



## Virtual Lab 1: Introduction to Instrumentation

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### Purpose:

- Measurements and options on the Agilent 34401A multimeter
- Saving test results on the Agilent 54601A oscilloscope
- I-V curves using the Agilent 54601A oscilloscope

### Equipment:

- Agilent 34401A Multimeter
- Agilent 33120A or Agilent 8116A Function Generator

### Introduction:

This course will use the Agilent 8116A or Agilent 33120A function generator, Agilent 34401A multimeter, and Agilent 54601A oscilloscope. For the most part, the basic functions of all these instruments are self-explanatory. The purpose of this lab is to teach useful functions which you may not have had the opportunity to use.

Attached to the back of the scope is a Agilent 54657A Measurement and Storage Module that networks the scope through GPIB (General Purpose Interface Bus - IEEE.488). It also provides advanced functions such as fast fourier transforms, integration, phase calculations, and masking (setting tolerances on deviations from an acceptable waveform). For more detailed explanations on how certain measurements are made or to learn functions that are not covered, the following Agilent documentation may be helpful:

- Multimeter User's Guide
- Oscilloscope User and Service Guide
- Measurement and Storage Module User's Guide

These are all spiral bound instructional books. The larger three-ring binders contain volumes of information, but are not quite as helpful. Later in this course you may find them useful for looking up specific information on remote programming.

### Menu Navigation and Documentation in these Labs:

To follow the procedures in these labs, it will be necessary to explain step-by-step navigation for pushing a series of buttons. The following convention will be used to delineate a button sequence:

**Setup**→**MaskTest**→**Automask**

In other words, first push the **Setup** button, then the **Mask Test** button, and finally the **Automask** button. This sequence uses the built in automasker on the oscilloscope to create an upper and lower bound test mask for your signal. Notice that the buttons under the screen may not present to you the option you would like until you have first pressed other buttons.

When choosing some options on the multimeter, the shift key must first be pressed before using a function written in blue above the keys (e.g., DC current, Period, dB). To remind you of this fact, the prefix (**shift**) will be attached to these commands. You will see (**shift**)**Period**, etc. The multimeter also has a fairly large menu of options from which

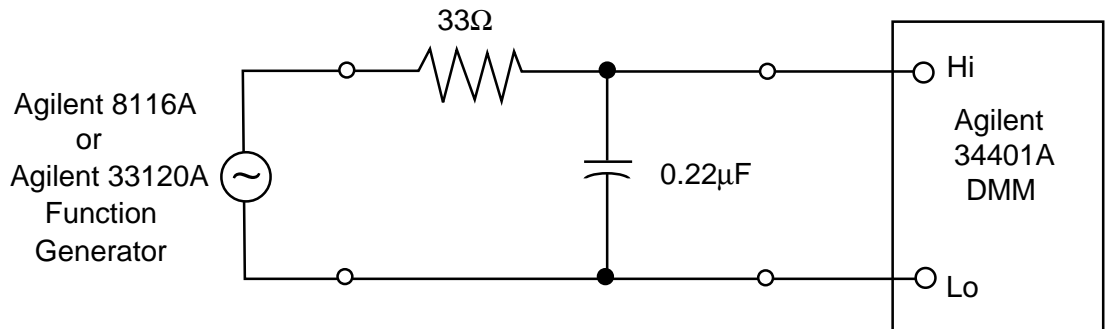


to choose. To learn what menu options exist and how to set them, look at page 3 of the *User's Guide* (attached to this handout).

**Procedure:**

**Part 1: Bode Measurements on the Multimeter**

Hook up a simple RC circuit in low or high pass form using the 33 Ω resistor and 0.22 μF capacitor. Hook up the function generator to your circuit and place the multimeter clips to measure the output.



**Figure A**

1. Using the values of resistance and capacitance marked on the components, calculate the frequency at which the transmission will be attenuated by 3dB.  
Calculated 3dB: \_\_\_\_\_
2. Set the function generator to a few volts and a frequency at least 2 decades below or above the calculated 3dB point for a low or high pass filter respectively. Then press **AC** **v** followed by **(Shift)dB** on the multimeter. The multimeter takes the very first reading and then compares every other reading to it. Consequently, the reading should be close to 0dB. Try modifying the reference value by using the following procedure: press **(Shift)Recall** to get to the "3: dB REL" screen. Next, press **v** to move to the **parameter** screen and show the parameter value (notice the units). Press **>** or **<** or select the digit you would like to change, and **^** or **v** to change the value of the digit. Press **Enter** when you are done. Notice the change in the reading. Turn the dB function off and then on again to reset the reference value (**(Shift)dB** toggles this function on/off).
3. The time constant of this circuit determines the 3dB point. Change the frequency until you reach the 3dB point and record this value. How does this compare with the calculated value?  
Frequency: \_\_\_\_\_
4. Check the specifications of the function generator to determine its output impedance, and the specifications of the multimeter to determine its input impedance. Estimate additional capacitive loading from cables. Which of these additional impedances have an effect on your measurement? Recalculate the 3 dB frequency and compare with your measurement.  
Frequency: \_\_\_\_\_
5. Sweep the frequency of the function generator in multiples of 1,2,5 and record your results for at least 2 decades in each direction from the 3dB point. Use MATLAB to plot these points on a linear-log graph. There's your Bode plot!
6. The multimeter is arranged to allow for the tradeoffs between precision and speed of measurement. It may be important to make many fast measurements in a computer-controlled setup. However, it may be more important to get a precision reading, so the multimeter is manually and remotely adjustable. The different settings are based on



