Experiment # 1
Introduction to Lab Equipment

1. Synopsis:

In this introductory lab, we will review the basic concepts of digital logic design and learn how to use the equipment available in the laboratory.

2. Terminology:

Digital circuits are made up of chips or *integrated circuits* ("ICs", for short) that contain logic gates. These logic gates take **inputs** and produce specific **outputs**. However, before the chips can function we need to provide a connection to **power** and **ground**. To provide power, we use the **power supplies** (Section 3.1) in our lab. Certain chips require certain inputs to be connected at minimum. For example, a flip-flop requires a clock input. To produce a clock signal, or other time varying signals, we use a **function generator** (Section 3.2). To measure the voltage we use a **multimeter** (Section 3.3) when the voltage is a constant value. An **oscilloscope** (Section 3.4) is used when a varying voltage has to be displayed against time. Before we go into the details of how each one of these equipment works, let us review the basic terminology used throughout this course.

We know from basic physics that potential difference between two points causes current to flow through a resistor. If this potential difference, or voltage difference, changes with time we usually call it a *waveform* or a *signal*. A waveform is characterized by the following five parameters.

2.1   Shape:

A waveform may have any of the well-known shapes (periodic waveform) or an arbitrary shape (aperiodic waveform).

Sinusoidal waveform (periodic)	Rectangular wave-form (periodic)	Triangular waveform (periodic)	An aperiodic signal

In this course, we will be primarily dealing with digital signals, i.e. waveforms that have only two voltage values - high (or, logical "1") and low (or, logical "0"). We use gates from the LS TTL family. For gates in this family, logic "1" refers to (2.4V to 5V) and logic "0" refers to (0V-0.4V).

2.2   Amplitude:

One of the parameters of a periodic signal is its *amplitude*. We will be referring to the amplitude of the signal as its peak-to-peak voltage value (V_{pp}) which is *the absolute difference between the maximum and the minimum value of the signal*.

2.3   Time Period and Frequency:

Time period and frequency of a waveform are inter-related concepts. Frequency is the number of cycles per second while time period is the time taken to complete one cycle. Frequency is usually expressed in **hertz** (Hz)

2.4   Duty Cycle:

Duty cycle is the percentage of time for which a signal remains HIGH as a fraction of the total time period.

$$DutyCycle = \left(\frac{HighTime}{(HighTime + LowTime)} \times 100 \right)$$

2.5   DC Offset:

The offset of the average of the waveform from zero voltage reference is called its DC *offset*. For example, for 0-5V square waveform with 50% duty cycle, the DC offset is 2.5V. For 6V to 7V square waveform with 50% duty cycle, the DC offset is 6.5V.

3. Lab Equipment:

In this section we will discuss the use of equipment available in the laboratory. Please read this section carefully before proceeding to the Procedure Section.

3.1   Power Supply:

All chips require to be powered. Usually this means connecting 5V to the Vcc pin and ground (0V) to the GND pin. We have variable power supplies in our lab (see Appendix II) that can produce two separate voltage levels. One has a maximum of 6V and the other has a maximum of 25V. Turn on the power supply and connect two leads to it; one to the red output, the other to the black. To specify the desired voltage across these leads, turn the knob and set the voltage. Usually this will be 5V for powering our chips. The 25V output is useful in certain applications such as serial communication where plus and minus 12V power supply is required. In this course, we do not use it since excess voltage may destroy the TTL chips.

3.2   Function Generator:

A function generator (shown in Appendix III) produces a voltage waveform. It differs from the power supply in that the power supply can only produce constant voltage levels while a function generator can produce a time varying pattern (i.e. a waveform like a sine wave or square wave, etc.). A power supply can provide a lot of power (a lot of current) whereas a function generator produces a signal which should not be loaded too much. The controls for changing each of the five parameters of a waveform that we discussed in Section 2, are clearly marked on the Function generator. Note that we use the terminal of the function generator labelled as OUTPUT. The other terminal labelled as SYNC is not used in our experiments. The function generator (in our lab) treats the DC offset adjustment as the *simple* average of the maximum and minimum of the signal being generated *without caring for its duty cycle*.

3.3   Multimeter:

Multimeter allows us to measure certain DC (constant) values such as voltage, current and resistance. We will typically use it to measure voltages only (see Appendix IV). Take the two leads (a red and a black one) from the multimeter and place them across the voltage you want to measure. Now press the DC volt button on the multimeter and you will see the voltage displayed. If the display is not steady, it usually means that you have a bad lead connection, or the output is not outputting anything, or the signal is varying. You may also use the multimeter to measure resistance.

