CPE 301L EMBEDDED SYSTEM DESIGN LABORATORY

LABORATORY 1
LAB SAFETY & LAB EQUIPMENT USE TUTORIAL

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
UNIVERSITY OF NEVADA, LAS VEGAS

GOALS:
Introduce laboratory safety procedures to safeguard lives and properties. Provide a basic tutorial on the functions of laboratory equipment that will be utilized during the term. Upon conclusion of this work, the student will be familiar with safe lab working procedure and with the basic setup of the equipment used in this laboratory class experiments.

SAFETY:
Safety is the most important issue that impacts successful implementation of any lab experiments. Improper equipment usage not only damage property, it can potentially jeopardize your life as well lives of the fellow students. Carefully read the safety manual posted on class website. After reading the safety manual, you must take the safety exam and pass the exam to continue the class.

Note: Your negligence in following the safety guidelines anytime during the semester will not be tolerated and you would be dropped from the class.

LAB SCHEDULE:
The plan for Lab#1 is as follows:
1. Laboratory safety exam
2. Work with each equipment unit using below instructions
3. Using knowledge learned during 2., do lab experiments listed at the end of this instruction.
EQUIPMENT USE:

The following equipment is located at each station:

Keithley-DMM 2110 5½ Digit Multimeter

![Front Panel of Keithley-DMM 2110 5½ Digit Multimeter](image)

<table>
<thead>
<tr>
<th>1</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Power Key</td>
</tr>
<tr>
<td>3</td>
<td>Function and operation keys</td>
</tr>
<tr>
<td>4</td>
<td>RANGE and scroll keys</td>
</tr>
<tr>
<td>5</td>
<td>TC input</td>
</tr>
<tr>
<td>6</td>
<td>Terminal and fuses</td>
</tr>
</tbody>
</table>

Figure 1  Front Panel of Keithley-DMM 2110 5½ Digit Multimeter

Measurement ranges and functions

The Model 2110 provides a wide number of measurement ranges and functions including:

- DC voltage: 0.1 V, 1 V, 10 V, 100 V, and 1000 V
- AC voltage: 0.1 V, 1 V, 10 V, 100 V, and 750 V
- DC current: 10 mA, 100 mA, 1 A, and 10 A
- AC current: 1 A, 3 A, and 10 A
- Two and 4-wire resistance: 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, 10 MΩ, and 100 MΩ
- Frequency: 3 Hz to 300 kHz
- Capacitance measurement: 1 nF, 10 nF, 100 nF, 1 µF, 10 µF, 100 µF, 1 mF, 10 mF
- Temperature measurement using RTDs, thermistors, and thermocouples (direct measurement using built-in cold junction compensation to improve accuracy); supports J-, R-, S-, T-, E-, N-, B-, C-, and K-type thermocouples

Connections for different measurements as follows:
Voltage measurements

The instrument is capable of measuring DC voltage (DCV) up to 1000 V and AC voltage (ACV) up to 750 V.

- DC voltage (DCV) measurement ranges: 100 mV, 1 V, 10 V, 100 V, and 1000 V
- AC voltage (ACV) measurement ranges: 100 mV, 1 V, 10 V, 100 V, and 750 V AC-coupled true RMS (1000 V peak)

WARNING

Do not apply more than 1000 V (peak) to the Model 2110. Applying higher voltage is an electric shock hazard and could result in personal injury or death. It may also damage the instrument.

Front-panel operation

Perform the following steps to measure voltage:

1. Press the DCV key to measure DC voltage or the ACV key to measure AC voltage.
2. Select a measurement range (auto or manual):
   - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press SHIFT and then ESC (AUTO) to select autorange.
   - For manual ranging, press the RANGE ▲ and ▼ keys to select a measurement range.
3. As shown below, connect the signal to the instrument and observe the reading on the display. If the input signal exceeds the selected range, the overflow message OVLD displays.

