EE 113 Introduction to Electrical Engineering Practice
2019-20/I
Expt 1: Familiarization with Measuring Equipment, and Building a Linear DC Power Supply (Ver 2)

Objectives:

a) To familiarize with the laboratory measuring instruments (DSO and DMM)
b) To design and build linear power supply (DC supplies: + 5V, ± 12V using a 15-0-15 step-down transformer, diodes, 7805 voltage regulator and Zener diodes)

Part A - Familiarization with Measuring Equipment

1.1 Familiarization with Bread board

Bread board is essentially a prototyping board meant for wiring electronic circuits. Fig.1.1A shows the bread board with a circuit connected. The right side shows the internal connections. Note that the central portion is the main area where circuits are wired. Each column has five holes connected together. Each column is isolated from the neighbouring column.

The top two rows and the bottom two rows are commonly used for GROUND and Power supply connections (as these two may require more connections). The bread boards you will be use have the bottom and top rows divided further into two halves.

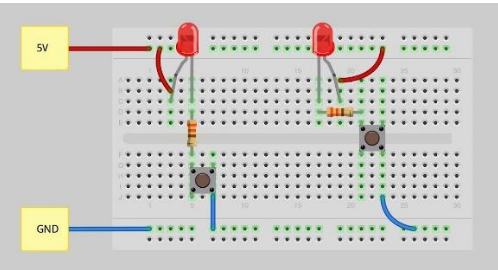


Fig 1.1A Bread board with a wired circuit

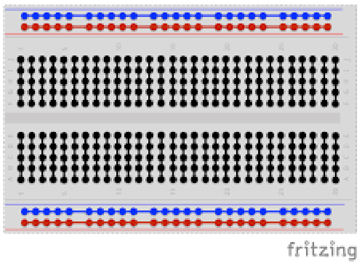


Fig 1.1B Bread board internal connections

1.2 Familiarization with Digital Multimeter (DMM)

You will be using a Laboratory Table-top Digital Multimeter (DMM). This is an electronic meter used for measuring voltages, currents and resistances. The meter display shows voltages, currents and resistances on the LED display panel.

Measurements: First of all you need to decide the parameter to be measured. We shall use the DMM primarily for measuring voltages and resistances. Choose the Voltage or Resistance function and the appropriate range (based on the maximum expected magnitude) for the parameter. Choose the ranges carefully.
Note: Resistance mode of the DMM assumes that there is no current flowing in the resistor. Take extra care when using the resistance mode.
You may think of DMM essentially as a voltage measuring equipment. Resistances and currents are converted into voltages by the DMM circuitry. AC voltages need to be < 400 Hz.

1.3 Familiarization with Digital Storage Oscilloscope (DSO) - Tektronix TDS 1002B

Oscilloscopes are versatile electronic instruments used for displaying and measuring parameters of time varying voltage signals. They are very useful in measuring the amplitude and frequency/time period of a signal. The instrument most commonly used is what is called a Cathode Ray Oscilloscope (CRO). CROs are now slowly getting replaced by Digital Storage Oscilloscopes (DSO), which makes signal measurements easier compared to a CRO.

CROs/DSOs are useful in measuring signals up to their rated bandwidth. TDS 1002B has bandwidth of 60 MHz. However DSOs cannot measure DC/AC voltages as accurately as a DMM. ADC Resolution for the DSO vertical signal is typically 8 bits (as compared to 12 bits or more in a DMM).

Reference material (uploaded on Moodle):
i) DSO-Introduction
ii) DSO- Operations

Part B – DSO Measurements using CRO Probes

1.4 CRO Probes

CRO probes are special cables with a built-in RC/LC network to compensate for the input capacitance of the CRO. Most CRO probes have 1X and 10X modes. The 1X mode would display the signal as it is, whereas the 10X mode would attenuate the input signal by 10. DSO channel input parameters can be adjusted for the probe setting chosen.

For high frequency signals, and also for measuring fast rising waveforms, the 10X mode should be used. It is best not to use 1X except when the input signal is < 20 mV.

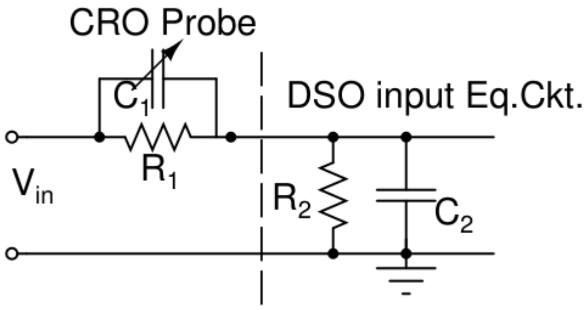


Fig. 1.4A CRO probe (10X mode) and the DSO input equivalent circuit

See Fig.1.4A. The input equivalent circuit of a CRO/DSO inputs is 1 MΩ (say R_2) in parallel with a capacitor (say C_2). CRO probe is essentially a 'compensated attenuator' used for compensating the CRO/DSO input capacitance. In the 10X mode the probe introduces a 9 MΩ resistance (say R_1) in series with the signal. The probe has an adjustable Capacitor (say C_1) connected parallel to R_1. If the input resistance of the DSO is R_2 (= 1 MΩ) and the input capacitance is C_2, then the signal at the DSO input (i.e. appearing across R_2) would be ($V_{in}\ R_2/(R_1+R_2)$), when $R_1\ C_1 = R_2\ C_2$. In order to achieve this condition the capacitor C_1 in the CRO probe is made adjustable. DSO front panels are provided with a 1 kHz Probe CAL Pulse signal.

