

ECE 85L Digital Logic Design Lab Manual

Spring 2018

California State University, Fresno
Lyles College of Engineering
Electrical and Computer Engineering Department

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Lab 1 – Introduction, Laboratory Procedures, and Equipment

1. INTRODUCTION

For those of us who live in a predominantly analog world, the concepts associated with the analysis and design of digital logic circuits, while admittedly different, are relatively simple, since there exists a standard methodology for implementing functions digitally. You will learn this design methodology in the lecture portion of ECE 85, and implement what you have learned in the lab. As is the case with most circuit design – digital or analog – there are potentially several ways to implement the same function. Thus many designs consist of tricks, where the simplicity of the design becomes tied to his or her experience. Consequently, the lab portion of ECE 85 is vital to the course.

As you become more proficient, you will learn that designing digital circuits on paper is relatively simple. The problems are usually encountered when you try to realize those designs with real components. Digital components such as gates and flip-flops are constructed internally from analog components such as transistors, capacitors, and resistors. Thus it is natural to expect that the analog parameters (e.g., transistor current gain, resistor tolerance) will affect the physical operation of the digital components – and this is indeed true. However, since the relationship between the analog parameters and the synthesis of a digital operation is not simple, a new set of terms expressing the effects of the analog parameters on digital circuits has also been developed. This has the added benefit of allowing a digital designer to be “shielded” from the specific knowledge of how these analog parameters directly affect a circuit’s digital performance. These parameters (e.g., Fan-In, Fan-Out, Propagation Delay, Rise and Fall Times, etc.) will also be stressed in this laboratory, as they are often difficult to represent analytically and (as a result) are often omitted from an initial theoretical design. Hence many of the initial laboratory procedures in ECE85 are designed to teach you about these experimental design considerations.

The first lab acquaints you with the equipment used in this lab. Most important is the Oscilloscope. It will be the primary analytical tool for this lab, as well as for most of the work you will perform in electronics. You will also use the multimeter, which measures voltage, current, and resistance, the waveform function generator, which supplies a square wave signal or pulse train of a specified amplitude and frequency, and some logic aids, which have been assembled together into an integral system, the **LOGIC DEVELOPMENT SYSTEM**.

As the term progresses you will learn how to document, build and debug basic digital circuits, as well as how to design them. Techniques for documenting and building digital circuits are relatively simple and straightforward – although for simple circuits, they may seem tedious and excessively time consuming. The time-saving advantages of these techniques will become apparent midway through the semester, especially as the material progresses toward more complex synchronous circuits.

Additionally, within the past decade, Electronic Design Automation (EDA) tools have been made available to assist the digital designer. Foremost among these tools are Schematic Capture and Simulation. As part of the course, we will show you how to rapidly simulate circuits using **MULTISIM**. Additionally, you will learn how to perform rapid prototyping of digital circuits using an EDA tool called **Quartus II** by Altera Corporation. You will learn step-by-step instructions of the digital design process by use of the schematic design entry method, in which the user draws a graphical diagram for the simulation and hardware implementation of a basic digital circuit in an Altera FPGA device. You will learn Schematic Capture tools are used extensively in subsequent courses, and of course, in industry.

Digital logic design tends to be one of the most practical fields you will encounter in college. The knowledge you gain from this course is readily applicable to many problems and needs in industry. You are, therefore, urged to try and get as much out of this course as you can.

The notation in this manual follows that of most texts. Standard symbols are used for all components (Gates, Flip-Flops, etc.). Boolean variables are all given upper case letter designations (A , B , C , etc.). Although the complement of a Boolean variable is usually indicated by a bar over the letter designation of the variable, a superscript asterisk may also be used (A^* , B^* , C^* , etc.).

2. GENERAL LABORATORY PROCEDURES

1. The lab periods or sessions are three hours long. You should be able to complete the lab in the allocated time period, if you are well prepared. The lab will be open for other labs between your scheduled periods. You may use this time to finish labs or do extra work. It is, however, the instructor's prerogative to allow (or disallow) such extra-laboratory work to be counted in your grade. Make sure you check in with the Instructor. He/she will assign you a work space and assist you in obtaining the required equipment. During a scheduled lab period, the people assigned to that period have priority for the equipment and the Instructor.
2. All the work performed in the lab should be recorded in a Quad-Ruled Laboratory Notebook. Each group member needs their own individual book. You should leave 1-2 pages for a Table of Contents, followed by a Cover Page, Equipment List, Prelab Section, Procedures and Results Sections (and Subsections), and

Conclusion for each laboratory. Each page should be numbered, dated, and initialed. After the conclusion, each member should sign and date the notebook.

3. Most of the Labs have Prelab assignments which require documentation. These must be completed prior to the lab. You are responsible for coordinating the assignments with your lab partners. The Prelab assignments must be included in your Laboratory Notebook as well as your Laboratory Report (if necessary) in the appropriate Section. Each member of the group is individually responsible for completing the Prelab assignment before class time.
4. Please consider the suggestions for finishing labs within the allotted times:
 - Read the lab write-up (repeatedly, if necessary) for understanding before coming to the lab period. If you have questions, see the instructor prior to the session.
 - Underline (or high-light) the lab procedures you are going to follow in the lab. This will enable you to refer to them easily during the lab session.
 - Circle or highlight questions you have to answer or the data you have to record. This way you can make sure you obtain all of the required data during the lab.
 - Have your laboratory notebook prepared in advance of class with information ready to fill in from data within the lab. If there are pictures or waveforms that can be drawn before lab, place them in your Laboratory Notebook before class.
5. While you are in the process of performing the Laboratory experiment, you will likely take notes to assist you in completing your Lab Report. Such notes would include Circuit Diagrams, drawings of Oscilloscope Traces, and Test Results – each of which should be included in your Laboratory Notebook. Some of them will also be translated to your Lab Report.
6. To provide you practice with organizing your laboratory experiments into a concise written report, a formal Laboratory Report may be required for each lab session. Each section of the report should be brief, concise, and use complete English sentences. It is helpful (but not mandatory) if you write the Laboratory Report immediately following the lab experiment so that the data is still fresh in your mind. The notes written in your Laboratory Notebook are vital to writing a strong Laboratory Report.
7. Laboratory Reports are due at the beginning of the next Laboratory session. They will be turned into the Instructor for grading at the beginning of the lab session, and will be marked, graded, and returned the following week. Once

