REPORT ON POWER SUPPLY

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ABSTRACT

A power supply is a device that supplies electrical energy to one or more electric loads. The term is most commonly applied to devices that convert one form of electrical energy to another, though it may also refer to devices that convert another form of energy (e.g., mechanical, chemical, solar) to electrical energy. All electronic circuits from simple transistor and op amp circuits to elaborate digital and microprocessor systems require one or more sources of DC voltage. Simplest supply is a dc battery. It is not an ideal one as its terminal voltage changes in accordance with load due to its internal resistance. Electronic components require a DC supply that is well regulated, has low noise characteristics and provides a fast response to load changes.

A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source. Fortunately it is easy to construct a stable power supply using negative feedback. Such output supplies are in universal use and can be constructed using voltage regulator IC’s. In this report we will see how to use such special purpose voltage regulator IC’s to construct stable power supplies.
INTRODUCTION

Virtually every piece of electronic equipment is powered from a low voltage DC supply. This source will be either a battery, a combination of battery and DC/DC converter or a power supply converting AC mains into one or more low voltage DC supplies, suitable for electronic components. AC power supplies, and most DC/DC converters, also provide isolation from the input to the output for safety, noise reduction and transient protection.

As electronic equipment has become smaller, the market has demanded that power converters do the same. Since the introduction of switch mode techniques, this has been an evolutionary rather than a revolutionary process. Conversion efficiency has increased, materials and components allowing higher switching frequencies have become available and packaging techniques have advanced. At the same time, unit cost has fallen as volumes have increased. With the global market for electronics becoming a reality, power supply systems operate from wide input ranges to cover worldwide AC mains supply variations.

There are a number of basic topologies used in power supplies, which are suited to various power levels, cost criteria and performance levels as discussed below:-

• Linear Power Supplies

Linear power supplies are typically only used in specific applications requiring extremely low noise, or in very low power applications where a simple transformer rectifier solution is adequate and provides the lowest cost. Examples are audio applications (low noise) and low power consumer applications such as alarm panels (low cost).
The 50/60Hz mains transformer reduces the voltage to a usable low level, the secondary AC voltage is rectified using a rectifier circuit and some form of circuit is employed to provide the necessary regulation usually containing a voltage regulator IC’s.

The benefits of this solution are low noise, reliability and low cost. On the downside, these units are large, heavy and inefficient with a limited input voltage range. In order to significantly reduce the size and increase efficiency, most applications utilize a Switch Mode Power Supply (SMPS).

- **Switch Mode Power Supplies**

  The use of switch mode topologies has reduced the size and improved the efficiency of power supplies by increasing the frequency of operation, reducing the physical size of transformers, inductors and capacitors, and utilizing an ‘on or off’ switching element to increase efficiency.

  The compromises in adopting this technique are increased ripple and noise on the output DC supply. As switching frequency increases, so do switching losses.

  The introduction of low voltage semiconductors and the consequent high output current demands have driven the development of synchronous output rectifier schemes, where the output diodes are replaced by power MOSFETs to reduce power dissipation in the secondary and achieve high efficiency solutions for these applications.
A general power supply unit has the following basic units.

- **SOURCE**
  Every power supply must obtain the energy it supplies to its load, as well as any energy it consumes while performing that task, from an energy source. Depending on its design, a power supply may obtain energy from:
  1. Electrical energy transmission systems. Common examples of this include power supplies that convert AC line voltage to DC voltage.
  2. Energy storage devices such as batteries and fuel cells.
  3. Electromechanical systems such as generators and alternators.
  Solar power.

- **PROTECTION**
  Input protection is implemented in power supplies in order to ensure safety. The input fuse fitted within a power supply is not intended to be field-replaceable. It is rated such that only a catastrophic failure of the power supply will cause it to fail. It cannot be damaged by overloading as the power supply will have some other form of overload protection, usually electronic. The fuse will often be soldered into the PCB rather than being a replaceable cartridge type fuse.
**RECTIFIER**

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapped secondary winding.

![Rectifier Diagram](image)

**FILTERING**

The R-C filter circuit as given in figure is used to reject input noise. By deliberate design R is kept much larger than XC1 at the ripple frequency. So the ripples are dropped across series resistor R instead of across the load resistor RL. Typically R is kept at least 10 times greater than XC2; this means that each section reduces the ripples by a factor of at least 10.

![Filter Diagram](image)

**REGULATION**

IC 723 is a voltage regulator designed primarily for series regulator applications. It is a flexible, easy-to-use regulator with excellent performance. The circuit features a temperature-compensated voltage reference, differential amplifier, series pass transistor, and current-limiting protective circuit.

By itself, it will supply output currents up to 150 mA; but external transistors can be added to provide any desired load current as shown in the figure below.

![IC 723 Circuit](image)
An external pass transistor Q1 is used. Q1 is added as a Darlington pair with the internal transistor.

