Experiment: Design and Verification of a Regulated DC Power Supply Using IC

1. Objective

To design and test a regulated DC power supply using voltage regulator IC 7805.

2. Circuit components/equipments used:

- Step-down Transformer.
- Normal P-N Junction diodes.
- Voltage Regulator IC (7805)
- Load Resistors (1.2 kΩ, 6.6 kΩ, 180 kΩ).
- Filter Capacitor (470 µF or 1000 µF)
- Ceramic Capacitors (0.33 µF and 0.1 µF)
- Oscilloscope.
- Digital Multimeters.
- Connecting wires.
- Breadboard.

3. Theory

A regulated DC power supply is an electronic circuit that converts AC voltage into a constant DC voltage while maintaining the output voltage within specified limits despite variations in input voltage and load current. The regulation process ensures reliable operation of connected electronic equipment.

A DC power supply is one of the most fundamental building blocks in electronic systems. Most electronic devices, including microprocessors, communication equipment, sensors, control systems, and laboratory instruments, require a stable direct current (DC) voltage for proper operation. However, the electrical power available from the utility grid is in the form of alternating current (AC). Therefore, a power supply circuit is required to convert AC power into a regulated DC voltage.

Ordinary DC Power Supply and Its Limitations

An ordinary DC power supply consists of a rectifier and a filter circuit. Although the filter reduces the AC ripple component, the output voltage still varies with changes in AC mains voltage and load current.

Limitations

1. The DC output voltage changes directly with fluctuations in the AC input voltage.
2. The DC output voltage decreases as load current increases due to voltage drops in the transformer windings, rectifier diodes, and filter components.
3. These voltage variations can cause inaccurate or unstable operation of electronic circuits.

Therefore, ordinary power supplies are unsuitable for many practical applications and are generally replaced by regulated power supplies.

Need for a Regulated Power Supply

In practice, AC line voltage is not constant and may fluctuate due to changing load conditions in the power distribution system. Similarly, electronic circuits may draw varying amounts of current depending on operating conditions.

A regulated power supply is therefore required to:

- Maintain a constant output voltage despite input voltage fluctuations.
- Compensate for changes in load current.
- Improve reliability and accuracy of electronic systems.
- Protect sensitive electronic devices from voltage variations.
- Ensure stable operation of analog and digital circuits.

A regulated DC power supply consists of an ordinary DC power supply followed by a voltage regulator. The regulator continuously adjusts its operation to maintain a nearly constant output voltage.

The design of a regulated DC power supply generally consists of four stages:

(A) Step-down Transformer,
(B) Rectifier
(C) Filter
(D) Voltage Regulator IC.

(A) Step-down Transformer

The transformer reduces the 230 V AC mains voltage to a lower AC voltage suitable for the circuit requirements. It also provides electrical isolation between the mains supply and the load.

(B) Full Wave Bridge Rectifier

This type of single-phase rectifier uses 4 individual rectifying diodes connected in a “bridged” configuration to produce the desired output but does not require a special centre tapped transformer, thereby reducing its size and cost.

The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown in below figure-1. Four diodes labelled D1 to D4 are arranged in “series pairs” with only two diodes conducting current during each half cycle.

During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below. During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch of as they are now reverse biased. The current flowing through the load is the same direction as before.

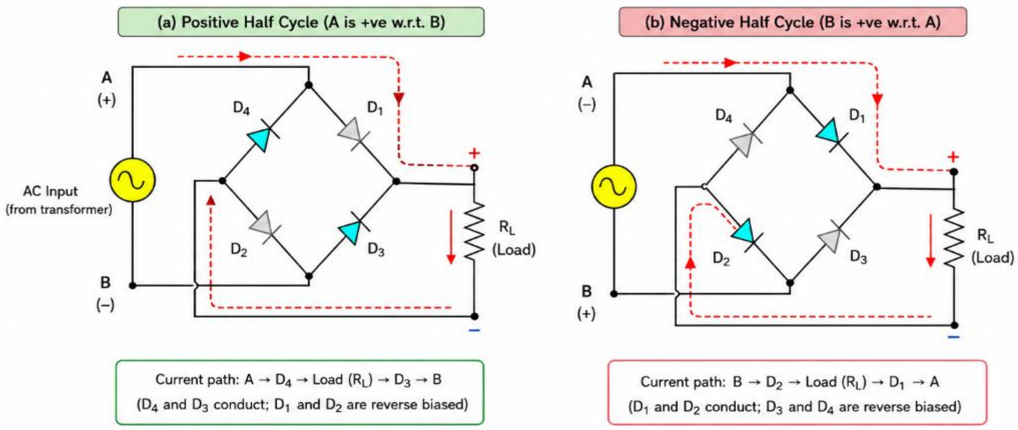

Figure 1: Working of Bridge Rectifier Circuit

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional during both the half cycles. Thus, the average DC output voltage across the load resistor is double that of a half-wave rectifier circuit, assuming no losses.