returned, they should be kept in a separate 3 ring binder for reference, as you may need to refer to data within the reports for future laboratories.

8. The white boards in the lab are used to inform you of changes in the lab or to provide guidance/suggestions about the lab. You are expected to be aware of anything posted. You should check the board for announcements at the beginning of each lab session.
9. The tools and components are available for purchase as a kit at the campus bookstore. There are no components or tools available in the lab.
10. There are no data sheets for the components in your lab kit. As is common for engineers in industry, you are expected to obtain such information via the web. A computer is available for each lab group.
11. Many of the experiments will require automated schematic capture and simulation. Such software also can provide the diagrams for insertion into your lab report. We will use Multisim. A copy of this software has been installed on each lab computer. You are encouraged to obtain a copy for your home computer.
12. Some of the lab experiments require you to draw reproductions of waveforms which you observe on the oscilloscope. A template is available at the end of this document which you may utilize if you wish. Feel free to copy it to a program of your choice.
13. To reinforce many of the practical concepts learned in the Laboratory, Review Questions are included at the end of each assignment. You are responsible for knowing the answers to these questions – they may need to be included in your Laboratory Report.
14. To allow time for cleanup and equipment or component return, each laboratory experiment will terminate 5 minutes before the end of the scheduled lab session.
15. Finally, follow normal common sense lab techniques. Keep the lab neat. Do not damage the equipment. Make all circuit modifications with the power OFF. If you do not understand something, ask! Report any broken equipment to the Instructor immediately so it can be fixed.

3. LABORATORY 1 – LABORATORY EQUIPMENT

3.1 Objectives

1. Become familiar with the equipment used in the laboratory
2. Become familiar with many of the definitions associated with Digital Circuits.

3.2 Discussion

The first procedure acquaints you with the equipment used in this lab. The most important piece of equipment is the **OSCILLOSCOPE**. It is the primary analytical tool for this laboratory, as well as for most of the diagnostic work you will perform with electronics. You will also learn how to use the **MULTIMETER**, which measures voltage, current, and resistance; the **WAVEFORM FUNCTION GENERATOR**, which supplies a Square Wave Signal or Pulse Train of a specified Amplitude and Frequency; and some logic components which have been assembled together into an integral system known as the **LOGIC DEVELOPMENT SYSTEM**.

3.2.1 The Oscilloscope

An **OSCILLOSCOPE**, or “scope”, is a device which allows the display of one or more analog or digital waveforms. On analog scopes, the display is drawn by a beam of electrons which is focused to a spot and then deflected to trace the waveform on a phosphor screen. On digital scopes, such as the ones currently being used in the lab, the display is drawn using a color LCD. This is shown in Figure 3.1.

The display screen of scope is divided into a grid of 8 x 10 1 cm divisions called the **GRATICLE**. Along the center axes (horizontally and vertically) the divisions are further subdivided into 5 subdivisions each. The reference to a “division” in this manual corresponds to one of the large (1 cm) divisions.



Figure 3.1: The Tektronix TBS 1152B-EDU Oscilloscope

In order to display a waveform, the scope beam must be deflected both horizontally and vertically. The vertical deflection, which corresponds to an input to the oscilloscope, is proportional to the signal voltage. The horizontal deflection (which is generated internally), corresponds to the time. Most oscilloscopes allow up to two independent inputs called **CHANNEL 1** and **CHANNEL 2**. Each input may be directly coupled to the scope (DC), or AC coupled through an internal capacitor, thereby removing any DC component. Knobs adjust the display amplitude of each input in units of Volts per (scope) Division.

The TBS 1152B-EDU scope is dual trace. Hence it can display:

- Channel 1 only (Single Trace) (**CH1**)
- Channel 2 only (Single Trace) (**CH2**)
- Channel 1 and Channel 2 (Dual Trace)
 - Subtracted Together (Either **CH1 - CH2** or **CH2 - CH1**)
 - Added Together (**CH1 + CH2**)
 - Multiplied Together (**CH1 x CH2**)

The toggles for turning ON and OFF CH1 and CH2 are given by the Yellow “1” Button and the Blue “2” Button on the scope, respectively. The mathematical operations can be selected by pressing the Pink “M” Button, followed by the “**Operation**” Button on the right side of the LCD display, and then selecting the desired math operation by rotating the “**Multipurpose**” Knob and pressing it to implement the operation. Turning off the math operations can be performed by pressing **M** a second time.

Oscilloscopes are very sensitive to proper grounding. If the inputs are not properly grounded, the traces most likely will contain extraneous noise and/or be unstable. The two input channels are grounded internally (within the scope chassis); hence providing a proper ground for one input will suffice also for the second.