Connections for DC and AC voltage measurements

**Figure 16: Connections for DCV and ACV measurements**

- **Input resistance:**
  - 10 MΩ on 1000 V, 100 V ranges
  - > 10 GΩ on 10 V, 1 V, 100 mv ranges

- **Input impedance:**
  - 1 MΩ in parallel with < 100 pF
Current measurements

The instrument is capable of measuring DC and AC current up to 10 A.
- DC current measurement ranges: 10 mA, 100 mA, 1 A, 3 A, and 10 A
- AC current measurements: 1 A, 3 A, and 10 A

Front-panel operation

Perform the following steps to measure current:

1. Select a current measurement function:
   - Press SHIFT and then DCV (DCI) to measure DC current.
   - Press SHIFT and then ACV (ACI) to measure AC current.
2. Select a measurement range (auto or manual):
   - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press SHIFT and then ESC (AUTO) to select autorange.
   - For manual ranging, press the RANGE ▲ and ▼ keys to select a measurement range.
3. Connect the signal to the instrument as shown below and observe the reading shown on the display. If the input signal exceeds the selected range, the overflow message OVL will be displayed.

Connections for DC and AC current measurements

⚠️ CAUTION

The maximum input on the 3 A input terminals is 3 A, 250 V. The maximum input on the 10 A input terminals is 10 A. Exceeding these input levels will damage the current fuses.
Resistance measurements

There are two measurement methods for resistance:

- 2-wire ohms
- 4-wire ohms

Front-panel operation

Perform the following steps to measure resistance:
1. Connect the device under test to the instrument, as shown below.
2. Select a resistance measurement function:
   - Press Ω2 to select 2-wire ohms.
   - Press SHIFT and then Ω2 (Ω4) to select 4-wire ohms.
3. Select a measurement range (auto or manual):
   - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press SHIFT and then ESC (AUTO) to select autorange.
   - For manual ranging, press the RANGE ▲ and ▼ keys to select a measurement range.
4. Observe the reading shown on the display.

Connections for resistance measurements

Source current flows from INPUT HI to INPUT LO as shown in the following figure.

Figure 19: Connections for resistance measurements
Frequency and period measurements

The instrument measures frequency from 3 Hz to 300 kHz (or 3.3 μs to 333 ms) using the AC voltage ranges (100 mV to 750 V) or AC current ranges (1 A, 3 A, or 10 A).

⚠️ WARNING

Do not apply more than 1000 V (peak) to the instrument. Applying higher voltage creates an electric shock hazard which could result in personal injury or death. It may also damage the instrument.

Front-panel operation

Perform the following steps to measure frequency or period:

1. Select the frequency or period measurement function:
   - Frequency: Press the FREQ key.
   - Period: Press FREQ and CONFIG, and with PERIOD displayed, press ENTER.

2. Select the AC signal (voltage or current) to measure:
   a. Press CONFIG, use the ▶ key to display INPUT JACK, and then press ENTER.
   b. Use the ◀ or ▶ key to display VOLTAGE or CURRENT, and then press ENTER.

3. Select a measurement range (auto or manual) for the AC signal to be measured:
   - Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press the SHIFT key and then ESC (AUTO) to select autorange.
   - For manual ranging, press the RANGE ▲ and ▼ keys to select a measurement range.

4. As shown below, connect the AC signal to the Model 2110 and observe the reading on the display. If the input signal exceeds the selected range, the overflow message OVLD displays.

Connections for frequency and period measurements

Figure 20: Connections for FREQ and PERIOD

Input impedance:
1 MΩ in parallel with < 100 pF
Capacitance measurements

The measurement ranges for capacitance measurements are 1 nF, 10 nF, 100 nF, 1 µF, 10 µF, 100 µF, 1 mF, and 10 mF.

Front-panel operation

Perform the following steps to measure capacitance:
1. Connect the capacitance to the Model 2110, as shown below.
2. Press the SHIFT and FREQ (4+) keys.
3. Select a measurement range (auto or manual):
   • Autorange is the power-on default. If manual ranging is selected (MAN indicator on), press SHIFT and ESC (AUTO) to select autorange.
   • For manual ranging, press the RANGE ▲ and ▼ keys to select a measurement range.
4. Observe the reading on the display.

Connections to measure capacitance

Figure 24: Connections for capacitance
DC Power Supply HY3000 Series

Figure 2 Front Panel of DC Power Supply HY3000 Series

1. DISPLAY CHOOSE SWITCH (master unit)
   Choose & display output voltage or current value of the master unit. Only is LED or two pointer meters display type is available.

2. OUTPUT INDICATOR (master unit)
   LCD and four pointer meters model:
   Show output voltage and current of the master unit output terminals simultaneously. (Two indicators for the master unit and the other two for the slave unit.)
   LED and two pointer meters model:
   Show master unit output voltage or current through setting display chooses switch of the master unit.

