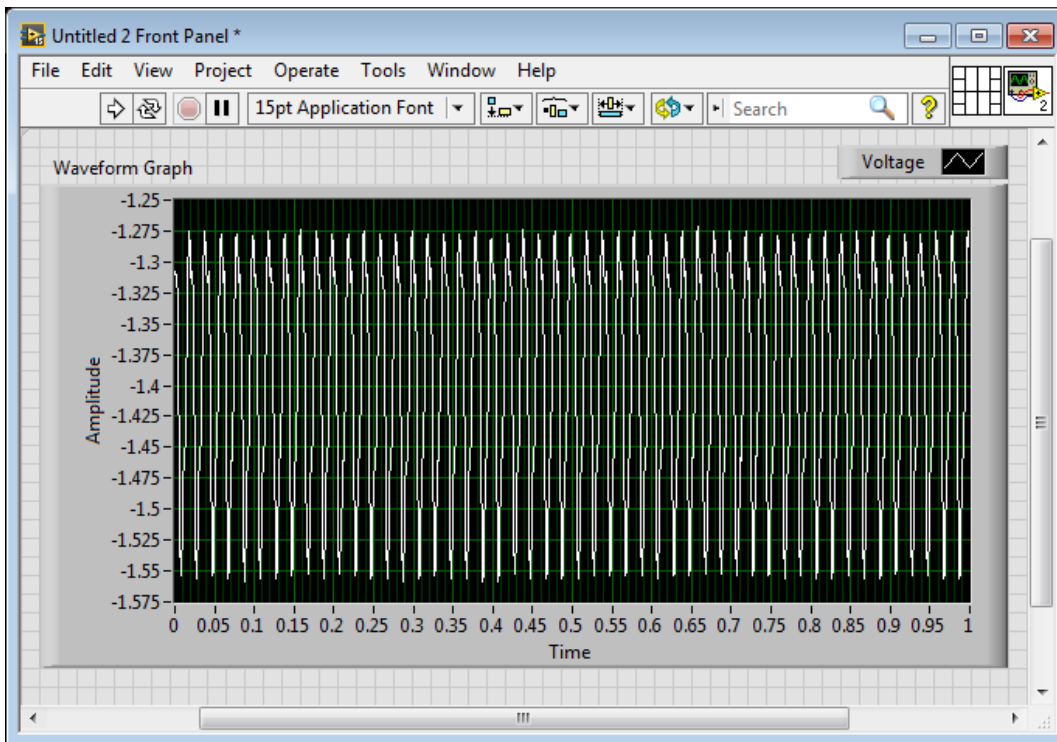
Click OK to exit DAQ Assistant. You should now have a Block Diagram with one item, the DAQ assistant.

On the front panel, add a “waveform graph” and enlarge it so that it is as about 15 to 25 cm width on your monitor. In its properties, leave the default settings as they are.

In the block diagram, connect the data output of the DAQ assistant to the input of the waveform graph. The block diagram will consist of only these two items, without any loops or other features.



Run the VI once. Your waveform chart should look like the example below. Print this waveform and label it as “Exercise 3, part B”. Manually count the number of oscillations that you see, and write this on your printout. (You should see 50 +/- 1, oscillations.) To understand this result, recall that you used a 50Hz signal, you digitized for 1k samples at 1k samples per sec, so the duration of the recording should be 1k samples / 1k samples/s = 1 sec.



Exercise 3, part C

For this exercise, you will use the same VI. The only difference is that you will now select different input frequencies generated on the 3.5 mm plug using the webpage.

- 1) Run the app for these frequencies: 504 Hz and 510 Hz.
- 2) Print the waveforms. Count the peaks of the oscillations that you see, within the 1 sec time interval that is plotted. You should obtain an answer that is a few Hz.
- 3) Write a maximum of two sentences to explain why the number of oscillations that you see is much smaller than the 504 and 510 that you might expect, based on the frequencies and the 1 sec long graph. (In grading your response, two items that we will look for are: a particular keyword that was a point of discussion in the lecture on analog-to-digital conversion, and the name of a particular equation, inequality, or parameter.)

Be sure to turn off your multimeter when finished.