LAB 1: Measuring Equipment

I. Introduction

In this lab manual, the general flow of writing a lab report will be introduced. In fact, this very lab manual can be used as a “fill in” template for writing the lab report. Furthermore than just learning how to write a formatted lab report, this lab is intended to introduce essential equipment that is commonly used in an electronics laboratory or at least something very similar. These devices will be used to investigate the behavior of some elementary electrical components. Techniques in creating and evaluating digital electronic circuits will be covered.

II. Equipment needed

- Oscilloscope
- Signal generator (with TTL output)
- Power supply (+12V, -12V and +5 V)
- Electronic solderless breadboard
- Logic Probe
- IC 7404 14pin DIP

III. Theory

The Cathode Ray Oscilloscope (CRO) is probably the most versatile piece of test equipment available to student of electronics. This device gives a visual representation of any voltage waveform present in an electrical circuit. The oscilloscope can measure both voltage and frequency information in a broad range. The voltage of any simple circuit can be calculated by using Ohm's Law stated in equation (1), where ***V***(voltage)[V] is a function of ***I***(current)[A] and ***R***(resistance)[Ω].

$$V = I * R \tag{1}$$

The value of voltage appears on the oscilloscope screen as a deflection of electrons in the vertical direction. The screen is a chemical phosphor that converts the energy of the electrons into light (photons). The screen's vertical divisions allow scientist to measure voltages in a wide range by adjusting the gain of the device from 5 mV per division to 5 V per division. Deflections of the electrons in the horizontal direction allow measurements of frequency or signal timing. The relationship between frequency and signal timing is given in equation (2), where ***T***(time)[s] is a function of ***f***(frequency)[Hz].

$$T = \frac{1}{f} \tag{2}$$

On the oscilloscope, T is the period of an alternating waveform and f is the frequency of the wave. The screen is divided into 1 centimeter divisions so the waveform timing can be measured over a large frequency range.

The signal generator is a device that produces known waveforms which can be evaluated by the oscilloscope. The most common waveforms that are produced by the generator are sine, square and saw-tooth waveforms at various frequencies and amplitudes. In digital electronics, the primary waveforms used are the square wave and transistor transistor logic (TTL) outputs. TTL is a family of packaged logic components that enjoys widespread use in industry. TTL components have been designed so they can be interconnected without too much concern about proper electrical operation. TTL components operate with a +5V power supply.

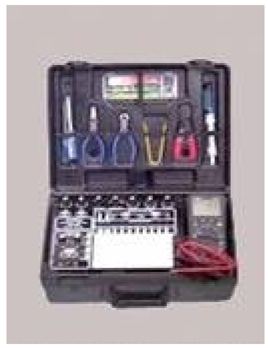


Figure 1: Electronic trainer kit that has a built in power supply.

The power supply is a voltage or current generator capable of suppling energy to the circuit. Because of the popularity of TTL technology, which dictates the required voltage necessary for proper digital circuit operation, the power source in this lab need only be stable outputs of +5(TTL technology) and +/- 12 volts (CMOS-Complementary Metal Oxide Semiconductor- technology). *Figure 1* depicts a electronic trainer kit which have built-in power supplies that can support TTL and CMOS technologies.

Figure 2: Electronic solderless breadboard, also known as a proto-board.

An electronic solderless breadboard is a device specially designed for the purpose of experimenting with electronic circuits that can easily be modified and evaluated. An example of one is shown in *figure 2*. The breadboard has numerous connected holes that are joined in series uniquely suited for TTL technology, specifically, logic gates that are available in rectangular dual in-line packages known as "DIPs". *Figure 4* has a picture of a 14 pin DIP.

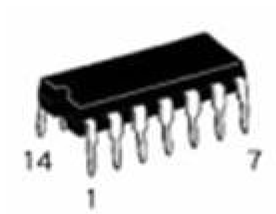


Figure 3: 14 pin DIP integrated circuit.

You will often find that troubleshooting an installation or problem requires you to know the state of a given digital port or integrated circuit pin. A logic probe makes this easy, which is displayed in *figure 4*. Simply attach the power leads and touch the probe to monitor the digital state of any part of an interfaces circuit. It's easy to read status LEDs give you the info you need quickly and easily.

Figure 4: Commerical logic probe.

Light Emitting Diodes (LEDs) are special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A clear (or often colored) epoxy case encloses the heart of an LED, which is the semi-conductor chip that is illustrated in *Figure 5*.

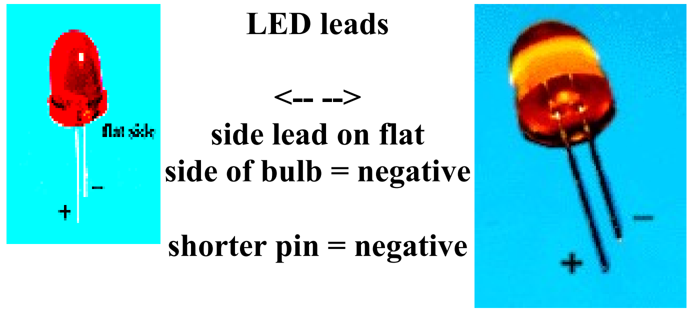


Figure 5: Examples of Light Emitting Diodes(LEDs).

The two wires extending below the LED epoxy enclosure or the "bulb" indicate how the LED should be connected into a circuit. The *negative* side of an LED lead is indicated in two ways: 1) by the *flat side* of the bulb, and 2) by the *shorter* of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LED chip. TTL chips have an output drive current of up to 30 mA in an output low configuration, which is under the maximum allowable current for LEDs.

LED Driver circuits (Logic probes)

Figure 6 shows the circuit diagram for a positive logic probe. This circuit is used to test for logical "1"s. *Figure 7* shows the circuit diagram for a negative logic probe. This circuit is used to test for logical "0"s. The line on the inverter's input is the logical probe.

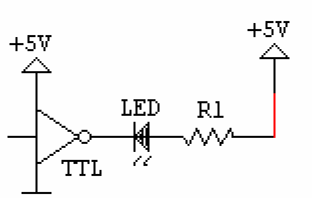


Figure 6: LED is on when the inverter's output is low.

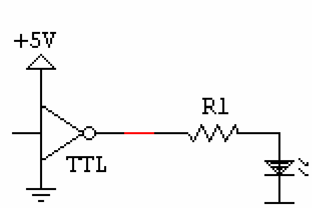


Figure 7: LED is on when the inverter's output is high.

R1 controls drive current in both drivers. When Vcc = 5V and Red LED is used, R1 = 3.3/(desired LED current). For example, for an LED current of 10 mA, R = 3.3/0.01 = 330Ω. Depending on outputs from the inverters, if a potential difference is created, that will create a current flow and turn on the LED. If the potential difference between the output of the inverter and the supply voltage is very small, then no current is allowed to flow and the LED will not turn on.

IV. Procedure

A) Oscilloscope calibration

1. Obtain an oscilloscope and a probe from the lab instructor. Turn on the device and plug the probe into channel 1 (CH1). Adjust the intensity of the scope trace so that it is easily seen but not too bright. Adjust the focus so the line is sharp and in focus.

2. Make sure the four buttons in the center of the device are all out. The var. knob beside the CH1 plug should be rotated all the way counterclockwise and set on cal.

3. Place the switch up and to the left to the GND position. Adjust the CH1 VOLT/DIV knob to 10 mV. Adjust the POS knob above and to the left so that the scope trace (line) is in the middle of the screen. The knob at the far top right adjusts the trace horizontally.

4. Touch the end of the scope probe to metal tab marked cal at the lower right hand corner near the on/off switch. Notice the trace on the screen jumps. Adjust the TRIG LEVEL knob until the trace becomes stationary. Record the peak-to-peak voltage, Vp-p (If the scope probe you are using reads x10 then the voltage must be multiplied by 10). If the Vp-p is not 0.2 Vp-p your scope is not calibrated and you should contact the lab instructor to make the proper adjustments.

B) Oscilloscope measurements

1. Connect the signal generator output to the oscilloscope input CH1. Turn on the signal generator and set it to 1000 Hz (use the course adjust knob to get close to the desired frequency and then the fine adjust to fine tune it). Make sure the function is a sine wave and adjust the amplitude of the waveform to 2 Vp-p.

2. Sketch the waveform on the oscilloscope, indicating the period and the peak-to-peak voltage.

3. Change the function and frequency of the waveform to a 3 kHz square-wave and repeat step 2.

4. Move the output from the signal generator to the TTL/CMOS plug just to the left.

5. Repeat step 2.

C. Solderless breadboard

1. Assemble the voltage terminals on the board. Connect the power supply +5 V output to one of the terminals on the board. Connect the -5 V output to another voltage terminal on the board. Connect the black(ground) terminals of the power supply and the board.

2. Connect CH1 of the scope to the -5 V terminal of the board. Sketch the voltage information on the oscilloscope, indicating the period and voltage.

3. Connect a jumper wire from the -5V terminal to a hole anywhere in the board.

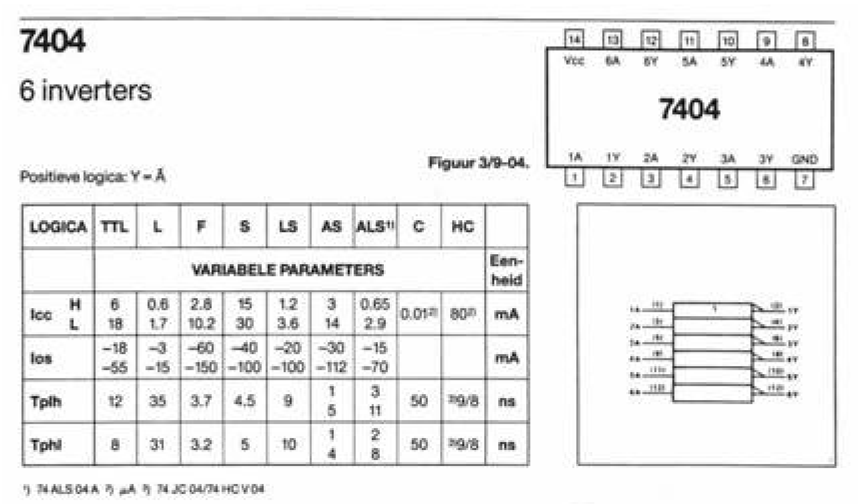
4. Use the scope probe to investigate how interconnection is made on the solderless breadboard.

5. Move the jumper wire to another hole in the board and repeat step 4.

6. Repeat step 5 several times, until you are satisfied that you know how the many rows and columns of the breadboard are interconnected.

D. <u>IC DIP 14 pin chip</u>

1. Insert the 7404 IC chip into the breadboard and provide power and ground to the chip. *Figure8* shows some general specifications for the 7404 class of IC's, which contain 6 inverter logical gates.



7404

6 inverters

Positieve logica: Y = Ā

Figuur 3/9-04.

LOGICA	TTL	L	F	S	LS	AS	ALS[1]	C	HC	
	VARIABELE PARAMETERS									Een-heid
Icc H Icc L	6 18	0.6 1.7	2.8 10.2	15 30	1.2 3.6	3 14	0.65 2.9	0.01[2]	80[2]	mA
Ios	−18 −55	−3 −15	−60 −150	−40 −100	−20 −100	−30 −112	−15 −70			mA
Tplh	12	35	3.7	4.5	9	1 5	3 11	50	[3]9/8	ns
Tphl	8	31	3.2	5	10	1 4	2 8	50	[3]9/8	ns

[1] 74 ALS 04 A [2] µA [3] 74 JC 04/74 HC V 04

Figure 8: 7404 IC specifications.

2. Verify the proper operation of the 6 inverters on this chip using the logic probe.

E. <u>LED Driver Circuits</u>

1. Wire up the circuit shown in *figure 9* and *figure 10*. A resistor value of 1kΩ would be a prudent value to use in both circuits.

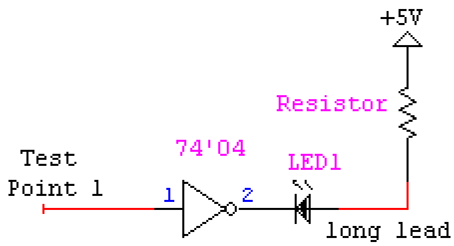


Figure 9: Positive logical probe wiring diagram[2].

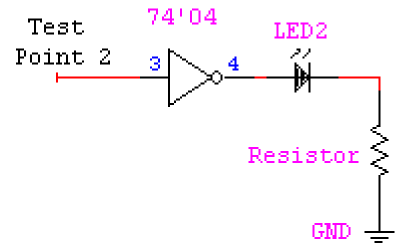


Figure 10: Negative logical probe wiring diagram[2].

2. Verify the proper operation of both logic probes.

3. Verify the proper operation of the switches and LEDs in the Analog-Digital Trainer kits.

V. Conclusions

Calculations to be done for the lab report

1. From the measured periods (T) of the waveforms recorded in section IV-part B, calculate the frequencies using equation (2).

2. Calculate the percentage difference between the calculated frequencies and the frequencies set on the signal generator. Keep in mind the calculated frequencies are your theoretical values and the measured frequencies are your experimental values.

Questions to answer for the lab report

- What is the difference between alternating and direct voltage and how is the oscilloscope used to measure these voltages?

- How is the solderless breadboard internally connected? Sketch these connections for future use.

- How might you use (wire-up) a single 7404 chip as a storage element? How about a ring oscillator? (Hint. If your not sure what a ring oscillator is, check it out online.)
- What is a diode? Why are LEDs considered diodes?

It is good to make a concluding paragraph. Essentially it is a summary of the significant finds in the laboratory. If any problems were encountered, state them and try to explain why they happened. Futhermore, try to state what could be done in the future to prevent such problems. This is where one gets the chance to demonstrate active thinking, which is a requirement for any good engineer. In the end, that is the ultimate goal of this course, to create a new generation of qualified engineers and . inserting knowledge of digital circuit design into the student's brain is secondary.

VI. References

[1] Rand, John; *EE 260 Digital Electronics*; accessed Jan. 13,2006;

<http://www2.hawaii.edu/~jrand/ElectricalEngineering/INDEX.HTML>.

[2] Dobry, Tep; *EE 260 Introduction to Digital Design*; accessed Jan 12, 2006;

<http://www-ee.eng.hawaii.edu/~tep/EE260/>