3. CONTROL SWITCH
   Double power control switch for independent, series and parallel operation.

4. CURRENT REGULATOR (master unit)
   Adjusting output current of master unit and delivered from the master unit.

5. VOLTAGE REGULATOR (master unit)
   Adjusting output voltage of the master unit.

6. C.V. INDICATOR (master unit)
   Constant voltage mode indicator
7. **C.C. INDICATOR** (master unit)
   Constant current mode indicator

8. **FIXED 5V3A OUTPUT POSITIVE TERMINAL OR NO.** (by purchase order)

9. **FIXED 5V3A OUTPUT NEGATIVE TERMINAL OR NO.** (by purchase order)

10. **POSITIVE OUTPUT TERMINAL** (master unit)

11. **GROUND OUTPUT TERMINAL** (master unit)

12. **NEGATIVE OUTPUT TERMINAL** (master unit)

13. **POSITIVE OUTPUT TERMINAL** (slave unit)

14. **GROUND OUTPUT TERMINAL** (slave unit)

15. **NEGATIVE OUTPUT TERMINAL** (slave unit)

16. **POWER ON/OFF SWITCH**
   This is the main power switch of the instrument.

17. **C.V. INDICATOR** (slave unit)
   Constant voltage mode indicator

18. **C.C. INDICATOR** (slave unit)
   Constant current mode indicator

19. **CURRENT REGULATOR** (slave unit)
   Adjusting output current of slave unit and delivered from the slave unit.

20. **VOLTAGE REGULATOR** (slave unit)
   Adjusting output voltage of the slave unit.

21. **CONTROL SWITCH**
   Double power control switch for independent, series and parallel operation.

22. **OUTPUT INDICATOR** (slave unit)
   LCD and four pointer meters model:
   Show output voltage and current of the slave unit output terminals simultaneously.
   (Two indicators for the slave unit and the other two for the master unit.)
   **LED and two pointer meters model:**
   Show slave unit output voltage or current through setting display chooses switch of the slave unit.

23. **POINT METER ZERO** (only pointer meter display)
   Each pointer meter has a mechanical screw adjustment for setting the zero point.
   Using a small screwdriver, turn off the power and adjust the screw under the meter respectively to read zero. There is only pointer meter model.

24. **DISPLAY CHOOSE SWITCH** (slave unit)
   Choose & display output voltage or current value of the slave unit. Only is LED or two pointer meters display type is available.
1. **CONSTANT VOLTAGE MODE**
   1.1 Turn the current regulator 4 & 19 clockwise to maximum position.
   1.2 Turn the voltage regulators 5 & 20 anti-clockwise to minimum position.
   1.3 Put the display choose switch 1 & 24 to the voltage display position (The operation is only LED and two pointer meters model).
   1.4 Press the power ON/OFF switch to ON.
   1.5 Turn the voltage regulators 5 & 20 clockwise respectively to get the output voltage value of master unit and slave unit as your desire.
   1.6 Connect the positive output terminal and negative output terminal with a load or similar component.
   1.7 The indicators show the output voltage and output current appeared on the output terminals.

2. **CONSTANT CURRENT MODE**
   2.1 Turn the voltage regulators 5 & 20 clockwise to maximum position.
   2.2 Turn the current regulator 4 & 19 anti-clockwise to minimum position.
   2.3 Put the display choose switch 1 & 24 to the current display position (The operation is only LED and two pointer meters model).
   2.4 Press the power ON/OFF switch to ON.
   2.5 Connect the positive output terminal and negative output terminal with a load or similar component.
   2.6 Turn the current regulators 4 & 19 clockwise respectively to get the output current value of master unit and slave unit as your desire.
   2.7 The indicators show the output voltage and output current appeared on the output terminals.