3.4   Oscilloscope:

The primary function of an oscilloscope is to display voltage signal with respect to time. Typically, it is used to display periodic waveforms at the input or output of a circuit. The oscilloscope (shown in Appendix V) has two channels which can be used to monitor two waveforms simultaneously. To change the settings for a particular channel, press the button corresponding to that channel and set the parameters using the vertical controls.

The oscilloscopes in our lab are digitalizing oscilloscopes. A digitalizing oscilloscope samples the input signal at a constant high rate and plots the values on the display grid. The vertical axis of the grid represents voltages and the horizontal axis represents time.

Volts/Division: Each vertical square (of the display grid) represents a certain number of volts. By changing the (bigger) knob in the vertical section we can change the number of volts per division. For example a 0 - 10V wave would take up 5 vertical squares if the volts per division was set to 2V. If we then change it to 5 V/div. the wave would only occupy 2 vertical squares. *Note: This is NOT changing the waveform; just the scale that we view the waveform with.*

Zero Volt Level: The zero volt or ground level (or reference level) is indicated by an arrow and number (indicating which channel it corresponds to) on the left side of the display. This shows where the 0V level for that channel is. It is important to realize that *the grid marks on the display do not represent a 0V level or any absolute voltage value.* By using the scroll knob we can move the 0V level to correspond to any grid mark of our choice. We usually want to do this so that we can see two waveforms separated from each other at the same time (for example, set the 0V level for channel 1 on the top half somewhere, and the that for channel 2 on the lower half)

Time/division: By changing the knob in the horizontal section we can change the number of seconds per division. This means that each horizontal square represents a certain number of seconds. For example, a 1 KHz waveform would repeat every 5 horizontal squares if the horizontal scale was set to 200 microseconds/div. However, if we adjusted the knob to 1 ms/div. the same waveform would repeat every square.

Display Modes: Oscilloscope has two display modes: Voltage-Time (YT) display mode and Voltage-Voltage (XY) display mode. In the YT-mode, which is the default/normal mode, the oscilloscope shows voltage value (Y) on the selected channel against time (T). Whereas, in the XY mode, the oscilloscope shows voltage across channel-1 (Y) against voltage across channel-2 (X). We rarely use the XY-mode.

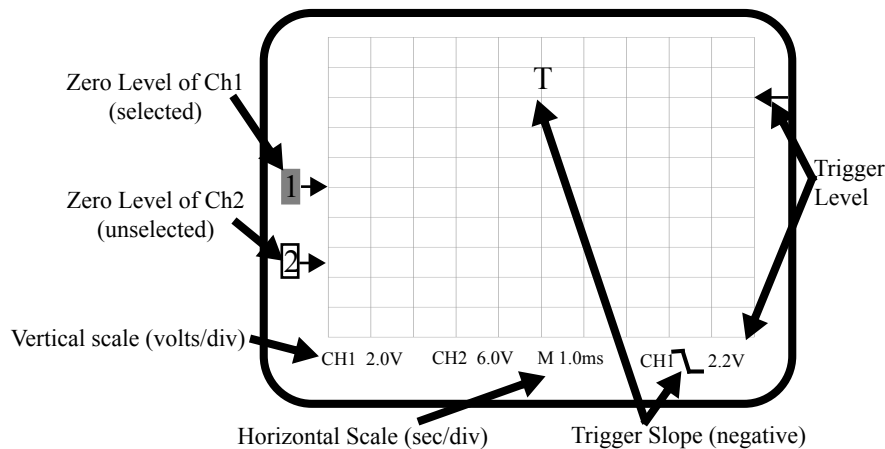Figure 1 shows the various parameters displayed on the oscilloscope screen.

Figure 1: The Oscilloscope screen

Trigger: A stable display on the oscilloscope is due to repeated drawing of the waveform over and over again at a fast rate. The same principle is used for displaying text or picture on your computer screen or TV monitor. The oscilloscope needs to know when to start drawing each time. This is done with the trigger. We set the trigger at a certain voltage and certain slope. For example if we set it to 2V, positive slope, it means that whenever it senses that the input waveform is going up and passes through 2V it will start drawing. It always starts at the point marked as "T" (on the horizontal axis) and displays waveform before and after the trigger. The knob in the trigger section can be used to adjust the trigger. Figure 2a and 2b show how the oscilloscope will show the *same waveform* for negative (figure 2a) and positive (figure 2b) trigger slopes.

