Laboratory Measurement Procedures

Objective: The objective of this laboratory is to review some basic laboratory measurement procedures and introduce students to a method for making computer-controlled measurements of electronic circuits.

Discussion: There are several issues that have limited the ability of quite a few students to efficiently make measurements in an electronics laboratory. Some measurement procedures that should help students become more proficient in making basic measurements will be reviewed.

In previous laboratory courses, all measurements have been made manually with instrument control through the front panel of the test equipment. Further more, all data generated by these measurements has been recorded manually. This process makes gathering large amounts of data very time consuming and increases the vulnerability to data recording errors. Much of the test equipment sold today includes a network interface capability that allows for control of the equipment with an external controller such as a personal computer. Most of the equipment in the laboratory used for this course has this interface capability. The industry standard interface with test equipment uses the HP-IB interface which was initially established by IEEE but which has been adopted as an industry-wide standard. Some refer to it as the IEEE-488 interface. With this interface, most if not all front panel controls can be redirected to the external controller and in some cases more control capability exists with the external controller. With this approach, the front panel of the instrument need not even exist and some test equipment has evolved that does not even have a local control panel.

There are several companies that provide software for controlling test equipment over the HP-IB bus. Hewlett-Packard developed VEE and it has been a product of Agilent since the Agilent spin-off from HP. National Instruments specializes in control of test equipment and has several software packages that are widely used in industry. Their flagship product is Lab View. More recently they have been providing Signal Express which has a simplified user interface. In this experiment we will work with Signal Express.

Just because an instrument has an HP-IB interface does not mean that it can be easily used with a particular software package. A software module, termed a driver, must be written for each piece of test equipment and this driver serves as the interface between the software and the piece of test equipment. Some drivers provide complete control capability of a piece of test equipment and others may provide more limited control capability. The same can be said for the software tools such as VEE, Lab View, and Signal Express.

In our laboratory, the multimeter (34401a), the signal generator (E33120a), the triple output power supply (E3631a), and the oscilloscope (54602b) all contain an HP-IB interface. The power supply (E3630a) does not contain the HP-IB interface. Through Signal Express, drivers for the multimeter, the signal generator, and the triple output

power supply are available. We do not have a driver for the oscilloscope. Documentation for the use of Signal Express is available form the National Instruments WEB site at http://sine.ni.com/nips/cds/view/p/lang/en/nid/14216 .

Signal Express provides a graphical interface that uses a "drag-and-drop" approach to define a sequence of signal generation and measurements. These measurements can be nested in loops for repeated measurements or for measurements under different test conditions. The outputs can be exported with a "drag-and-drop" approach directly into Excel.

A demonstration of the use of Signal Express for measuring the I-V characteristics of a device and for obtaining the frequency response of a circuit will be made by the Teaching Assistant at the beginning of this experiment.

Part 1   Review of Measurement Procedures

Theoretical and Experimental Results

Almost all measurements in the laboratory will involve experimental validation of characteristics of circuits that you design or are asked to characterize. The theoretical performance of all circuits should be known before taking any measurements and the measurements in the laboratory should be used to validate the expected performance. Any substantive deviations between the theoretical and experimental performance, particularly in the experiments that will be conducted in this course, are usually due to either an error in the theoretical analysis, an incorrect configuration, or a measurement error.

Oscilloscopes

Oscilloscopes provide a visual indication of waveforms in a circuit and are probably the most useful measurement devices in this laboratory. In this laboratory, they should be used to monitor all signals and waveforms that are being measured, even if another piece of equipment is being used to make a measurement. In some situations (which likely will not be encountered in this course), the loading of the oscilloscope on the circuit is too large and in these cases the oscilloscope can either not be used to make measurements or monitor waveforms.

The oscilloscope in the laboratory has a button on it with a label "Auto-scale". It is the most worn button on most of the scopes in the laboratory and also the most miss-used. Although there may be occasions where the Auto-scale function is convenient, the user should always know what signals to expect for a circuit and should set both the vertical scale and the horizontal time scale to see the desired response of a circuit. As such, there is no need for the auto-scale function and most will probably save time in the laboratory if they never use the "Auto-scale" button.

Port Impedance of Test Equipment

Each piece of test equipment generally interfaces with a circuit through a port. This port invariably has a port impedance that is neither infinite or zero. Always be aware of the port impedances of the test equipment you are using.
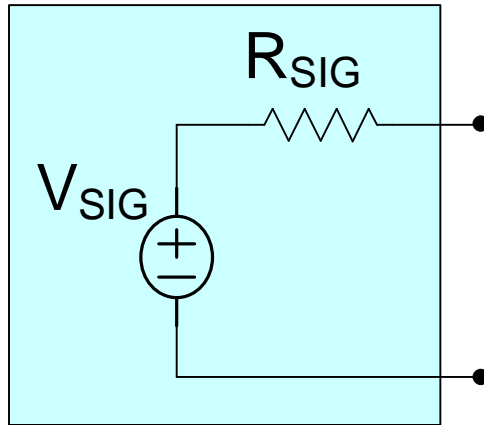
Thevenin Equivalent Circuit of Signal Generator