The horizontal deflection signal is called a **Trigger**; the movement of the beam horizontally across the face of the scope corresponds to time. The Trigger effectively tells the oscilloscope when to display the waveform after detecting a specific voltage (which may be rising or falling) by the source of the Trigger signal. The Trigger signal may be either:

- Channel 1 (Internally) (**CH1**)
- Channel 2 (Internally) (**CH2**)

- An External Trigger Signal (**EXT**)
- And External Trigger/5 (**EXT/5**)
- The AC Line (**AC LINE**)

Selecting the Trigger source is performed by pressing the **Trigger Menu** Button under the Trigger section of the scope, followed by the **Source** Button on the right side of the LCD display, and rotating the **Multipurpose** Knob to the desired trigger source before pressing the knob to activate it.

The Trigger can also be set to initiate the beam's horizontal sweep on the positive or negative slope of the Trigger signal. This operation may be selected by pressing the **Slope** Button in the **Trigger Menu**. Additional operations of the Trigger source by the scope include triggering off the **Edge** of a normal Trigger signal (or off a **Video** or **Pulse** signal) by selecting its **Type**; allowing the **Mode** of the Trigger signal to be automatically detected (**Auto**) (or detected only once via **Normal**); and triggering off a **DC** or **AC** signal by the Trigger's **Coupling**. In addition, the sweep can be delayed from the Trigger by a preset amount by the **Set Trigger Holdoff** – thus initiating the horizontal sweep at any desired time relative to an input signal (say, from CH1 or CH2). All of these options may be configured when pressing the **Menu** Button on the scope, followed by selecting the desired trigger function with the buttons on the right side of the LCD display, using the **Multipurpose** Knob to select the operation, and pressing the knob to implement it.

3.2.2 The Function Generator

The Function Generator provides a source of repetitive signals. The signal output from the Function Generator can be varied in:

- Frequency (from 1.0 Hz to 5.0 MHz)
- Amplitude (from approximately 20 mV_{pp} to 20 V_{pp}, where V_{pp} is the peak to peak voltage)
- DC Offset (from -10 V to +10 V)

The Function Generator also provides a **SYNC** output to generate a source of pulses (0 – 3.5 V in Amplitude). The SYNC Output is Unaffected by the Amplitude, Function, or DC Offset controls.

Figure 3.2 provides a picture of the BK Precision 4005DDS Function Generator we will be using in the lab.

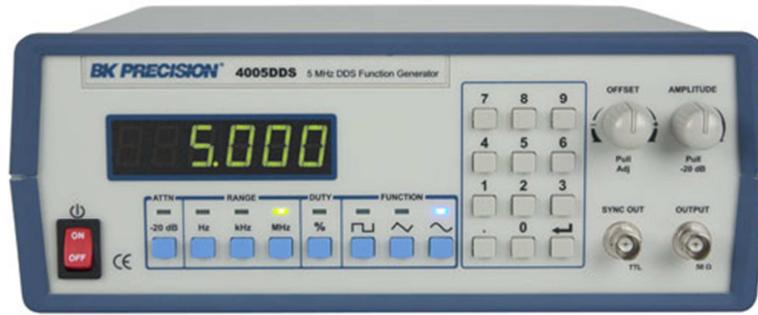


Figure 3.2: The BK Precision 4005DDS Function Generator

3.2.3 The Logic Development System

The **LOGIC DEVELOPMENT SYSTEM (LDS)** is a collection of circuits and interconnection facilities which allow you to conveniently interconnect and test logic circuits. The LDS consists of:

- A location where you can place a Breadboard (Prototype Board, or Protoboard), on which you will mount and interconnect your digital components.
- A 5 Volt (5 V) Power Supply, connected internally to **VCC** and Ground (**GND**). The supply is driven from AC and is switched and fused. In addition, two LED's indicate power ON/OFF and overload (excessive current).
- Two External Inputs (at the top of the LDS):
 - **V2** and **GND** (via a BNC connector), which are connected internally to the 4x4 array of holes V2 and the 4x4 array of holes GND on the LDS, respectively. Wires can be jumped from these arrays of holes to your Breadboard.
 - Binding Posts **V3** and **GND**, which are connected internally to the 4x4 array of holes V3 and the 4x4 array of holes GND on the LDS, respectively. Wires can also be jumped from these arrays of holes to your Breadboard.
- A Variable Frequency Square Wave Clock (top right) with an ON/OFF switch, Fast/Slow range switch and Frequency adjust knob. The output of this Clock is connected internally to the 4x4 array of holes on the LDS.
- Sixteen bit inputs (left) which also are connected internally to the 1x5 array of holes just to the right of the inputs on the LDS:

- 8 ON/OFF Toggle Switches (and corresponding LED indicators) labeled IP-0 to IP-7. These are referred to as *Logic Bit Input Switches*.
- 4 Momentary Contact Pushbutton Switches (and corresponding LED indicators) labeled IM-0 to IM-3. These are referred to as *Logic Bit Input Momentary Contact Pushbutton Switches*.
- 4 Push-ON/Push-Off Latching Pushbutton switches and corresponding LED indicators labeled IL-0 to IL-3. These are referred to as *Logic Bit Input Latching Pushbutton Switches*.
- 16 LED Output Indicator Lamps labeled Q-0 to Q-15 which are connected internally to the 1x5 array of holes to the left of the LED indicators. These are referred to as *Logic Bit Output LEDs*.