Important: The trigger must be set at a value that is within the range of the waveform you are looking at. If you are looking at a 0-5V waveform and if the trigger is set to 7 V you might see scrolling of the waveform (the waveform is unstable) and the light of triggered will be off
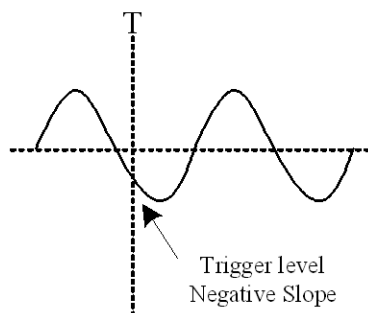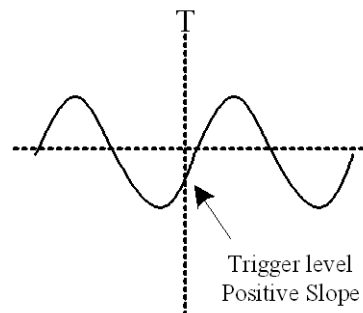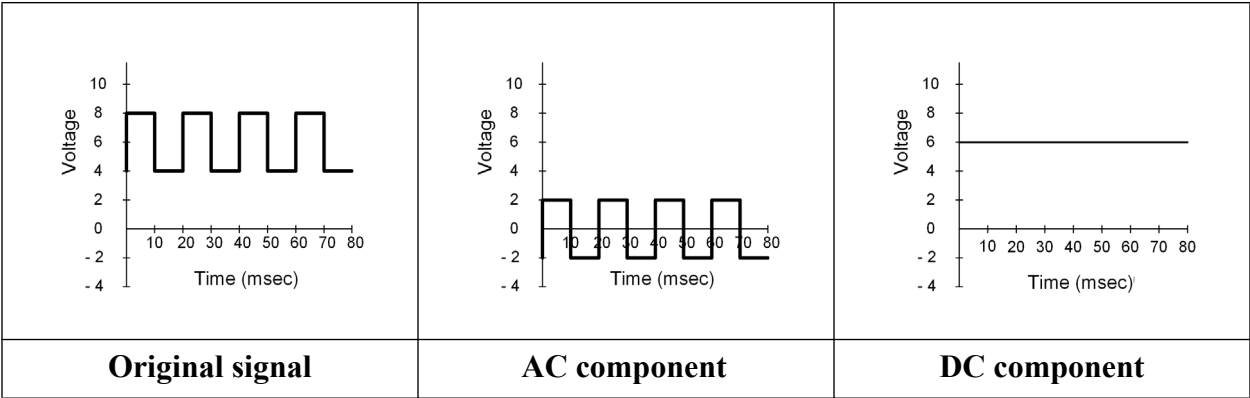.

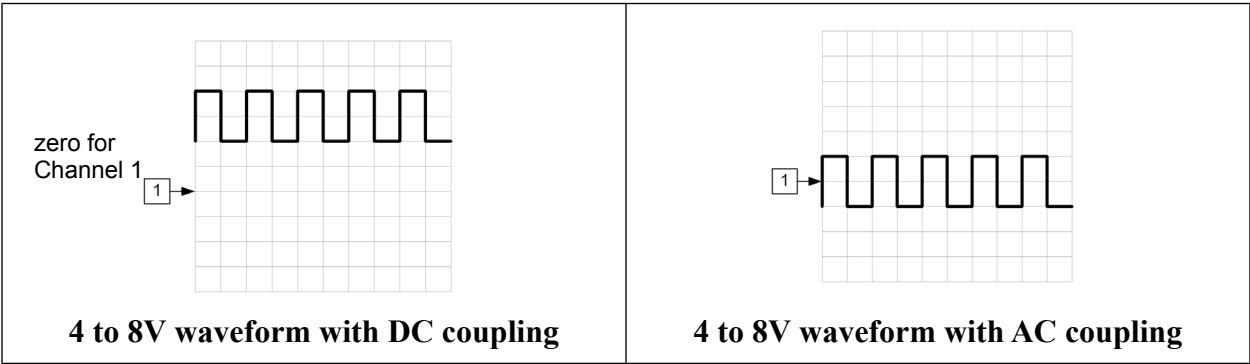Figure 2a: Trigger at negative slope   Figure 2b: Trigger at positive slope

4. Coupling:

Every signal has two components: a DC component and an AC component. The DC component is the average value of the signal, whereas the AC component is the alternating part of that signal.