**C.C. AND C.V. INDICATOR**

The C.C. indicator is controlled by the constant current mode. Otherwise C.V. indicator is controlled by the constant voltage mode.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>OUT VOLTAGE regulated</th>
<th>OUT CURRENT regulated</th>
<th>OUT FIXED</th>
<th>DISPLAY TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HY3003-3</td>
<td>(0~30V) x2</td>
<td>(0~3A) x2</td>
<td>5V3A</td>
<td>LED</td>
</tr>
</tbody>
</table>
GW Instek Arbitrary Function Generator AFG-2225

### LCD Display
- **Function keys, Return key**: Activates functions which appear on the right-hand side of the LCD display.
- **Scroll Wheel**: Goes back to the previous menu level.
- **Arrow keys**: The waveform key is used to select a type of waveform.
- **Operation keys**: The FREQ/Rate key is used to set the frequency or sample rate.
- **Number pad**: AMPL sets the waveform amplitude.
- **Operation keys**: Sets the DC offset.
- **Preset Key**: The preset key is used to recall a preset state.
- **Output Key**: The Output key is used to turn on or off the waveform output.
- **Channel Select Key**: The channel select key is used to switch between the two output channels.

---

**Figure 3 Front Panel of GW Instek AFG-2225**

<table>
<thead>
<tr>
<th>LCD Display</th>
<th>TFT color display, 320 x 240 resolution.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function Keys F1-F5</td>
<td>F1</td>
</tr>
<tr>
<td>Return Key</td>
<td>Return</td>
</tr>
<tr>
<td>Operation Keys</td>
<td>Waveform</td>
</tr>
<tr>
<td></td>
<td>FREQ/Rate</td>
</tr>
<tr>
<td></td>
<td>AMP</td>
</tr>
<tr>
<td></td>
<td>DC Offset</td>
</tr>
<tr>
<td>Preset Key</td>
<td>Preset</td>
</tr>
<tr>
<td>Output Key</td>
<td>OUTPUT</td>
</tr>
</tbody>
</table>

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Output ports

- CH1: Channel 1 output port
- CH2: Channel 2 output port

Power Button

Turns the power on or off.

Arrow Keys

Used to select digits when editing parameters.

Scroll Wheel

The scroll wheel is used to edit values and parameters.

Keypad

The digital keypad is used to enter values and parameters. The keypad is often used in conjunction with the arrow keys and variable knob.

Display

Status Tabs

Parameter Windows

Waveform Display

The Parameter display and edit window.

Displays the current channel and setting status.

Used to display the waveform.

The function keys (F1~F5) beside the Soft Menu keys correspond to the soft keys.
Sine Wave

Panel Operation 1. Press the Waveform key.

2. Press F1 (Sine).

Square Wave

Panel Operation 1. Press the Waveform key.

2. Press F2 (Square) to create a square waveform.

3. Press F1 (Duty). The Duty parameter will be highlighted in the parameter window.

4. Use the arrow keys and scroll wheel or number pad to enter the Duty range.

5. Press F2 (%) to select % units.

<table>
<thead>
<tr>
<th>Range</th>
<th>Frequency</th>
<th>Duty Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤100kHz</td>
<td>1.0%–99.0%</td>
<td></td>
</tr>
<tr>
<td>100kHz–≤1MHz</td>
<td>10.0%–90.0%</td>
<td></td>
</tr>
<tr>
<td>&gt;1MHz–25MHz</td>
<td>50% (Fixed)</td>
<td></td>
</tr>
</tbody>
</table>
Setting the Frequency

Panel Operation 1. Press the FREQ/Rate key.

2. The FREQ parameter will become highlighted in the parameter window.

3. Use the arrow keys and scroll wheel or number pad to enter the frequency.

4. Choose a frequency unit by pressing F1~F5.

Range
- Sine wave: 1μHz~25MHz
- Square wave: 1μHz~25MHz
- Pulse wave: 500μHz~25MHz
- Ramp wave: 1μHz~1MHz
Setting the Amplitude

Panel Operation

1. Press the AMPL key.

2. The AMPL parameter will become highlighted in the parameter window.

3. Use the arrow keys and scroll wheel or number pad to enter the amplitude.

4. Choose a unit type by pressing F1~F5.

50Ω load High Z
Range 1mVpp–10Vpp 2mVpp–20Vpp
Unit Vpp, Vrms, dBm
Setting the DC Offset

Panel Operation
1. Press the DC Offset key.

2. The DC Offset parameter will become highlighted in the parameter window.

3. Use the arrow keys and scroll wheel or number pad to enter the DC Offset.

4. Press F1 (mVDC) or F2 (VDC) to choose a voltage range.

<table>
<thead>
<tr>
<th>Range</th>
<th>5Vpk</th>
<th>10Vpk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>50Ω</td>
<td>High Z</td>
</tr>
</tbody>
</table>

50Ω load

±5Vpk

±10Vpk
Tektronix MSO2000 Series Oscilloscope

Functional Check

Perform this quick functional check to verify that your oscilloscope is operating correctly.