Experiment: Connect the probe to the DSO CAL input and adjust C_1 with a screw driver to obtain a proper square wave. Repeat the same for the second probe. Ensure that the DSO input channel setting is correctly set for 10X mode. This will ensure that the input channel setting (10 V/div, 20V/div etc) is correctly displayed.

Note: Students often mistake the CRO probe to a nice BNC cable, and are often tempted to use it in the 1X mode, and treat it like a BNC cable. This is a wrong practice as in the 1X mode the probe introduces an LC circuit in series with the signal (to partially compensate for C_2) which distorts the signal.

Part C – DC Power Supply

1.5 Step Down Transformer (15-0-15)

You are given a 15-0-15V step-down transformer. (See Fig.1.5A). Take care to avoid any contact with the primary side of the transformer which is connected to the 230 VAC input.

Experiment: Connect the center tap of the secondary to GND. Observe on the DSO the outputs of the step-down transformer (i.e. A and B outputs with respect to GND). Observe also the phase-inversion of the two outputs. Measure the peak amplitudes and calculate the RMS voltages for the two windings. Measure the A and B output voltages on the DMM. Verify your calculations with the DMM measurements.

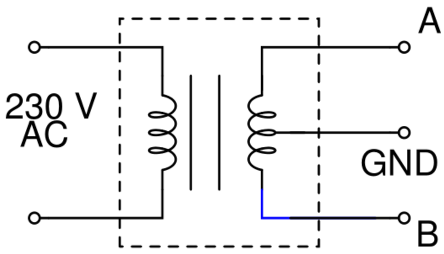


Fig 1.5A 230 V to 15-0-15V Step-down transformer

1.6 Full-wave rectifier

Fig.1.6A shows the circuit diagram of unregulated DC voltages, V+ and V-. (Cathode terminal of the diode is identified by the black band close to it).

A) Unregulated Supply - without Capacitive Filter

Connect the full wave rectifier circuit shown in Fig.1.6A, without connecting the 1000 µF capacitors shown. (i.e. connect only 10 kΩ resistor as loads for V+ and V-).

<u>Observation and Measurement</u>: Observe and sketch the V+ and V- outputs on the DSO. Measure the peak voltages and calculate the DC (average) values. Measure DC value of V+ and V- outputs on DMM. Compare your results.

B) Unregulated Supply - with Capacitive Filter

Connect the 1000 µF capacitors as shown. (Before connecting the Capacitors, switch-OFF the transformer. Take extreme care to connect the electrolytic capacitors as per the polarities shown).

<u>Observation and Measurement</u>: Observe the V+ and V- outputs on the DSO. Measure the peak voltages. Measure ripple voltages, if any using DSO for the 10 kΩ load resistance. Change the load resistance to 1.5 kΩ and measure the peak and ripple voltages.

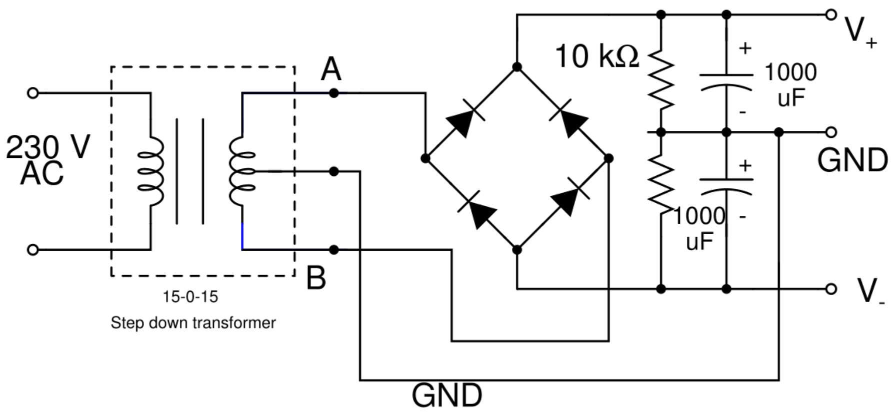


Fig. 1.6A Full-wave bridge rectifier (Note: Cathode - circular band)

1.7 Zener diode – Voltage regulator

We shall use 12V Zener diodes to design +12 V and -12 V regulators. Circuit diagram of the +12 V Zener regulator circuit is shown in Fig. 1.7A and the -12 V Zener regulator circuit in Fig. 1.7B.