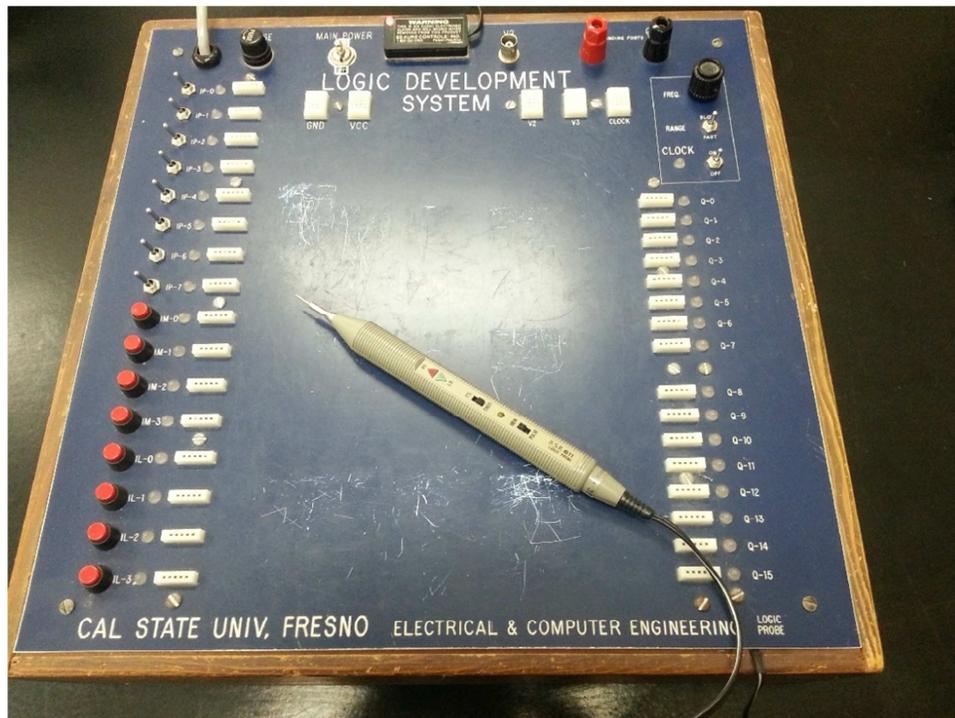


Figure 3.3: The Fresno State ECE Department LOGIC DEVELOPMENT SYSTEM

3.3 Prelab

There is no Prelab Assignment for Laboratory 1, other than reading Pages 9-40 of the User Manual for the TBS 1152B-EDU Digital Oscilloscope.

3.4 LAB Procedure

This lab may take the full three hours, so you should be ready to work quickly. The following lab steps should familiarize you with the equipment.

3.4.1 Oscilloscope

1. Display a single trace with no input:
 1. Turn the **Power ON** (press the button on the top left of the scope from its 0 to 1 position).
 2. Select **CHANNEL 1** as the vertical input (press the Yellow “1” Button to select **CH1**). You should see a yellow waveform display on the screen. If you also see a blue waveform, press “2” to turn off **CH2**.
 3. Verify the submenu settings for CH1 on the right side of the LCD. The **Coupling** should be set to **DC**; the **BW Limit** to **Off**; the **Volts/Div** to **Coarse**; the **Probe** to **10X Voltage** (selected via the **Attenuation** submenu under **Probe**); and **Invert** to **Off**. Change the settings as necessary by pressing the appropriate submenu buttons and using the **Multipurpose** Knob to change each setting to the correct value.
 4. Move the beam to the (vertical) center of the scope face. This is accomplished by rotating the yellow **Vertical Position** Knob. As you rotate the knob, you should notice that the scope informs you of CH1’s vertical position. Rotate the knob so that the vertical position is set to **0.00 divs (0.00 mV)**.
 5. Trigger the scope internally off of CH1. Under the **Trigger Menu**, set the **Type** to **Edge**; the **Source** to **CH1**; the **Slope** to **Rising**; the **Mode** to **Auto**; the **Coupling** to **DC**; and the **Set Trigger Holdoff** to **500.0ns**. (The last two options are on Page 2 of the submenu).

You should see a single yellow horizontal line as traced across the scope in the center of the graticule. Move the trace up and down with the **Vertical Position** Knob. Leave the trace positioned one vertical division above the centerline (**1.00 divs**).

Regarding the submenu settings when turning on CH1: setting the Coupling to DC allows for signals with a DC component to be shown on the device; turning off the BW Limit allows for all frequencies in the waveform between 0 – 150 MHz to be displayed; setting the Volts/Div to coarse allows macro adjustments to be made to the display of the waveform; setting the Probe to 10X voltage displays the actual voltage of the waveform without attenuation, since the probes supplied by the scope automatically attenuate the input voltage by a factor of 10; and setting Invert to Off prevents the waveform from being inverted.

2. Display dual traces with no inputs:

With the single trace (CH1) displayed as in Step 1 above, also display a trace for CH2:

1. Select **CHANNEL 2** as a second vertical input (press the Blue “2” Button to select **CH2**).
2. Set the submenu settings for CH2 to be the same as those for CH1.

Move the second (CH2) trace to the vertical center of the scope graticule as you initially did with CH1 trace in Step 1 (**Vertical Position** to **0.00 divs**). You now should see two horizontal traces, the top Yellow Trace corresponding to CH1 and the bottom Blue Trace to CH2.

3. Display of the Calibration Waveform:

Return the scope to a mode where only the CH1 trace is displayed in the center of the graticule – be sure to adjust the **Vertical Position** of the trace to **0.00 divs (0.00 mV)**. If not already connected, attach the yellow probe into the **CH1** BNC input (the BNC connection requires a gentle push and half twist clockwise until clicking into place).