1. Connect the oscilloscope power cable as described in Powering On the Oscilloscope. (See page 10.)

2. Power on the oscilloscope.

3. Connect the P221 probe tip and reference lead to the PROBE COMP connectors on the oscilloscope.


5. Push Autoset. The screen should now display a square wave, approximately 5 V at 1 kHz.

NOTE. For best performance, it is recommended that you set the Vertical scale to 1 V.

If the signal appears but is misshapen, perform the procedures for compensating the probe. (See page 12.)
Compensating a Passive Voltage Probe

Whenever you attach a passive voltage probe for the first time to any input channel, compensate the probe to match it to the corresponding oscilloscope input channel.

To properly compensate your passive probe:

1. Follow the steps for the functional check. (See page 11.)

2. Check the shape of the displayed waveform to determine if your probe is properly compensated.

   Properly compensated  Under compensated  Over compensated

3. If necessary, adjust your probe. Repeat as needed.

Quick Tips

Use the shortest possible ground lead and signal path to minimize probe-induced ringing and distortion on the measured signal.

Signal with a short ground lead  Signal with a long ground lead
Setting Up Analog Channels

Use front-panel buttons and knobs to set up your oscilloscope to acquire signals using the analog channels.

1. Connect a P2221 probe or a TekVPI probe to the input signal source.


*NOTE:* If you are using a probe that does not supply probe encoding, set the attenuation (probe factor) on the oscilloscope vertical menu to match the probe. The default attenuation for the oscilloscope is 10X and is set in the Probe Setup lower-bezel menu of any analog channel.

3. Select the input channel by pushing the front-panel buttons.

4. Push Autoset.

5. Push the desired channel button. Then adjust the vertical position and scale.

6. Adjust the horizontal position and scale.

   The horizontal position determines the number of pretrigger and posttrigger samples.

   The horizontal scale determines the size of the acquisition window relative to the waveform. You can scale the window to contain a waveform edge, a cycle, several cycles, or thousands of cycles.
Taking Automatic Measurements

To take an automatic measurement:

1. Push Measure.

2. Push Add Measurement.

3. Turn multipurpose knob a to select the specific measurement. If needed, then turn multipurpose knob b to select the channel to measure on. Then push OK Add Measurement.

4. To remove a measurement, push Remove Measurement. Then push the side-bezel menu for the measurement you want to remove, or Remove All. Then push OK Remove Measurement.

Selecting Automatic Measurements

The following tables list each automatic measurement by category: time or amplitude. (See page 87, Taking Automatic Measurements.)

### Time Measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>The first cycle in a waveform or gated region. Frequency is the reciprocal of the period; it is measured in hertz (Hz) where one Hz is one cycle per second.</td>
</tr>
<tr>
<td>Period</td>
<td>The time required to complete the first cycle in a waveform or gated region. Period is the reciprocal of frequency and is measured in seconds.</td>
</tr>
<tr>
<td>Rise Time</td>
<td>The time required for the leading edge of the first pulse in the waveform or gated region to rise from the low reference value to the high reference value of the final value.</td>
</tr>
<tr>
<td>Fall Time</td>
<td>The time required for the falling edge of the first pulse in the waveform or gated region to fall from the high reference value to the low reference value of the final value.</td>
</tr>
<tr>
<td>Delay</td>
<td>The time between the mid reference (default 50%) amplitude point of two different waveforms. See also Phase.</td>
</tr>
</tbody>
</table>

And MORE!!
Taking Manual Measurements with Cursors

Cursors are on-screen markers that you position in the waveform display to take manual measurements on acquired data. They appear as horizontal and/or as vertical lines. To use cursors on analog or digital channels:

1. Push Cursors.
   This changes the cursor state. The three states are:
   - No cursors appear on the screen.
   - Two vertical waveform cursors appear. They are attached to the selected analog waveform or digital waveforms.
   - Four screen cursors appear. Two are vertical and two are horizontal. They are no longer specifically attached to a waveform.

2. Push Cursors again.
   In the example, two vertical cursors appear on the selected screen waveform. As you turn multipurpose knob a, you move one cursor to the right or left. As you turn knob b, you move the other cursor.
   If you change the selected waveform by pushing the front-panel 1, 2, 3, 4, M, R, or D15-D0 button, both cursors jump to the new selected waveform.