Some signal generators have a digital display that is used to interface with the user. This can be used for setting the equipment. There are situations, however, where the displayed value of some signals that are being generated to not correspond to the signals that will be measured. This is particularly troublesome with the Ag 33120a where signal amplitude displayed may not correspond to the actual signal level that will be measured. This apparent discrepancy is not an equipment malfunction but rather an issue associated with the correct interpretation of the readings that are provide as they are affected by the output impedance of the source and the impeadance of the load that is being driven.
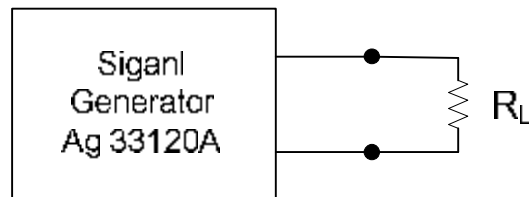
Load on Signal Generator

Often signals that are much smaller than can be readily provided with the test equipment in the laboratory are needed or when working with very low level signals they appear to be noisy when observing on an oscilloscope. A practical way to generate good small signals is to use an external voltage divider such as a $1K\Omega$ to 10Ω divider. If the value of the two resistors is accurately known (they can be measured), then the voltage divider equation will precisely give the relationship between the two signals assuming there is no further significant loading of the signal appearing across the smaller resistor. The larger signal can then be observed on the oscilloscope or used to trigger the oscilloscope whereas the smaller desired signal can be used to drive the desired circuits.
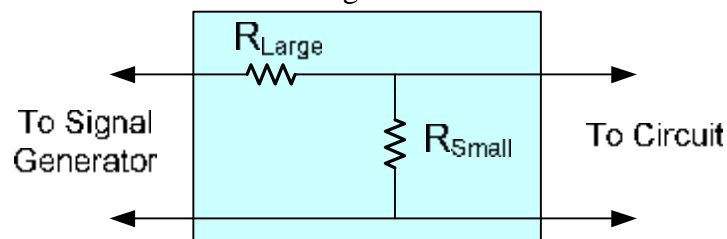
a) Determine the port impedance of the waveform generator, the multimeter, and the oscilloscope (both directly and with a 10X probe)

b) Program the Ag 33120a to provide a 1V p-p signal with no load ($R_L = \infty$). Monitor the signal on the multimeter and the oscilloscope and compare the readings on the signal generator, the multimeter, and the scope. Switch between the 50Ω and HighZ modes and comment on how the three readings differ. Describe what is going on. Now add a 100Ω resistor ($R_L = 100\Omega$) as a load and compare the three readings in both the 50Ω and HighZ modes. Provide an assessment of how to set and monitor the output voltage levels from the Ag 33120a. Of what use is the numerical display of the amplitude on the Ag 33120a?

c) Develop a signal generator that can generate a 10uV P signal at 1KHz. Observe this signal on the oscilloscope directly and measure it with a multimeter. Now develop a 10mV P signal directly with the signal generator (you will need to place an appropriate small resistor in shunt with the output terminal of the signal generator to reduce it to this level)and observe on the oscilloscope. Set the scope to trigger on the positive going zero crossings of this signal. Then develop the same 10mV using a 100:1 attenuator and use the larger signal to generate the trigger on the scope. Comment on how the two measurements compare.

Part 2   Computer Aided Measurements

Signal Express can be used to control test equipment and to take measurements. This approach is useful for making basic measurements and in particularly attractive when repeated measurements are to be made. If repeated measurements are made, the output from the measurement made by Signal Express can be placed directly in an Excel spreadsheet.

a) Using Signal Express, set the dc voltage on the E3631A to a dc output of 3.5V. Monitor this voltage on the oscilloscope and measure it manually with the multimeter.

b) Using Signal Express, generate a 750mV P sinusoidal waveform at a frequency of 2KHz. Monitor this voltage on the oscilloscope and measure it manually with the multimeter.

c) Without changing the settings from parts a) and b), measure the dc voltage and the ac voltage using Signal Express. Continue to monitor the corresponding voltages on the oscilloscope.

d) Obtain the dc transfer characteristics (Vo vs Vin) for the circuit shown by sweeping the input voltage from -5V to +5V using Signal Express. Take measurements in 100mV increments in the input voltage. Transfer the outputs to Excel and plot the relationship. Do now worry about understanding how this circuit operates, the emphasis at this point is only on making the measurements. Any diode in your parts kit can be used for the diode shown.

10K   V_{OUT}

V_{IN}

10K

2V
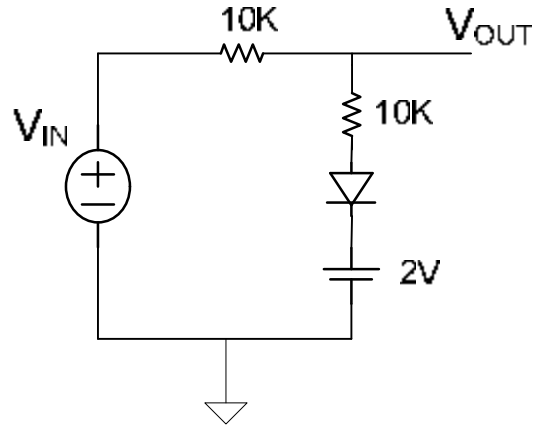
e)   Put a 10V P sinusoidal signal into the circuit shown and sweep the frequency
between 200Hz and 20KHz. Manually make measurements of the gain
(defined to be the ratio of the magnitude of the output voltage to the
magnitude of the input voltage) at several frequencies throughout this range
and plot the resultant gain versus frequency. Use SiganlExpress to gather gain
measurements at a large number of frequencies in this interval and export to
EXCEL. Plot this gain with both a linear and logarithmic frequency axis.
Com pare these results to what is obtained with SPICE..

1K   V_{OUT}

V_{IN}

0.1uF