LABORATORY REPORT - CHAPTER 2

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Total Grade	/100

Remarks: Record all your measurements and write all your answers in the boxes provided. Do not write anything in the cells labelled as GRADE. Never forget to explain your results and to specify the units of your measurements.

Preliminary Work

1. Oscilloscope probe

1. Probes are vital to high-quality oscilloscope measurements. A probe makes an electrical connection between a test point and an oscilloscope, but it is more than just a piece of wire. An ideal probe has the following properties:

   - Signal fidelity (the signal at the test point is faithfully duplicated at the oscilloscope input)
   - Does not *load* the test point (it does not change the value of voltage it is trying to measure)
   - Immune to electromagnetic noise sources in the environment (it shields the noise in the environment from reaching the oscilloscope input).

   Consider the equivalent circuit of an oscilloscope input composed of a resistor R_{in} in parallel with a capacitance C_{in}. The oscilloscopes are frequently used with *probes.* The oscilloscope input impedance connected to an oscilloscope probe can be modeled as shown in Fig. 1.

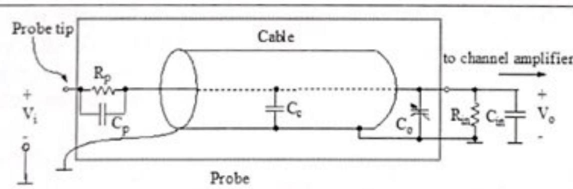

Figure 1: An oscilloscope probe connected to the input of an oscilloscope.

The attenuation ratio of the probe is always written on the probe, as 1:1 or 10:1 (sometimes 100:1). Some probes have switches with the option of setting the attenuation ratio. Assuming that capacitors do not exist and the oscilloscope input resistance, R_{in}=1 MΩ, find the value of R_p such that V_i:V_o is exactly equal 10:1. Note that R_p and R_{in} form a voltage divider, and the attenuation ratio is

$$\frac{V_o}{V_i} = \frac{R_{in}}{(R_{in} + R_p)} = \frac{1}{10} \Rightarrow R_p = 9M\Omega \qquad (1)$$

$R_t = 10M\Omega$

When the attenuation ratio is 10:1, the probe does not perturb the voltage value under measurement significantly. What is the total resistance, R_{total}, between the probe tip and ground?

R_p= 9 MΩ	R_{total}= 10 MΩ

1.1. GRADE:

2. C_c is the capacitance of the probe cable and is parallel to C_{in} (the input capacitance of the oscilloscope input). C_o is a small compensation capacitance, usually mounted on the probe connector. In some probes, it is an adjustable capacitor parallel to C_{in}. When C_o is adjusted such that $(C_c + C_o + C_{in})R_{in} = C_pR_p$, the transfer response becomes equal to that given in Eq 1. Hence, V_o/V_i is independent of frequency even though capacitors exist. Under this condition we say the probe is *compensated.* The typical input capacitance of an oscilloscope is C_{in}=20 pF. C_o is typically about 10 pF. The probe cable capacitance C_c is typically about 40 pF. Estimate the value of C_p for the 10:1 probe when the probe is compensated.

   70pF

   C_p = 7.78

   When the probe is compensated, the effective input capacitance of the probe, C_{eff}, is equal to C_p in series with $C_c + C_o + C_{in}$:

   40pF 10pF 20pF → 7.78 pF

$$C_{eff} = \frac{(C_c + C_o + C_{in})C_p}{C_c + C_o + C_{in} + C_p} \qquad (2)$$

   → 77.8 pF

   Since $C_{eff} < C_p$ and C_p is a small capacitance, the effective input capacitance of the probe is relatively small. The capacitance of the probe should not *load* the node under measurement. At low frequencies, the probe does not affect the voltage at the node. But at high frequencies, the small probe capacitance may affect the measurement.