3. Push Select.
   This turns the cursor linking on and off. If linking is on, turning multipurpose knob a moves the two cursors together. Turning multipurpose knob b adjusts the time between the cursors.

4. Push Fine to toggle between a coarse and a fine adjustment for multipurpose knobs a and b.
   Pushing Fine also changes the sensitivity of other knobs as well.

5. Push Cursors again.
   This will put the cursors into screen mode. Two horizontal bars and two vertical bars span the graticule.
6. Turn multipurpose knobs a and b to move the pair of horizontal cursors.

7. Push Select. This makes the vertical cursors active and the horizontal ones inactive. Now, as you turn the multipurpose knobs, the vertical cursors will move.
Push Select again to make the horizontal cursors active again.

8. View the cursor and the cursor readout. You can take timing measurements with cursors on digital channels, but not amplitude measurements.

9. Push Cursors again. This will turn off the cursor mode. The screen will no longer display the cursors and the cursor readout.
Using Cursor Readouts

Cursor readouts supply textual and numeric information relating to the current cursor positions. The oscilloscope always shows the readouts when the cursors are turned on.

Readouts appear in the upper right corner of the graticule. If Zoom is on, the readout appears in the upper right corner of the zoom window.

When a bus is selected, the readout shows the decoded bus data in the format you have selected, hexadecimal, binary, or ASCII (RS-232 only). When a digital channel is selected, the cursors show the values of all displayed digital channels.

**NOTE:** When buses are selected, the data value at that point is displayed in the cursor readout.

\[\Delta\text{ Readout:}\]

The \(\Delta\) readouts indicate the difference between the cursor positions.

- a Readout:
  Indicates that the value is controlled by multipurpose knob a.

- b Readout:
  Indicates that the value is controlled by multipurpose knob b.

The horizontal cursor lines on the display measure the vertical parameters, typically voltage.

The vertical cursor lines on the display measure horizontal parameters, typically time.

The square and circle shapes in the readout map to the multipurpose knobs when both vertical and horizontal cursors are present.

Using XY Cursors

When the XY Display mode is on, the cursor readouts will appear to the right of the lower graticule (XY). You can choose which readouts to display: rectangular, polar, product, or ratio.

**NOTE:** Push the Measure button for additional cursor menu options, such as Bring Cursors On Screen and Configure Cursors.
Tektronix TDS2000C Series Oscilloscope

Taking Simple Measurements

You need to see a signal in a circuit, but you do not know the amplitude or frequency of the signal. You want to quickly display the signal and measure the frequency, period, and peak-to-peak amplitude.

Using Autoset

To quickly display a signal, follow these steps:

1. Push the 1 (channel 1 menu) button.
2. Push Probe ▶ Voltage ▶ Attenuation ▶ 10X
3. If using P2220 probes, set their switches to 10X.
4. Connect the channel 1 probe tip to the signal. Connect the reference lead to the circuit reference point.
5. Push the AutoSet button.

The oscilloscope sets the vertical, horizontal, and trigger controls automatically. If you want to optimize the display of the waveform, you can manually adjust these controls.

NOTE: The oscilloscope displays relevant automatic measurements in the waveform area of the screen based on the signal type that is detected.
Taking Automatic Measurements

The oscilloscope can take automatic measurements of most displayed signals.

**NOTE:** If a question mark (?) appears in the Value readout, the signal is outside the measurement range. Adjust the Vertical Scale knob (volts/division) of the appropriate channel to decrease the sensitivity or change the horizontal Scale setting (seconds/division).

To measure signal frequency, period, and peak-to-peak amplitude, rise time, and positive width, follow these steps:

1. Push the Measure button to see the Measure Menu.
2. Push the top option button; the Measure 1 Menu appears.
3. Push Type ➤ Freq.
   The Value readout displays the measurement and updates.
4. Push the Back option button.
5. Push the second option button from the top; the Measure 2 Menu appears.
6. Push Type ➤ Period.
   The Value readout displays the measurement and updates.
7. Push the Back option button.
8. Push the middle option button; the Measure 3 Menu appears.
9. Push Type ➤ Pk-Pk.
   The Value readout displays the measurement and updates.
10. Push the Back option button.
11. Push the second option button from the bottom; the Measure 4 Menu appears.
    The Value readout displays the measurement and updates.
13. Push the Back option button.
14. Push the bottom option button; the Measure 5 Menu appears.
15. Push Type ➤ Pos Width.
    The Value readout displays the measurement and updates.
16. Push the Back option button.