Display the internal calibration square wave (this is a waveform with a specified amplitude and frequency from a source inside the scope itself):

1. Attach the smaller portion of the Black Alligator Clip to ground. This is accomplished by clipping the lead to the Bottom **PROBE COMP** Terminal.
2. Attach the longer probe lead to the Top **PROBE COMP** Terminal. This will allow CH1 to measure the 5 V, 1 kHz calibration waveform generated within the oscilloscope.
3. Set the Vertical Scale to **2.00 V/div** by rotating the Yellow **Vertical Scale** Knob appropriately. This sets each vertical division on the display to 2.00 V per vertical graticule division.
4. Set the **Horizontal Scale** to 250 $\mu\text{s}/\text{div}$ by rotating the **Horizontal Scale** Knob appropriately. This sets each horizontal division on the display to 250 μs (or 0.25 ms) per horizontal graticule division.
5. Adjust the **Trigger Level** Knob so that the display is stable (clockwise increases the level). This can be performed by rotating the **Trigger Level** Knob so that the trigger is between 0 and 5.0 V. To quickly set the Trigger

level to 50% of the maximum voltage of the Trigger Signal (in this case 2.5 V since the maximum voltage of the signal is 5.0 V), simply push the **Trigger Level** Knob. This should create a stable waveform.

6. Adjust the **Trigger Position** to be in the center of the display. This is performed by rotating the **Horizontal Position** Knob so that the Trigger Signal position is set to the center of the graticule display (the Orange "T" should be in the center of the display at the top). To quickly center the Trigger Position, simply push the **Horizontal Position** Knob.

With these settings, you should see approximately 2 cycles of the calibration square wave (a square wave is a digital waveform in which the time in the "High" state is the same as the time in the "Low" state). Switch the **CH1 Coupling** (under the "1" submenu settings on the right side of the LCD) from **DC** to **AC** and observe the effect on the waveform. You may need to reset the Trigger level to stabilize your waveform? Can you explain your observations (DC versus AC)?

Change the **Coupling** back to **DC**, and re-stabilize the waveform.

4. Zooming in on a Waveform

The zoom feature can be used to magnify and display a selected portion of a waveform.

With the 2 cycles of the calibration square wave displayed as in Step 3, create a (horizontally) magnified version:

1. Press the **Zoom** Button (the button with the magnifying glass). The original waveform will continue to be displayed in the upper quarter of the screen.
2. Select the **Scale** submenu from the button on the right side of the LCD.
3. Turn the **Multipurpose** Knob to change the scale factor of the portion of the waveform to zoom **Factor: 10X**.
4. Adjust the **Horizontal Scale** Knob to **10.0 $\mu\text{s}/\text{div}$** . Notice that the "square wave" actually possesses curvature as it rises from 0.0 V to 5.0 V. With a zoom factor of 10X, the horizontal zoom time base should now be set to 1.00 $\mu\text{s}/\text{div}$. Verify this by noting **Z 1.00 μs** on the display.
5. Select the **Position** submenu from the buttons on the right side of the LCD. Then rotate the **Multipurpose** Knob so that the position of the waveform is exactly centered on the display. This is achieved when the display reads **Pos: 50.00%**.

You should now be viewing two versions of the same waveform. The top quarter of the screen displays the original waveform (with a time base of 10.0 $\mu\text{s}/\text{div}$), and the waveform on the larger portion of the display shows the magnified version of the wave with a time base of 1.0 $\mu\text{s}/\text{div}$.

5. Calculation of Time Duration (Period) and Frequency.

Figure 3.4 describes the relationship between the period **T** and frequency **F** of a periodic wave.

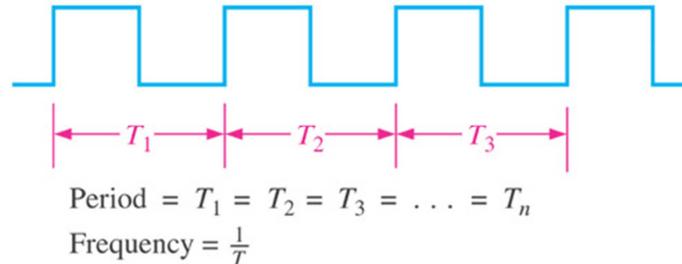


Figure 3.4: Relationship between the Period and Frequency of a Periodic Wave

A value of the period **T** can be obtained from the scope by multiplying the width of one cycle of the wave (the combined width of 1 positive half cycle and 1 positive negative half cycle) in divisions **DIV** as observed on the scope with the setting of the time base in **SEC/DIV** ($T = \# \text{ DIV} \times \text{SEC/DIV}$).

Turn off the zoom feature, and adjust the horizontal time base to 250 $\mu\text{s}/\text{div}$. What value do you obtain when counting the number of divisions over one period of the waveform and estimating the period **T**?

The period can be more accurately measured using the measurement cursors:

1. Press the **Cursor** Button, and select press the **Type** Button from the submenu on the right side of the LCD.
2. Use the **Multipurpose** Knob to select a **Time** Cursor.
3. In a similar manner, set the cursor **Source** to **CH1**.
4. Select **Cursor 1** from the submenu on the right side of the LCD.
5. Use the **Multipurpose** Knob to rotate **Cursor 1** to the first rising edge of the waveform.
6. Select **Cursor 2** from the submenu on the right side of the LCD.

7. Use the **Multipurpose** Knob to rotate **Cursor 2** to the second rising edge of the waveform.

Notice the below the **Source** and above the **Cursor 1** portions of the submenu, the submenu displays the difference between the two cursor positions (Δ).

What is the time difference Δ between the 2 cursor positions? How does this time compare to your previous estimation of the period?

Press the **Type** submenu button, and turn the cursors **Off**.