measurements taken for a period of time (integration) delineated by PLC's (Power Line Cycles). The carefully regulated 60Hz of the AC outlet is monitored by the multimeter and used as a time reference. In this case, measurements can be taken over periods in time of length 0.02, 0.2, 1, 10, or 100 PLC's (0.3, 3, 17, 167, or 1667ms). The default is 10 PLC's. Try changing this setting in the **Meas Menu** → **Resolution** menu (**(Shift) Menu On/Off** → **v** → **>** → **>** → **>** → **>**). Then press **v** and **>** to select the choices **Fast/slow 4 Digit** (0.02 PLC/1 PLC), **Fast/slow 5 Digit** (0.2 PLC/10 PLC), and **Fast/slow 6 Digit** (10 PLC/100 PLC). Press **Enter** when you are finished. Do you notice any differences?

7. The multimeter has three different internal AC filters to optimize low frequency precision or achieve faster settling times. The bandwidth of each determines the period of time required to settle to the measured value. The filter bandwidths are (from slow to fast): 3Hz - 300kHz, 20Hz - 300kHz, 200 Hz - 300kHz. Settling times are 7 sec/reading, 1 reading/sec, and 10 readings/sec respectively. Adjust this in the **Meas Menu** → **AC Filt** menu. While on the "Slow" filter, measure a 10Vpp sine wave from the function generator, then quickly short the multimeter clips together. Try this again with the other filters and note any changes in the response time.

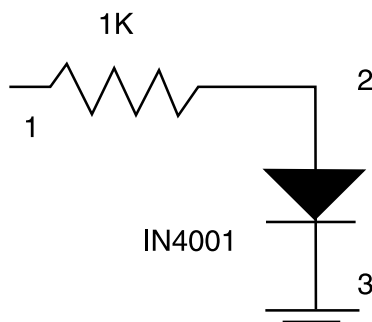
## Part 2: Saving the Oscilloscope Screen

1. Hook up a 10X probe to both the input and output of the circuit constructed in part 1, and monitor these waveforms on Channels 1 and 2 of the scope, respectively. Set the function generator to a 10Vp pulse at 100Hz with a duration (width) of 2ms. Press **Autoscale** on the scope. Examine the channel with the input signal (Channel 1) and then turn off that channel. Set your output channel (channel 2) settings to **Bandwidth Limiting** on, and ensure the **Probe** setting matches the probe. Set the **Coupling** to AC, and press **source** → **1** (use the "1" soft key under the screen) to trigger off channel 1. Adjust voltage and time sensitivities as desired to zoom in on a waveform edge.
2. Press **Autoscale** again. Look at your output channel settings; are they the same? Chances are, the answer is no. You may press **Autoscale** to simply change the voltage and time scales, but other things may change also! **Autoscale** can have undesired effects on settings you don't want to change. You may not have noticed, but it also triggers off channel 2 if a waveform is present on that channel. Press **Setup** → **Undo Autoscale**. This is helpful for those of us who get a little trigger happy with the autoscale button!
3. Press **Autostore**. This keeps any pixels lit if they are activated. To demonstrate, turn the horizontal control knob on the scope. Maybe this is not the effect you desired, so press **Erase**. Notice that the **STORE** indicator in the upper right-hand corner of the screen is still on. Adjust time/div so that you can see one entire pulse on the screen. Change the width of the pulse on the function generator until you catch multiple images of it on the screen. Notice that the scope keeps the reference point upon which it is triggering at a constant point on the screen. This is often convenient when displaying effects of particular changes to a circuit while using autostore. Turn off the channel monitoring the circuit output. The autostore image should still be on the screen.
4. Push the **Trace** button, and turn the light gray knob closest to this button until you are on trace 1. Choose **save to Trace**. Then press **Erase** (right beside the autostore button). The screen should be blank.
5. Now turn **Trace 1** on. The scope should briefly flash the date and time of the store on the screen. Also, pressing **Recall Setup** will recall all the settings for each probe at the time the trace was saved. Trace storage works for ANYTHING displayed on the screen, not just things that are autostored. 100 screens (and their setups) may be saved/recalled in this manner. They may be overlaid with any current screen.

non-volatile memory. You may find others already saved from months before if you try turning some of them on. Remember this because we will be storing traces throughout this course for a lab grade (to be demonstrated at the end of each lab). To help you remember what each trace is, try **Edit Label**. Select the desired letter with the grey knob nearest the **trace** and **setup** buttons, and move horizontally in the label field using the **horizontal** knob.