$$V_{DC} = \frac{2V_{Max}}{\pi} = 0.637\ V_{max}$$

(C) Filter Circuit

The output of the rectifier contains ripples and is not pure DC. A filter capacitor is connected across the rectifier output to smooth these fluctuations. The capacitor charges during voltage peaks and discharges during voltage drops, reducing ripple and producing a smoother DC voltage.

i. Ripple factor

As mentioned in the previous lab the ripple factor is a measure of purity of the DC output of a rectifier and is defined as

$$V_{DC} = \frac{V_{Ac\,(output)}}{V_{Dc}(output)} = \sqrt{\frac{V_{RMS}^2 - V_{Dc}^2}{V_{Dc}^2}} = \sqrt{\frac{V_{RMS}^2}{V_{Dc}^2}} - 1 = \sqrt{\frac{(0.707)^2}{(0.637)^2}} - 1 = 0.48$$

In case of a full-wave rectifier $V_{rms} = Vmax/\sqrt{2} = 0.707\ Vmax$. The ripple frequency is now twice the supply frequency (eg. 100 Hz for a 50 Hz supply).

ii. Rectification efficiency

Rectification efficiency η is given by

$$\eta = \frac{\textbf{DC power delivered to load}}{\textbf{AC power at input}}$$

$$= \frac{V_{DC}^2/R_{RL}}{V_{(Input)}^2/R_D+R_{RL}} = \frac{(0.637\ V_{max})^2}{(0.707V_{max})^2\left(1+\frac{V_{Rd}}{R_L}\right)}$$

$$= \frac{0.811}{\left(1+\frac{V_{Rd}}{R_L}\right)}$$

where R_D is the forward resistance of the diode. Under the assumption of no diode loss (rd << RL), the rectification efficiency in case of a full-wave rectifier is approximately 81.1%, which is twice the value for a half-wave rectifier

(D) Voltage Regulator IC 7805

Although filtering reduces ripple, variations in input voltage and load current can still affect the output voltage. A voltage regulator IC 7805 is used to maintain a constant output voltage regardless of these variations.

Common regulator ICs include:

- IC 7805 for +5 V output
- IC 7809 for +9 V output
- IC 7812 for +12 V output
- IC 78XX for +XX V output

The 78xx series regulators contain internal circuitry for voltage regulation, current limiting, thermal shutdown, and short-circuit protection. These features improve reliability and ensure a stable output voltage.

Pin Configuration of 7805 IC:

Pin	Description
1	Input
2	Ground
3	Output (+5 V)

The regulator maintains a constant output voltage despite changes in input voltage and load current.

Voltage Regulation

The ability of a power supply to maintain a constant output voltage with changing load current is known as voltage regulation.

The percentage voltage regulation is given by:

$$\% \, Regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

where:

- V_{NL}= No-load output voltage
- V_{FL}= Full-load output voltage

A good regulated power supply has a voltage regulation close to zero.