![Waveform Diagram]
Taking Cursor Measurements

You can use the cursors to quickly take time and amplitude measurements on a waveform.

Measuring Ring Frequency and Amplitude

To measure the ring frequency at the rising edge of a signal, follow these steps:

1. Push the Cursor button to see the Cursor Menu.
2. Push Type ► Time.
4. Push the Cursor 1 option button.
5. Turn the multipurpose knob to place a cursor on the first peak of the ring.
6. Push the Cursor 2 option button.
7. Turn the multipurpose knob to place a cursor on the second peak of the ring.

You can see the Δ (delta) time and frequency (the measured ring frequency) in the Cursor Menu.

8. Push Type ► Amplitude.
9. Push the Cursor 1 option button.
10. Turn the multipurpose knob to place a cursor on the first peak of the ring.
11. Push the Cursor 2 option button.
12. Turn the multipurpose knob to place Cursor 2 on the lowest part of the ring.

You can see the amplitude of the ring in the Cursor Menu.
Connecting oscilloscope and function generator
The oscilloscope probe is the only thing you can connect to the oscilloscope:

Oscilloscope probe

The function generation cable can be only connected to function generator:

Function generator cable

Remember that you CANNOT connect function generator cable to oscilloscope.
LAB DELIVERIES:

PRELAB:

Equipment Usage:
Review video lectures on equipment usage posted on the class website.

Lab Experiments:
For experiments 1-4, record all the steps as a write-down list, and take a picture of the result.

Experiment 1: DC Power Supply Set Up with Multimeter
Goal:
- connecting DC power supply to the multimeter
- changing the power supply output values and verifying them on the multimeter.
  a) Turn on power supply with Power and Output Switch buttons, and also power on the multimeter
  b) Turn both the Current and Voltage knobs of Channel 1 fully counter clockwise
  c) Use black wire/cable to connect the “-“ port of power supply CH1 to the “com” on the multimeter, and use red wire/cable to connect the “+” end of power supply CH1 to the “V” input of the multimeter. Observe and write down the readings of both power supply CH1 and multimeter.
  d) Slowly turn, clockwise, the “Current” knob of CH1 on power supply, until C.C LED turns off, and C.V LED goes on. Observe the readings of both power supply CH1 and multimeter.
  e) Slowly turn, clockwise, the “Voltage” knob of CH1 on power supply, and see if readings on power supply CH1 and multimeter are the same. Continue doing so, SLOWLY, until the Voltage reading stop increasing. Write down the maximum voltage reading (30.6V).

Experiment 2: DC Power Supply Set Up with Oscilloscope
Goal:
- connecting DC power supply to the oscilloscope
- measuring DC power supply output voltage with the oscilloscope
  a) Turn on oscilloscope and press “Autoset”. Perform the self-detection of both coax measurement probe and oscilloscope. Adjust probe for capacity compensation if necessary.
  b) Connect the coax measurement probe from Channel 1 to the output of the power supply. Connect the hook of coax probe to the positive output of the power, and the clipper of the coax probe to the negative output of the power.
  c) On the power supply, turn both the Current and Voltage knobs of Channel 1 fully counter clockwise, then turn on the power supply.
  d) Slowly adjust the power supply voltage from 0V to 10V. Observe the changes on the oscilloscope. Press “Autoset” when necessary (e.g. trace goes off the grid or unstable).
  e) Press the yellow button of “CH1”. Change “Coupling-DC” to “AC”, and see what happens.
Choose the Oscilloscope you have at your workstation:

(TBE-B311 MSO2014B):

f) Press “Probe Setup”, and toggle between “Set to 1X” and “Set to 10X”. See what happens. (Vertical grid 5V ↔ 500mV)

(TBE-B350 TDS2014):

g) In “Probe”, toggle between “1X” and “10X”. See what happens. (Vertical grid 5V ↔ 500mV)

h) Turn the “Vertical-Scale” and “Vertical-Position” knob of CH1, clockwise or counter clockwise, and see what happens (Vertical grid scales).

i) Turn the “Horizontal-Scale” and “Horizontal -Position” knob of CH1, clockwise or counter clockwise, and see what happens (Horizontal grid scales).

j) Adjust the power supply voltage to 5.0V and then to 10.0V. The trace on the oscilloscope should reflect the change

k) Experiment with other power supply voltages and change the Volts/Div knob accordingly in order to indicate the value on the oscilloscope.