### Part 3: I-V Curves Using the Oscilloscope

1. Construct the circuit shown below. The objective is to examine the I-V characteristic of the diode by monitoring the voltage across each component (remember  $V=IR$  for the resistor!).



Input a triangular wave at 100Hz/10Vp to the circuit (1 to 3, pos. to neg.). Hook up one probe across the diode (2 to 3), and one across the input (1 to 3). Hit **Autoscale** on the scope and examine the output. Why is this circuit not sufficient for our purposes? (Note that we could obtain the voltages we need if we could subtract these two measurements. This is possible with the Agilent VEE measurement software, as we will see in future labs.)

2. Now hook channel 2 across the resistor (1 to 2), and channel 1 across the diode (3 to 2, reversed). Did you notice what happens to the output?
3. Regardless of the probe coupling (DC, AC, GND), both the function generator and the oscilloscope have a common ground. Occasionally, this fouls up the way we want to make a measurement. The present circuit has a ground clip at each end of the diode. Therefore, there is no voltage drop across it! If the ground clip of each instrument were floating, this problem would be eliminated.

The solution is to disconnect any common grounds between the scope and function generator. Insert a 3-to-2 prong adapter between the function generator power cord and outlet (Your Lab Assistants have them). This decouples the AC outlet ground. Does it matter whether it is on the scope or the function generator?

Watch out! There is another ground connection between the instruments! The GPIB has a ground connection. Therefore, remove any GPIB cables attached to the function generator (not just the one connecting it and the scope). Now the function generator has a floating ground.

### **WARNING:**

*The standard 3-prong plugs on the instruments ensure that the cases are at ground potential (if the outlet is wired correctly!). This is an important safety feature since the case is the part of an instrument you are most likely to touch. Consequently, if you mistakenly connect the ground clip to a high voltage, or there is an internal instrument failure that shorts a high voltage to the case, the current will flow to ground rather than through your body. However, using the 3-to-2 prong adapter as we have done here defeats this safety feature. Although no voltages in our circuit are large enough to present a danger you should keep this in mind any time you find it necessary to float an instrument ground.*



4. Set the function generator to 1Hz. **Invert** Channel 1 and press **Main/Delayed** → **XY**.
5. Adjust the **vOlts/DiV** knobs for channels 1&2 until the signal doesn't quite leave the screen. You may want to adjust the position knobs as well. Now, increase the frequency to 60Hz. Look familiar? It should look like the standard diode curve you have seen in so many books before. Save the trace.
6. Now adjust the frequency from 1kHz up to 52MHz. Notice the shape of the curve changing. Save a few of the interesting screens. Can you explain the changes in the plots?

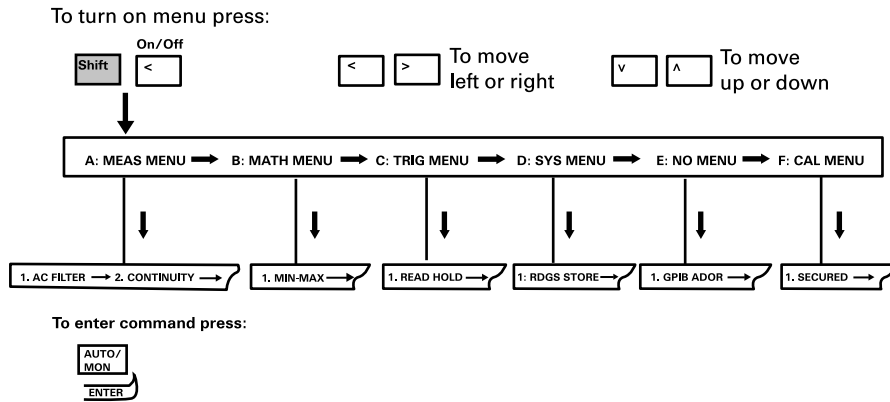
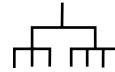
**You should be able to:**

- Show the measured and calculated 3dB point.
- Show a Bode plot (Using MATLAB or some other graphing program)
- Describe any effects of resolution and AC filtering on multimeter function.
- Display saved traces showing pulses of different widths on the same screen (2.3) and several interesting diode I-V traces (3.6), including one at 60Hz (3.5).
- Describe the problem with a common ground between all the instruments, and why it is important to have one.



### The Front-Panel Menu at a Glance Agilent 34401 Multimeter

This menu is organized in a top-down structure with three levels.



**A: MEASurement MENU**



**B: MATH MENU**



**C: TRIGer MENU**



**D: SYStem MENU**



**E: Input / Output MENU**



**F: CALibration MENU**



NOTE: The two commands enclosed in square brackets ([]) in the CAL MENU are "hiddin" unless the multimeter is UNSECURED for calibration.