4. Circuit Diagram

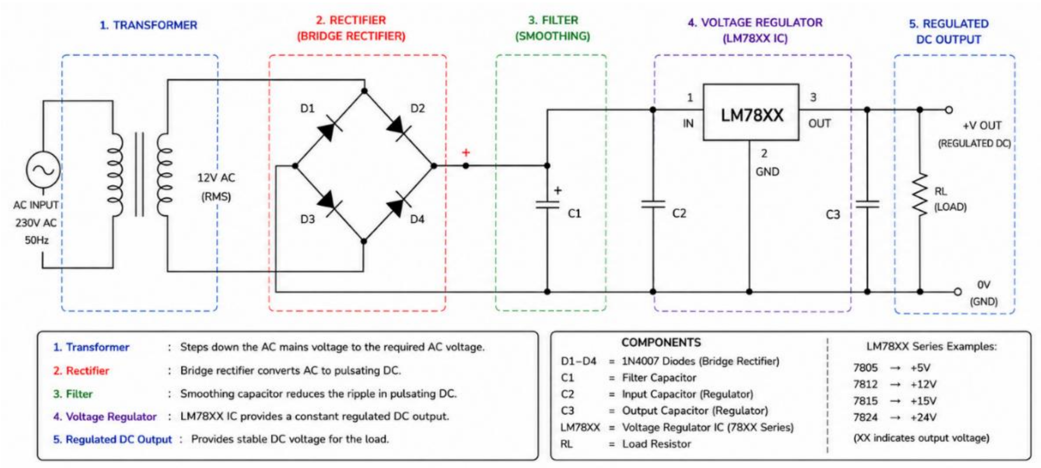

Figure 2: Circuit Diagram of voltage regulator circuit using IC's

5. Working Principle

The AC mains voltage is first stepped down to a lower AC voltage (from 230 V to 12 V AC) by the transformer. This lower AC voltage is converted into pulsating DC by the bridge rectifier. The filter capacitor smooths the pulsating waveform to reduce ripple and produce an unregulated DC voltage. Finally, the LM78X voltage regulator IC stabilizes the voltage and delivers a constant DC output suitable for powering electronic circuits. This sequence ensures a reliable, safe, and stable power supply from a standard AC source.

Applications

- Electronic laboratory power supplies
- Microcontroller and embedded systems
- Communication equipment
- Industrial control circuits
- Consumer electronic devices

Thus, a regulated DC power supply using a voltage regulator IC provides a reliable and stable DC output required for the proper operation of electronic circuits and systems.

6. Procedure

- Configure the circuit using IC-7805 as shown in the circuit diagram. Note down all the values of the components being used.

For observation Table-A: rectifier Performance without capacitive filter

- Change the load resistor (R_L) in range: 1 kΩ to 200 kΩ and measure AC voltage (V_{AC}) and DC voltage (V_{DC}) at the rectifier output using multimeter.
- Measure the regulated DC output voltage from the output of regulator IC pin no. 3.
- Calculate the ripple factor and efficiency.

For observation Table-B: Rectifier Performance with capacitive filter

- Fix the load resistor value and change the capacitor values and measure AC voltage (V_{AC}) and DC voltage (V_{DC}) at the rectifier output using multimeter.
- Measure the regulated DC output voltage from the output of regulator IC pin no. 3.
- Calculate the ripple factor and efficiency.

For observation Table-C: Load Regulation

- Change the load resistor (R_L) in range and measure load current (I_L) and load Voltage (V_L) using multimeter.
- Calculate the % regulation.

7. Observation Table- A: Rectifier Performance without capacitive filter

Code number of diode = ___
Transformer output Voltage (V_{AC}) = ___ V

FWR: Full wave rectifier

Sl No	Load Resistance (R_L)	AC Output Voltage of FWR (V_{AC})	DC Output Voltage of FWR (V_{DC})	Regulated DC Output (V)	Ripple factor (Experimental)	Efficiency (η)
1						
2						
3						
4						
-						

Observation Table- B: Rectifier Performance with capacitive filter

Sl No	Capacitor (µF)	AC Output Voltage of FWR (V_{AC})	DC Output Voltage of FWR (V_{DC})	Ripple Factor (Experimental)	Regulated DC Output (V)	Efficiency (η)
1						
2						
3						
4						
-						

Observation Table- C: Load Regulation

Load Resistor (R_L): ___ Ω

Sl No.	Load Resistance (kΩ)	Load Current I_L (mA)	Regulated DC Output Voltage (V_{out})	% Regulation
1			V_{NL}	
2				
3				
4				
-			V_{FL}	

8. Calculations

Load Current

$$I_L = \frac{V_{out}}{R_L}$$

Percentage Voltage Regulation

$$\%\,Regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

9. Graph

Plot the following graphs:

1. Output Voltage versus Load Current
2. Ripple Factor versus Filter Capacitance

10. Error

$$\%\,Error = \frac{V_{measured} - 5\,V}{5\,V}$$

where

- $V_{measured}$ = measured output voltage

- $5\ V$ = Ideal output voltage

11. Conclusion

A regulated DC power supply converts AC mains voltage into a stable DC voltage through the processes of transformation, rectification, filtering, and voltage regulation. The bridge rectifier efficiently converts AC into pulsating DC, the filter capacitor reduces ripple content, and the voltage regulator IC provides a constant output voltage independent of input and load variations. Thus, the regulated power supply serves as a reliable source of DC power for a wide range of electronic applications.

12. Result

13. Precautions

- Verify the pin configuration of the 7805 regulator IC before making connections.
- Ensure proper orientation of the bridge rectifier diodes.
- Make sure all connections are proper and tight before applying power.
- Switch off the power supply before making any changes to the circuit.
- Avoid short-circuiting the regulator output and touching the terminals of the mains and transformer output with bare hands during operation.
- Check all connections before switching ON the power supply.
- Use insulated probes while taking measurements.
- Keep the measuring instruments in appropriate ranges to avoid damage and obtain accurate readings.