Finally, the period of the wave can be measured directly by the scope:

1. Press the **Measure** Button.
2. Select **CH1** from the submenu on the right side of the LCD.
3. Use the **Multipurpose** Knob to select **Period**.

Notice that the period of the waveform is now displayed on the bottom portion of the screen.

How does this time compare to the previous two measurements of the period?

The oscilloscope can calculate a number of mathematical operations associated with the wave, including the Frequency, Peak-to-Peak Amplitude, the Minimum Voltage, Maximum Voltage, Mean Voltage, Cyclical Mean, Cursor Mean, Root-Mean-Square (RMS), Cursor RMS, Rise Time, Fall time, etc.

Press the **Multipurpose** Knob again to turn off the measurement of the period.

Note that:

$$\text{Frequency} = 1/(\text{Period}) = 1/T$$

So for our example, the Frequency is 1 kHz. What values do you obtain for the frequency, based upon your three measurements of the period? Compare these values against the scope's measurement of the frequency directly (use the **Measure** Button and select **Frequency**). Comment on your results.

6. Measurement of the Rise Time

The measurement of the Rise Time is determined by measuring the time difference between the 10% and 90% voltage levels of the waveform as it transitions from its minimum voltage (in this case, 0.00 V) to its maximum voltage (here, 5.00 V). To measure the Rise Time:

1. Turn the **Horizontal Scale** Knob to display only the rising edge of the waveform (around **250 ns/div**).
2. Turn the **Vertical Scale** Knob to set the waveform amplitude to about five divisions (**1.00 V/div**), and adjust the **Vertical Position** so that all five divisions of the waveform can be shown on the screen (**-2.00 divs**).
3. Push the **1** (CH1 Menu) Button.
4. Adjust **Volts/Div** from **Coarse** to **Fine**.
5. Turn the **Vertical Scale** Knob to set the waveform amplitude to exactly five divisions.
6. Turn the **Vertical Position** Knob to center the waveform (**-2.5 divs**) so that baseline of the waveform is 2.5 divisions below the center of the graticule.
7. Push the **Cursor** Button to see the Cursor Menu.
8. Push the **Type** submenu button.
9. Turn the **Multipurpose** Knob to highlight **Time**, and push the knob to select it.
10. Push the **Source** submenu button.
11. Turn the **Multipurpose** Knob to highlight **CH1**, and push the knob to select it.
12. Push the **Cursor 1** submenu button.
13. Turn the **Multipurpose** Knob to place a cursor crosshair where the waveform has risen to 10% of its peak value. Since we have adjusted the waveform to 5.00 divs (centered around 0), this is where the waveform crosses the second graticule line below center screen.
14. Push the **Cursor 2** side-menu button.
15. Turn the **Multipurpose** Knob to place a cursor crosshair where the waveform has risen to 90% of its peak value. Since we have adjusted the waveform to 5.00 divs (centered around 0), this is where the waveform crosses the second graticule line above center screen.

The Δ readout in the submenu is the Rise Time of the waveform.

Compare this value against the scope's direct measurement of the Rise Time (use the **Measure** Button to select **Rise Time**).

Press the **Autoset** button to allow the scope to quickly display the base waveform.

3.4.2 Function Generator

1. Set the Function Generator

Set the Function Generator controls as follows:

1. Red Power Button **ON** (to turn the generator ON).
2. Push the square wave **FUNCTION** button (in this position the Function Generator will produce a square wave).

This is the way you typically will use the generator in this lab.

2. Connect the Function Generator

Connect the **MAIN** Output of the generator to input **CH1** of the scope via a coaxial cable. Adjust the **FREQUENCY RANGE**, **DC OFFSET**, and **AMPLITUDE** controls on the Function Generator to obtain a waveform with an Amplitude between 0.0 V – 5.0 V and a Frequency of 1.0 kHz:

1. Adjusting the Amplitude of the wave is performed by rotating the **AMPLITUDE** Knob on the Function Generator between its **MIN** and **MAX** setting. If necessary, additional attenuation (20 dB, or a factor of 100) can be added to the waveform by pulling out the knob before rotating.
2. Adjusting the DC Offset of the wave is performed by first pulling out the **DC Offset** Knob before adjusting it between its – and + setting. This will adjust the overall “average” voltage of the signal. In this case, an average 2.5 V DC offset is required to produce a square wave between 0 – 5 V.
3. The Frequency of the wave can be selected by pressing **kHz** under **RANGE**, and then pressing **1.000** on the keypad and pressing the **Enter** key. This knob allows for fine tuning the frequency from its base value.
4. The **DUTY** button will not be displaying the adjoining light, which indicates that the default 50% Duty Cycle is selected. The Duty Cycle is defined as the ratio of the time the wave form is high compared to the total period of the waveform. For a square wave, the Duty Cycle is always 50%. Press the **DUTY** button to select the Duty Cycle, and use the keypad to adjust the Duty Cycle, if necessary.

You must use the scope to help you accurately obtain your 0.0 – 5.0 V, 1 kHz Square Wave. The 0.00 V reference for the scope (Ground) can be located by setting the scope's **Vertical Position** to a set reference point, say **-2.00 divs**. Adjusting the **Vertical Scale** Knob on the scope to **1.00 V** will then set the display to 1.00 V/div vertically. A 0.0 – 5.0 V waveform will then span the vertical region between -2.00 divisions below center graticule to +3.00 divisions above center graticule. Setting the **Horizontal Scale** to **250 μ s/div** will allow approximately 2 periods of the waveform to be displayed on the scope.

You may need to adjust the **Trigger Level** Knob as well so that the waveform is triggered to create a stable display. If the display repeatedly becomes unstable as you adjust the Amplitude and DC Offset, push the **Trigger Level** Knob to set the trigger to 50% of the current maximum input voltage, if necessary.