C_p= 7.78 pF	C_{eff} = 7.0 pF

1.2. GRADE:

2. Voltage Regulator

1. Examine the power adapter given in the TRC-11 kit. The adapter generates a +12 V DC *regulated* voltage supply for TRC-11, obtained from the 220 V mains line by AC to DC conversion with a good efficiency. The TRC-11 power adapter provides up to 1 A current. When the current drawn from the supply is below this limit, the terminal voltage of the regulated supply is almost exactly equal to its nominal no-load level. When the limit is exceeded, the terminal voltage drops. A regulated supply behaves almost like an ideal voltage source if the drawn current does not exceed the specified limit.

2. An electrolytic capacitor is a polarized capacitor. It is composed of a metal layer immersed in a gel. The metal layer acts as the positive plate, and the gel electrolyte is the negative plate. The metal surface is covered with a thin insulating oxide layer. Since the insulating layer is very thin, a very large value of capacitance can be obtained. Search the internet and find the smallest and largest valued electrolytic capacitors.

Smallest valued electrolytic capacitor = 0.1 pF	Web site= www.quora.com
Largest valued electrolytic capacitor= 10 KF	Web site= www.eepower.com

2.2. GRADE:

3. A 6 V voltage regulator is used in the voltage regulator circuit. Voltage regulators are integrated circuits comprising many transistors. The regulator used has three pins: input, output, and ground. A voltage regulator converts a voltage level at its input terminal into a clean DC voltage level without any ripple. The supply voltage of 6 V is obtained at the output of the regulator 7806. The datasheet of 7806 is given in pages 344. In order to perform regulation, a voltage regulator requires that the minimum voltage level that appears across its input be somewhat higher than the nominal output voltage. This voltage difference, V_{do}, is known as *dropout voltage*. Go to page 346 to find the dropout voltage for 7806. For example, if the dropout voltage is V_{do}=2.5 V, the minimum value of the unregulated voltage at its input should be 6+2.5=8.5 V, in order to provide a regulated nominal 6 V output. Find the absolute maximum voltage at its input. The output voltage value has a tolerance. For 7806, the output voltage can be between V_{min} and V_{max} at room temperature. This does not mean that it can fluctuate between these values, but the level at which the output is fixed can be anywhere between these limits.

   Find the output current, I_{Omax}, that can be drawn from the regulator, while the voltage regulation is typically better than 5 mV (I_O in the Load Regulation row of the datasheet). Find V_{min} and V_{max} from the datasheet.

7806: I_{Omax}= 1.5 A 7806: $V_{dropout}$= 2V	V_{min}= 5.75 V	V_{max}= 6.25V

2.3. GRADE:

4. The line voltage has a sinusoidal waveform. The frequency of the line, f_L, differs from country to country, but it is either 50 Hz or 60 Hz. For some specific environments, there are other line frequency standards (in aircraft, for example, the AC power line is 400Hz).

   When an AC *line* voltage is specified, e.g., 220 V, it usually means that the line potential is 220 V_{rms}. Hence, the voltage on this line is of sinusoidal form with a peak amplitude of approximately (nominally) $220\times\sqrt{2}$=311 V.

   If we measure an AC voltage with a multimeter, the reading is the *rms* value of the voltage.

   The power adapter of TRC-11 provides a 1 Watt, 12 V output voltage. It converts 220 V rms AC line voltage to 12 V DC.

5. Study the datasheet of PTC thermistors (C910) on page 414. Determine the rated, I_N, and switching, I_S, current of C910 (PTC1). What is the on resistance R_N of these thermistors? Record these figures.

I_N= 530 mA	I_S= 1.1 A	R_N= 0.9 Ω

2.5. GRADE:

6. D1 (1N4001) is a silicon p-n junction diode. Refer to its datasheet on page 391. Find the forward voltage drop on the diode if 1 A flows through it.

D1: V_F (from data sheet, when I_F=1 A)= 1 V

2.6. GRADE:

Experimental Work

1. Oscilloscope probe

1. Fluorescent lamps and motors in the environment are some of the electrical noise sources. Connect a 30 cm to 1 m long wire to the tip of the oscilloscope probe. Do not connect the wire to anything. Set the Trigger Source to AC Line in the Trig Menu. Set the SEC/DIV to 5msec. Find out what the oscilloscope shows on its screen. Move the wire around and observe. Write down your observations.