<u>Note</u>: Please remember to remove the 10kΩ resistors connected as load at the V+ and V- outputs.

+12 V Zener Regulator

Wire the circuit of Fig. 1.7A on the bread board. Connect the unregulated output V+ to the input of the Zener regulator. Cathode terminal of the Zener diode is identified by the black band.

Choice of R_S

Assume input voltage to be 20 V. Choose R_S assuming the Zener diode to be ideal, I_Z = 5 mA and I_L = 10 mA. Choose R_1 for 2 mA through LED. Assume the LED junction voltage to be 2 V. Choose R_L for a current of 8 mA. (Standard resistor values: 10, 12, …., 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820, 910, 1k, 1.2k, ..) Choose standard resistor values closer to the ones obtained as per your calculations. Connect the full circuit and measure the V+ input and the +12 V output voltages using DMM.

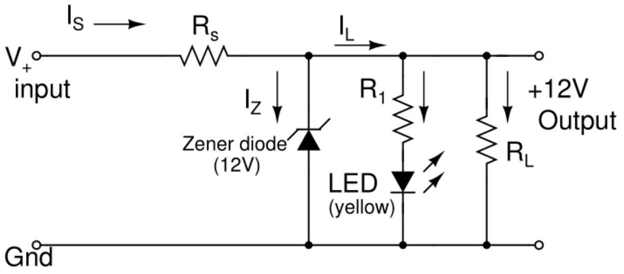


Fig. 1.7A +12 V Zener regulator circuit

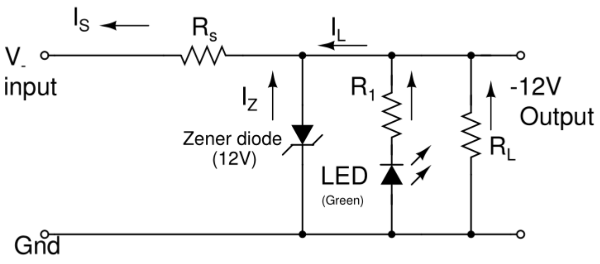


Fig. 1.7B -12 V Zener regulator circuit

-12 V Zener Regulator

Wire the circuit of Fig. 1.7B on the bread board. Connect the unregulated output V- to the input of the Zener regulator. We shall assume I_Z and I_L to be same as for this circuit too. Hence use the same values of resistors R_S, R_1, and R_L.

1.8 +5 V Regulated Supply using 7805 IC

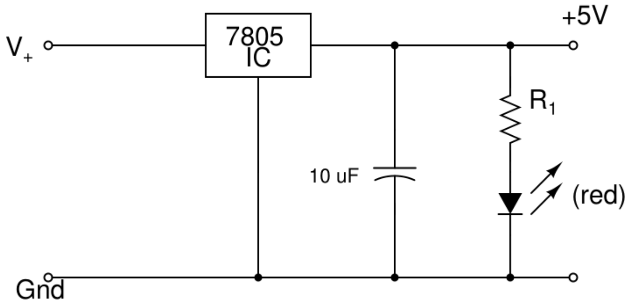
Wire the 7805 IC based +5V voltage regulator circuit shown in Fig.1.8B. Pinout of the IC is shown in Fig.1.8B. Connect GND to the Common terminal of 7805. The +5V regulated output will be available at the Output terminal. (Data sheet of the 7805 IC regulator is uploaded on Moodle).

Choose R_1 such that the current through the LED is about 2 mA. Assume LED junction voltage to be 2 V.

Experiment:

A) Instead of V+ output of the unregulated power supply, connect the adjustable 0 – 30V DC supply as the input to the 7805 IC. Vary the input voltage from +7V to +30V. Measure the +5V output at different voltages: (+7V, 10V, 15V, 20V, 25V and 30V). As you increase the input voltage, you will observe that the 7805 IC becoming more and more warm. Explain why this happens.

B) Remove the adjustable 0 – 30V DC supply connections and now connect V+ from the unregulated power supply to input terminal of 7805. Measure the +5V output voltage.



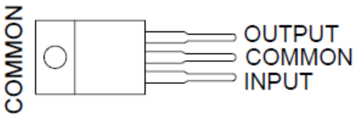


Fig. 1.8A 7805 (+5 V regulator) circuit

Fig.1.8B 7805 Pinout

Part D – DC Power Supply Assembly

Objective: Assemble the DC power supply in a PCB and prototype box for use in the subsequent experiments

Assemble the DC Power supply (+12 V, -12 V and +5 V) you made on to a general purpose PCB by soldering the components. You need to do this very carefully. Fix the PCB inside the given plastic box and make connections to the transformer and the +12 V, -12 V, +5 V and GND terminals to the terminals on the plastic box.

This power supply will be used in later experiments as the DC Power supply. You can be proud that you made the DC Power Supply yourself!