NOTE: Since we are no longer using the probes to connect to the oscilloscope, but are providing a voltage input directly via the BNC cable, you **MUST** change the attenuation factor of the input to 1X to get an accurate reading from the scope. To do this, press **1**, select **Probe**, and set the **Attenuation** to **1X**.

Use the Measure Button to simultaneously measure the **Minimum**, **Maximum**, and **Frequency** of the wave. Verify that you have generated a 0.0 – 5.0 V, 1 kHz waveform with your instructor.

How do the measurements obtained from the scope compare with the settings on the generator? This is a good demonstration of why the signal from the Function Generator should always be verified on a more accurate piece of equipment such as the scope before connecting it to your circuit.

3. Connect the Sync Output

Connect the **SYNC** Output of the Function Generator to input **CH 2** of the scope via a coax cable. Turn on **CH2** of the scope (press the Blue **2** Button), and adjust the **Vertical Scale** of both scope channels to **5.00 V/div**. Change the **Trigger Source** to **CH2** (use the **Trigger Menu** Button and submenu options). Use the **Vertical Position** Knobs to adjust the **CH1** to display the waveform between 1 – 2 divisions above center graticule (**+5.00 divs**), and the **CH2** to display its waveform between 1 – 2 divisions below the center of the graticule (**-10.00 divs**). Note that adjusting the **DC Offset** and **Amplitude** controls on the Function Generator have no effect on the **SYNC** Output. Changing the Duty Cycle, however, does.

The digital scope allows digital images of the screen to be saved to a connected USB drive. To do this, insert a USB drive into the USB port in the front of the oscilloscope and wait for it to recognize and load the drive. Then you can click the **"Save"** button (an image of a floppy disk) to save the current display to your USB drive as a .BMP file. This will be useful for saving figures to be used in your lab reports. Save a copy of the current display on your USB drive now for inclusion in your first lab report.

NOTE: Before hooking up a Function Generator to your circuit, you should always check to ensure the Amplitude does not exceed 0.0 – 5.0 V. Excessive voltage can damage TTL components.

3.4.3 The Logic Development System (LDS) and BreadBoard

Power Supply

The **MAIN POWER** Supply in the **LOGIC DEVELOPMENT SYSTEM** is a 5 V, 1 A supply. When the main power switch is turned **ON**, +5 V is applied between the **VCC** and **GND** contacts at the top left of the **LOGIC DEVELOPMENT SYSTEM**.

Insert wires into the **VCC** and **GND** contacts. Use your Multimeter to measure the power supply output (between **VCC** and **GND**); make sure the Multimeter leads (positive and negative) correspond to the power supply polarity. Set the Multimeter to the appropriate scale (you will measure a DC voltage of approximately 5 V). Turn **ON** the power supply and measure the voltage. When your measurement is complete, turn **OFF** the power supply and remove your wires.

The Breadboard (Prototype Board)

The Breadboard consists of an array of holes on 0.1 inch centers, corresponding to standard pin spacing of Integrated Circuits (ICs). Most of the wiring activity takes place in the center columns of the strip. On either side of each center gutter, is an array of 64 rows by 5 columns of socket terminals (holes). The five holes in each row are connected together electrically. The spacing across the gutter is 0.3 in., the same as the spacing between the rows of pins of standard 14, 16, or 18 pin IC dual in-line packages (DIPs). Hence, an IC can be plugged into the board straddling the gutter with contact pins on each side; for each IC pin there will be four holes remaining (in that row) that are electrically interconnected. These holes are used for point-to-point interconnections to other IC pins, power, output LEDs, and input switches. Discrete components such as resistors and transistors also can be plugged in to the board.

The Breadboard also has several two-pin vertical columns of holes distributed about the board. The holes in each column are interconnected (as opposed to the previously-described holes which were interconnected in rows). Such holes are usually used for the distribution of power and ground, clocks, and other common signals to the DIPs in adjacent positions.

The inputs to and outputs from the Breadboard use the left and right (two-pin column) sections. Two such (two-pin column) sections also appear at the top of the board, arranged horizontally. These sections are usually utilized for the (master) distribution of common signals to the vertical (two-pin column) sections.

Clock

Turn **ON** the main power switch on the **LOGIC DEVELOPMENT SYSTEM** and turn the **CLOCK ON**. The clock **LED** adjacent to the **ON/OFF CLOCK** switch should indicate an

output. Obtain a cable with a BNC connector at one end and Alligator Clips at the other. Connect a short length of hookup wire to any hole of the 4x4 bank of holes associated with the **CLOCK** and the red lead of an **Alligator Clip** on the **BNC** Cable. In a similar manner, hook up a wire from the **GND** terminal on the **LOGIC DEVELOPMENT SYSTEM** to the black **Alligator Clip** on the **BNC** Cable. Connect the **BNC** connector to **CH 1** input of the Oscilloscope. With the scope, measure the following:

1. The Frequency of Clock at the minimum frequency setting (set the **RANGE** and **FREQ** settings appropriately). You may find this measurement easier by using a stop watch and counting the clock transitions in some fixed time intervals.
2. The Frequency of Clock at the maximum frequency setting (set the **RANGE** and **FREQ** settings appropriately).

Logic Bit Switches

Toggle switches, slide switches, and push button switches are typical devices found with logic breadboards. Such devices are used to simulate inputs to digital circuits.

There are 16 Input Switches to the LDS Board, 8 Toggle Switches, 4 Momentary Contact Pushbutton Switches, and 4 Latching (Push ON/Push OFF) Pushbutton Switches. Each has associated with it an LED which is Red when the switch output is in the HIGH (Logic 1) state and Green when the switch is in the LOW (Logic 0) state.