Observations: When SEC/DIV has been adjusted to 5ms, the waveform began to appear on the oscilloscope display and after adjusting VOLT/DIV knob almost sine waves were visible but with noise.

1.1. GRADE:

2. Touch your finger to the probe tip. Observe the oscilloscope. What happened? Note that since the human body is conducting, the body picks up the electrical noise in the environment, which is what you observe on the oscilloscope. In fact, touching the finger to the probe tip is a fast and practical way of determining if the probe and/or oscilloscope are working properly.

Observations: When oscilloscope probe has been touched with the finger as suggested my body acted like an anthena and stronger waves appeared on other words amplitude of the waves increased but they were still noisy.

1.2. GRADE:

3. Connect the inner wire (or the center pin of the BNC connector) of a coaxial cable to the probe tip. Observe the signal on the oscilloscope. Now, connect the probe's ground clip to the outer wire (or outer metal of the BNC connector) of the coaxial cable. Touch the probe tip to the inner wire. What happens?

Observations: Oscilloscope probe and BNC cables center part was connected while ground pin of the oscilloscope probe was still attached to the oscilloscope then a stronger signal was observed but for the both cases they were noisy sine waves.

1.3. GRADE:

4. Set the attenuation ratio of your probe to 10:1 (if there is a switch). A DC resistance measurement using an ohmmeter can reveal the value of R_p. Measure the resistance between the probe tip and the center pin of the BNC probe connector and record it. How does it compare to the value you found in the preliminary?

R_p= 8.98 Ω

Comparison: The calculated value and the measured one had small difference but they were close enough that it worked properly.

1.4. GRADE:

5. The attenuation ratio of the probe being used must be known by the oscilloscope, otherwise, the oscilloscope may show false voltage values. Learn how to set the probe ratio on the Channel Menu of the oscilloscope.

   Oscilloscopes have a special terminal for compensation, usually marked PROBE COMP for probe compensation. This is an output where a 1 kHz 5 V_{pp} square wave signal is provided. Connect the probe tip to this terminal (ground connection is not necessary) to compensate the probe. Display the signal on the scope. If the signal is a perfect square wave, there is no need for an adjustment. If the square wave has corners that are higher or lower than the final level, this is because the probe is uncompensated.

   If your probe has a compensation screw: Turn the screw of the variable capacitor C_o. Adjust until you get a square wave with right-angled corners. The probe is compensated.

   Always use the 10:1 setting of the probe to reduce the loading on the circuits when making measurements, unless the signal is very small and the probe loading is not important.

2. Voltage Regulator

1. Place the TRC-11 PCB on the workbench. This PCB is double-sided with two layers of copper foil laminated on both sides of an insulating material called FR4. FR4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder. If the circuit is low density, single-sided PCBs are preferred for their low cost. The *solder* side is coated with a green-colored *solder-mask* layer to prevent soldering in unwanted locations. Solder can only be done at locations where the solder mask is absent. The exposed copper at those locations is coated with a thin layer of solder to ease the soldering and to prevent corrosion of the copper. The other side of the PCB is the *component* side. This side has an *overlay* (or silkscreen) layer showing the positions and designations (like R1) of the components. TRC-11 PCB is a relatively large board, designed with very comfortable spaces between components to ease the soldering. Actually, the same circuit can be fit on a board half the size easily with less separation between the components. The board can be made even smaller, if the board has components are both sides, and all components are *surface-mount*.