CIRCUIT OF POWER SUPPLY USING IC 723

The external pass transistor must be mounted on a heat sink. 723 does not incorporate internal shut-down circuitry to protect against excessive load current so provision is made for either linear or foldback current limiting as discussed in output protection.
POSITIVE REGULATOR

Figure below shows how to make a positive voltage regulator with the 723. Voltage divider R1,R2 compares a fraction of the output with the voltage reference, this circuit is identical with the op amp non inverting amplifier with Vref as the input to the non inverting terminal and a fraction of output voltage to the inverting terminal. What it does is look at its input terminals and swing its output terminal around so that the external feedback network brings the input differential to zero. Thus we get a required regulated output.

The input voltage must stay a few volts more positive than the output at all times, including the effects of ripple on the unregulated supply. The "dropout voltage" is 3 volts (minimum) for the 723.

NEGATIVE REGULATOR

Figure below shows how to make a negative voltage regulator with the 723. It’s working is similar to the positive regulator. Voltage divider R1,R2 compares a fraction of the Vref with the output voltage. The input to the non inverting terminal is the output voltage and a fraction of Vref voltage goes to the inverting terminal. What it does is look at its input terminals and swing its output terminal around so that the external feedback network brings the input differential to zero. Thus we get a required regulated output.

723 regulator: $V_{out} > V_{ref}$. 
Output protection is implemented on power supplies and DC/DC converters in order to prevent damage to the power supply and the end equipment. Power supplies are protected against overload and the end equipment against over-voltage and excessive fault current.

**OVERLOAD PROTECTION**

In the case of an overload or short circuit being applied to the output, circuits are employed to limit the current or power that the unit will supply, protecting both the power supply and the load from excessive current. Cutting off drive to the pass transistors is used to limit output currents to non-destructive levels.

**OUTPUT**

Using the above components a regulated supply with output voltage ranging from to the maximum allowable output voltage can be made. Obviously the choice of output is left for the requirement of user. The input voltage must stay a few volts more positive than the output at all times, including the effects of ripple on the unregulated supply. Output current can be controlled by suitably choosing the values of components.
**TESTING A POWER SUPPLY**

**LINE REGULATION**

Line regulation is a static performance measure of how well a power supply holds the output voltage constant in the face of a changing input. Line regulation defines the change in output voltage or current resulting from a change in the input voltage over a specified range.

\[
\% \text{ Line Regulation} = \frac{\text{VOUT(Max)} - \text{VOUT(Min)}}{\text{VOUT(Normal)}} \times 100
\]

Where,
- \( \text{VOUT (Normal)} \) is the output voltage at nominal line input voltage
- \( \text{VOUT (Max)} \) is the output voltage at maximum line input voltage
- \( \text{VOUT (Min)} \) is the output voltage at minimum line input voltage

**Example:** A power supply’s output is nominally 5.02V but when the AC input is varied from its minimum to maximum value the output varies from 5.015V to 5.03V.

\[
\% \text{ Line Regulation} = \frac{(5.03 - 5.015)}{5.02} \times 100 = 0.29 \%
\]

**LOAD REGULATION AND CROSS REGULATION**

Load regulation is a static performance measure, which defines the ability of a power supply to remain within specified output limits for a predetermined load change. Expressed as a percentage, the range is dependent upon the product design and is specified in the product data sheet.

\[
\% \text{ Load Regulation} = \frac{\text{VOUT(Load Max)} - \text{VOUT(Load Min)}}{\text{VOUT(Normal)}} \times 100
\]

Where,
- \( \text{VOUT (Normal)} \) is the nominal output voltage
- \( \text{VOUT (Load Max)} \) is the output voltage at maximum output current
- \( \text{VOUT (Load Min)} \) is the output voltage at minimum output current

**Example:** A power supply manufacturer specifies that for a load change of 5% to 100% its power supply output changes from 5.02V to 5.05V around a nominal voltage of 5.02V.

\[
\% \text{ Load Regulation} = \frac{(5.05 - 5.02)}{5.02} \times 100 = 0.6 \%
\]
For multiple output power supplies, another factor affecting the output voltage is cross regulation. This is an extension of the load regulation test and determines the ability of all the power supply outputs to remain within their specified voltage rating for a load current change on another output. It is calculated in the same manner as load regulation and is often specified as a percentage change in output voltage for a percentage change in another output load, e.g. V1 cross regulation = 1% per 10% change in V2.
CIRCUIT FOR A POWER SUPPLY USING IC 723

NOTE: Only one type of regulation can be used at a time.
BOOK

The Art of Electronics, by Paul Horowitz and Winfield Hill

WEB

http://www.circuitstoday.com/rc-filters
http://www.xppower.com/pdfs/tece.pdf
http://en.wikipedia.org/wiki/Power_supply
http://en.wikipedia.org/wiki/Active_load