| Original signal | AC component | DC component |

DC coupling means we accept both AC and DC components of the signal while AC coupling means that we only accept the AC only. DC coupling gives us the actual output of the signal but sometimes we are only interested in the small changing part of the signal.We can set the coupling by pressing the vertical menu button and then selecting coupling menu. In this lab we use DC coupling only.
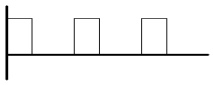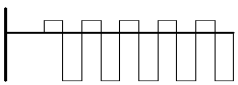
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| 4 to 8V waveform with DC coupling | 4 to 8V waveform with AC coupling |

5. Lab Report:

Name:_____   Date: _____
Lab Session:_____   TA's Signature: _____

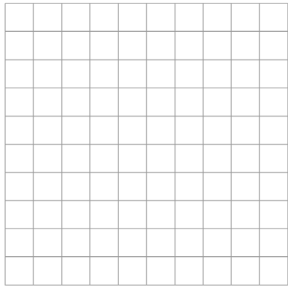**For TAs:** Report (out of 100): ___

Comments

5.1   The frequency of a waveform with time period of 2 msec is _____ Hz.(5 pts)

5.2   Consider the waveforms A and B below and indicate which of the waveforms has the higher amplitude, negative DC offset etc. Assume that the horizontal and the vertical scales in both figures are the same.(25 pts)
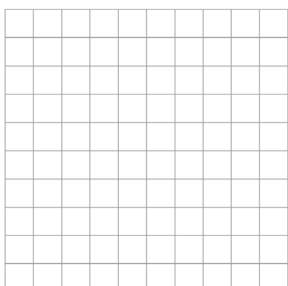
		Higher amplitude: A or B
		Higher Frequency: A or B
		Higher Duty Cycle: A or B
Waveform A	Waveform B	Positive DC Offset: A or B
		Negative DC Offset: A or B

For exercise questions 5.3, 5.4 and 5.5 connect the function generator (the OUTPUT terminal) to the oscilloscope (channel 1) directly. Adjust the setting on the function generator to produce the three square waveforms. Use the oscilloscope to measure/monitor the adjusted signal. Make sure that at least two periods of the waveform fit in the display grid.
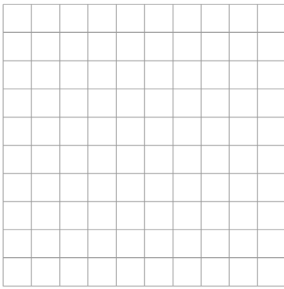
5.3   Square wave 1KHz 0 to +5V   (10 pts)

Vertical Scale: ___ volts/div
Horizontal Scale: ___ μsec/div

Trigger slope: Negative/Positive
Trigger Level: ___Volts

Input coupling: AC / DC

5.4   Square wave 2KHz   -4V to +1V (10pts)

Vertical Scale: ___ volts/div
Horizontal Scale: ___ μsec/div

Trigger slope: Negative/Positive
Trigger Level: ___Volts

Input coupling: AC / DC

5.5   Square wave 100 Hz +2V to +7V (10 pts)

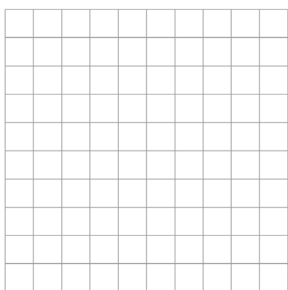Vertical Scale: ___ volts/div
Horizontal Scale: ___ µsec/div

Trigger slope: Negative/Positive
Trigger Level: ___Volts

Input coupling: AC / DC

For the following two questions, first draw the waveform on the grids given below, and then use the oscilloscope to verify your sketched waveform. **The arrow indicates the zero level on the grid**.

5.6   The waveform is -2V to 8V, 25 KHz in frequency and the ON (or HIGH) period is one fourth of the time period (Hint: use this information to calculate the duty cycle). (20 pts)

Vertical Scale: 2 volts/div
Horizontal Scale: 10 µsec/div

Trigger slope: Positive
Trigger Level: 4 Volts

Input coupling: DC

5.7   The waveform is +4V to -6V, 2500 Hz in frequency and the OFF (or LOW) period is one third of the time period. (20 pts)

Vertical Scale: 2 volts/div
Horizontal Scale: 100 µsec/div

Trigger slope: Negative
Trigger Level: 0 Volts

Input coupling: **AC**

Appendix I: Quantities, Units and Prefixes

Quantity	Unit	Symbol
Current	Ampere	A
Voltage	Volts	V
Resistance	Ohm	Ω
Frequency	Hertz	Hz

Table 1: Quantities and their standard units

Prefix	Abbreviating	Quantity
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
Kilo	K	10^{3}
Mega	M	10^{6}
Giga	G	10^{9}
Tera	T	10^{12}

Table 2: Metric Prefixes