Experiment 3: Signal Generator Setup with Oscilloscope

Goal:
- Setting up the function generator
- Connecting the function generator to the oscilloscope
- Verifying the function generator setting on the oscilloscope display

a) Initially set up the signal generator with the following parameters (be sure the CH1 Coupling is DC and do not change the other oscilloscope settings) and measure the output with Oscilloscope.

  Set:  Frequency: 1kHz  Amplitude: 1V  Offset: 0V

b) Change the signal generator output to the following, and observe the waveform on the Oscilloscope.

  Set:  Frequency: 2kHz  Amplitude: 0.5V  Offset: 1V

c) Change the Oscilloscope to AC coupling, and observe the results.

Experiment 4: measuring resistance with multimeter

a) Instructor will provide the resistor for your team

b) Set the appropriate mode and range on the multimeter

c) Connect red banana cable to “HI Input VΩ”, black banana cable to black connector LO

d) Connect resistor to remaining banana ends.

e) Read the value of the resistance from the display, compare with declared resistor value. Use the https://www.allaboutcircuits.com/tools/resistor-color-code-calculator/ to read value from the resistor using color codes.
Experiment 5

Go back to DC coupling. Change the signal generator to a square waveform (freq. 1MHz, ampl. 1V, offset 0V, duty 75%). Measure the rising (23ns) and falling time (23ns) by using following methods.

f) Built-in function in the measure menu. (You can also try other built-in measurement, e.g. freq. falling time, period, but require appropriate setup of waveform)

g) Use multipurpose cursors to manually measure the rising and falling time, period, etc.

h) (300/400 level labs) Press “Autoset” to reset the Oscope image. Press “Trigger-Menu” and change “rising edge” in “Slop” to “falling edge”. What changes?

Experiment 6 (Optional): Demonstrate the following to TA:

1. Power Supply:
   - Show: how to set up the supply for positive and negative valued voltages.
   - Show: proper set-up of the ground.

2. Function Generator:
   - Show: how to set a given frequency and amplitude.
   - Show: how to provide a DC offset.
   - Answer: what is the difference between Main and Sync outputs.

3. Multimeter:
   - Show: how to measure voltage and resistance.
   - Answer: how to properly use the range settings.
   - Answer: When is the multi-meter the appropriate instrument and when it is not

4. Oscilloscope
   - Show: how to adjust probe.
   - Show: how to properly display a wave shape(s).
   - Show: how to measure voltage and frequency (with cursors and division counting)
POSTLAB REPORT:

Include the following elements in the report document:

<table>
<thead>
<tr>
<th>Section</th>
<th>Element</th>
</tr>
</thead>
</table>
| 1       | Theory of operation  
*Include a brief description of every element and phenomenon that appears during the experiments.* |

<table>
<thead>
<tr>
<th>Results of the experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
| 1             | a. Description of what you have measured during the lab  
b. Picture(s) of the setup  
c. Obtained results |
| 2             | a. Description of what you have measured during the lab  
b. Picture(s) of the setup  
c. Obtained results |
| 3             | a. Description of what you have measured during the lab  
b. Picture(s) of the setup  
c. Obtained results |
| 4             | a. Description of what you have measured during the lab  
b. Picture(s) of the setup  
c. Obtained results |
| 5             | a. Description of what you have measured during the lab  
b. Picture(s) of the setup  
c. Obtained results |
| 6             | For all the ‘Show’ questions, provide brief description, picture of the setup and obtained results. |

<table>
<thead>
<tr>
<th>4</th>
<th>Answer the questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question no.</td>
<td>Question</td>
</tr>
<tr>
<td>1</td>
<td>What is <em>ground</em> and why it’s used in electrical circuits?</td>
</tr>
<tr>
<td>2</td>
<td>What is the difference between <em>oscilloscope probe</em> and <em>function generator cable</em>? (include pictures, it’s allowed to use pictures from the Internet)</td>
</tr>
<tr>
<td>3</td>
<td>What is DC coupling and AC coupling?</td>
</tr>
</tbody>
</table>

| 5 | Conclusions  
*Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.* |