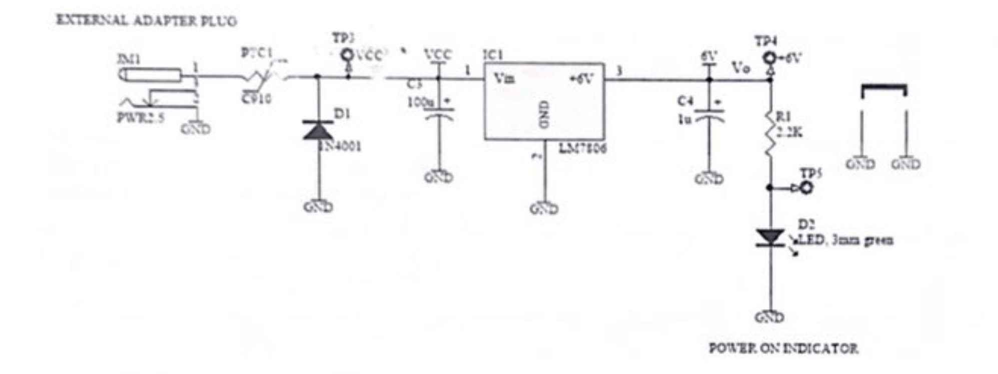

Figure 2: Schematic of the voltage regulator

Designator	Comment	Description
C3	100u	Electrolytic Capacitor, Polarized, 16V
C4	1u	Electrolytic Capacitor, Polarized, 50V
D1	1N4001	Diode
D2	LED, 3mm green	Light-Emitting-Diode
IC1	LM7806	Linear voltage regulator, 6V
JM1	PWR2.5	Low Voltage Power Supply Connector
PTC1	C910	PTC
R1	2.2K	Resistor, carbon film, axial leaded, 1/4W

Figure 3: Bill of materials for the voltage regulator

2. Find the VOLTAGE REGULATOR region on the PCB.
3. Mount and solder JM1, 2.5 mm external adapter jack. Power adapter plug enters into this jack.
4. Mount and solder PTC1. Trim the leads of the PTC at the other side of the PCB using a side cutter.
5. It is a good idea to solder a wire loop in test points (TP) and between GND points as shown in the photos. These will make the connection with an oscilloscope probe easy. Solder loops of wire at the test points, TP3, TP4, and TP5.

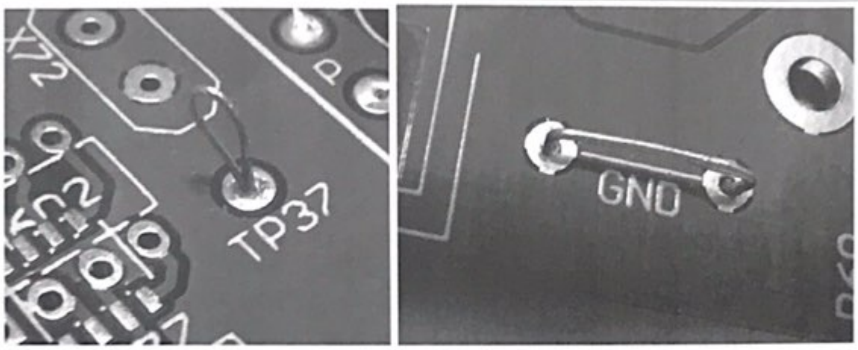

Figure 4: Photos of a test point and a ground wire loop.

6. Solder both ends of a wire between the holes marked GND (near IC1). You can use the clipped leads of the PTC for this purpose. You need this wire to make the ground connection to the oscilloscope probe.

7. Measure the power adapter output DC voltage between TP3 and GND using the oscilloscope. For this purpose, you should set the coupling of the oscilloscope channel to DC. The ripple on the output should be too small to observe.

V_{TP3}= 12.29 V

2.7. GRADE:

8. Set the multimeter in "diode test" mode. Connect the multimeter leads across the 1N4001 diode. In this mode, the multimeter applies a current (about 1 mA) through the diode and measures the voltage across it. When the diode is reverse biased, the multimeter displays "OL".

   This diode is used to protect TRC-11 in case a reverse voltage is applied to the power adapter jack. With a reverse voltage, it conducts and PTC heats up, and goes into a high impedance state to protect the circuit and the diode. Mount and solder D1.