Connect one end of a short length probe wire to a hole for one of each of the three types of input switches, and another wire to GND. Leave the other ends free (you will touch the other ends with the Multimeter). Use the Multimeter to measure the voltage of the switches by touching the Multimeter leads to the corresponding wire (and GND) on the LDS. Manipulate the switch, and note the correlation between the switch position, the switch indicator LED, and the Voltage (Logic Level 0 or 1). Repeat the process for all 3 types of switches.

Logic Bit Output LEDs

The LDS contains 16 output Light Emitting Diodes (LEDs). The circuit which drives each LED is designed such that the LED is Red if the input is HIGH (Logic 1) and Green if the input is LOW (Logic 0). With the short jumpers still connected as in the previous experiment, apply a second (longer) jumper from the hole of each of the 3 switches to one of the holes associated with 3 of the Logic Bit Output LEDs. Again touch the Multimeter leads to one of the (shorter) probe wires. Manipulate the switch and note the correlation between the 2 LEDs that are now monitoring the signal and the Multimeter voltage for a given switch: the Indicator LED for the switch itself and the Logic Bit Output LED correspond to the 0 V and 5 V logic levels measured by the Multimeter. Repeat the process for the other two switches.

3.4.4. Lab Toolbox

The Toolbox contains parts and components which will be used for ECE85L throughout the semester. The following table familiarizes you with the parts and components to be used in ECE 85L.

Table 3.1: Parts List for ECE 85L

Integrated Circuits		
Quantity	P/N (Part Number)	Identifier
4	74LS00	2-Input NAND
4	74LS02	2-Input NOR
2	74LS04	Hex Inverter
2	74LS06	Hex Inverter Buffer
4	74LS08	2-Input AND
2	74LS10	2-Input NAND
2	74LS11	2-Input AND
2	74LS14	Hex Schmitt Trigger Inverter
2	74LS20	4-Input NAND
2	74LS27	3-Input NOR
4	74LS32	2-Input OR
4	74LS47	BCD-to-7 Segment Decoder
2	74LS76	JK Flip-Flop
2	74LS86	2-Input XOR
2	74LS93	4-Bit Binary Counter
2	74LS151	8-Input Multiplexer
2	74LS153	4-Input Multiplexer
2	74LS154	4-To-16 Decoder/Demultiplexer
2	74LS194	4-Bit Bi-Directional Shift Register
2	74LS221	Dual Monostable Multivibrator
2	74LS283	4-Bit Binary Full Adder
2	LM555N	Timer
Resistors (1/4 W)		
10	680 Ω	Resistor
10	1 k Ω	Resistor
10	1.5 k Ω	Resistor
10	2.2 k Ω	Resistor
10	4.7 k Ω	Resistor
10	10 k Ω	Resistor
Capacitors		
6	0.01 μ F Mylar Cap	0.01 μ F Capacitor
5	0.1 μ F Mylar Cap	0.1 μ F Capacitor
5	1 μ F Mylar Cap	1 μ F Capacitor
5	10 μ F Tantalum Cap	10 μ F Capacitor
Miscellaneous		
2	ATF750C	Programmable Logic Device
4	MAN71A	7-Segment Display

8	LEDRDT13/4	Red LED
1	Wire Stripper/Cutter	Wire Stripper/Cutter
1	Breadboard	6.9" x 5.75"
1	WK-140	Wire Jumper Kit
1	Screwdriver	Philips Screwdriver
1	IC Extractor	IC Extractor
1	1/2 W, 5 kΩ POT	Potentiometer
1	Minigrabber to Banana	Test Leads Kit
1	Multimeter	Ohmmeter, Ammeter, Voltmeter
1	Plano Enclosure	14" x 9" x 3" Container

Assembling Your Breadboard

Your toolbox comes with parts to assemble to a complete Breadboard. Follow the steps for the assembly of the Breadboard:

1. Locate the parts to assemble a Breadboard; board (MB-106), 4 color voltage terminals and nuts.
2. Peel off the tape under the 4 terminals.
3. Place 4 terminals over the 4 big holes on the top of the board.
4. Attach the terminals to the backside of the board (MB-10) using the nuts.
5. Attach rubber feet to the back of your Breadboard.
6. Show the finished Breadboard to your instructor.

Color Marking

Resistors have colored bands identifying the resistance value. On the lab computer, you can find a resistance color map to help you read color marking on resistor. We will take several resistors to practice reading resistance values two different ways – reading color markings and using the Multimeter. Follow the steps:

1. Find 7 resistors with different color markings from your parts.
2. Read the resistance of the resistors by referring to the color marking chart on the Lab computer.
3. Place the resistors in order on the Breadboard, and mark their color in the table.
4. Use Multimeter to verify the resistance value using the color marking. Write the value to the table.

Table 3.2: Resistor Measurements

Resistors	Color Marking	Multimeter Reading
Resistor 680 Ω		
Resistor 1 k Ω		
Resistor 1.5 k Ω		
Resistor 2.2 k Ω		
Resistor 4.7 k Ω		
Resistor 10 k Ω		

3.5 Review Questions

1. For what range of frequencies will the Logic Probe give meaningful results?
2. How many times must the Logic Bit Input Latching Pushbutton switch be pushed to produce 1 full clock cycle?
3. What is the duty cycle corresponding to a square wave?
4. What is the relationship between Frequency and Period? Between Frequency and Duty Cycle?
5. What is the mathematical definition of the Rise Time, and how is it measured?