D1: V_F (from measurement in forward direction, red lead on anode) = 0.55 V
D1: V_F (from measurement in reverse direction, red lead on cathode) = Overload

2.8. GRADE:

9. The voltage regulator generates +6 V necessary for the operation of TRC-11 using +12 V input voltage. Install IC1 (7806) and bend it so that its metal backside touches the PCB. Align the hole of IC1 with the hole on the PCB. Use the screw and nut through the holes to secure the IC1 in place. The copper region under the regulator acts like a *heat sink*. A heat sink has a large area which allows radiation of dissipated power into the air. Solder its leads. 7806 is a +6V voltage regulator. Its output voltage should remain at a constant +6V even though its input voltage may vary.

10. Electrolytic capacitors are large value capacitors with a polarity. They contain a liquid electrolyte in their case. The negative pin is usually marked with a white bar on the capacitor case. Set the multimeter to Ω position and adjust your multimeter to x.xxx kΩ scale by successively pressing

the RANGE button. Touch the leads of the electrolytic capacitor to each other to discharge the capacitor. Connect the red (positive) lead of the multimeter to the positive terminal of the capacitor and the black (negative) lead of the multimeter to the negative terminal of the capacitor. Observe that the resistance reading changes with time. As the capacitor is fully charged, the resistance becomes infinity. Measure the time to reach infinity. You can use this method to test the integrity of an electrolytic capacitor.

If the electrolyte of the capacitor dries up due to long-time exposure to high temperature, the capacitor loses its value, and it should be replaced.* Repeat the resistance measurement procedure for the smaller electrolytic capacitor. To test the 1μF capacitor, set your multimeter to x.xxx MΩ position. Measure the time to reach infinity. If your multimeter has a capacitance scale, use that mode to measure the capacitance value.

Install C3 (watch the polarity) and C4 (watch the polarity) on the PCB and solder them. Both capacitors are needed for a proper operation of the voltage regulator. Connect the power adapter. Measure and record the output voltage, V_o, at TP4, with one decimal unit accuracy.

C3: Time to reach ∞ = 4.3 seconds
C4: Time to reach ∞ = 3.2 seconds
C4 (measured value, if your multimeter has capacitance scale) = 1,078 μF

2.10. GRADE:

TP6: V_o= 12.30V (TP3)

2.10. GRADE:

11. Read the color code of R1. Referring to the color-code table on page 36 determine the nominal resistance value. Measure the resistance value using the multimeter. Record the values. Mount and solder the resistance R1.

R1: Colors: Red - Red - Red - Gold

R1: R(nominal)= 2.2 K Ω

R1: R(measured)= 2.16 kΩ

2.11. GRADE:

TP6: V_{DC}= 6.01V (TP5)

2.11. GRADE:

12. We would like to investigate the electrical difference between a green and a red LED. Inspect the red light-emitting-diode (LED), D70. Install the diode D70 in place of D2. Its longer lead is its positive terminal. Do not solder it. Measure the voltage between TP5 and GND using DC-V scale of the multimeter. Remove the red LED after measurement.

*Dried up electrolytic capacitors are a common reason of the failure of many analog circuits.

13. Inspect the 3mm green light-emitting-diode (LED), D2. Its longer lead is its positive terminal. From the datasheet of the LED on page 399, find the range of forward voltage (V_F). Solder the diode D2 in its place.

14. Measure the voltage between TP5 and GND. Is it different than the red LED? Different colored LED's have different voltage drops. Calculate the current flowing through it using Eq. 2.75 on page 73.

D70(red LED): V_F(measured)= 1.84 V

D2(green LED): V_F(range)= [1.8-2.2 V]

D2(green LED): V_F(measured)= 1.88 V

D2(green LED): I_D(calculated)= 1.67 mA

2.14. GRADE:

15. Connect the multimeter between TP4 and GND as an ammeter (not voltmeter) at the highest scale (should be larger than 2 A) to find the short-circuit current, I_{short}, value. Record the current after it reached the steady state.

TP4 to GND: I_{short}= 0.516 A

2.15. GRADE:

16. Remove the ammeter leads and connect the multimeter between TP4 and GND as a voltmeter. Record the supply voltage.

TP5: V_o= 6.0 V

2.16. GRADE:

CHECK POINT: