1. Definition
A power supply is an electronic device that supplies electric energy to an electrical load.

![Figure 1: Power Supply](image)

The power supply does not create the energy. It receives an electric energy from a single energy source or from multiple energy sources, which are combined together.

Electrical transmission systems (e.g. the city electricity), energy storage systems (e.g. batteries and fuel cells), and electromechanical systems (e.g. wind turbines and solar cells) are examples of the energy sources. A power supply may receive its input energy from another power supply or from other multiple power supplies. Several energy source may combine together to provide the energy for a power supply. The structure of input depends on the availability of energy sources, cost, design requirements, etc.

The input can be AC or DC. The output can also be AC or DC.

Thus, the primary function of a power supply is to convert one form of the electrical energy to another. The conversion of the electrical energy from one form to another is known as power conversion. Then, a power supply is in fact a power converter.

2. Types of Power Supplies (Converters)

2.1. DC power supplies:
Supply a regulated (constant) DC voltage to its load.

Depending on the energy source(s), DC power supplies are classified as follows:

- DC-to-DC
- AC-to-DC

2.2. AC power supplies:
Supply a controlled AC voltage to its load. Depending on the energy source(s), AC power supplies are classified as follows:

- AC-to-AC
- DC-to-AC

2.3. Additional notes:
- A power supply may provide multiple outputs, which may differ in their polarity (positive or negative voltages), phase (in-phase or out-of-phase), and voltage and current ratings.
- A power supply may provide isolated or non-isolated output(s).

This course is on DC power supplies, with a particular focus on the DC-to-DC converters.
3. DC power supplies:

3.1. Basic Structures
The general schematic of AC-to-DC power supplies is shown below.

![General schematic of AC-to-DC power supplies](image)

Figure 2: General schematic of AC-to-DC power supplies

The DC-to-DC converter mainly consists of the voltage regulator as shown below. However, the input filter may be used.

![General schematic of DC-to-DC power supplies](image)

Figure 3: General schematic of DC-to-DC power supplies

3.2. Rectifier
3.2.1. Half-wave diode rectifier

![Half-wave diode rectifier](image)

Figure 4: Half-wave diode rectifier
3.2.2. Full wave diode rectifiers

![Full-wave half-bridge diode rectifier](image)

Figure 5: Full-wave half-bridge diode rectifier

![Full-wave full-bridge diode rectifier](image)

Figure 6: Full-wave full-bridge diode rectifier

3.3. Filter

![Capacitor filter in half-wave rectifier](image)

Figure 7: Capacitor filter in half-wave rectifier

![Capacitor filter in full-wave rectifier](image)

Figure 8: Capacitor filter in full-wave rectifier

The ripple of the full-wave rectifiers is lower than that of the half-wave rectifiers.
3.4. Voltage Regulators (VRs)

The responsibility of the voltage regulator is to provide a constant output despite variations in operating conditions, load and input circuitry.

The VR system consists of sensors, stable reference values, a controller, a drive circuit and pass elements. The pass elements are solid-state devices (such as transistors and MOSFETs) that control the load’s voltage and/or current.

The sensors measure the load voltage and/or current, the compare them with the reference values. The differences are sent into the controller, to generate a control signal which aims to regulate the output at the desired level. The control signal is fed into a drive circuit to generate electronic signals that are required to drive the pass elements.

![Structure of the voltage regulator](image)

The VR is a DC-DC converter.

3.4.1. Linear Voltage Regulator

If the pass element works at any point in its active region, the VR is referred to as a linear power supply.

The output voltage in the LVR is adjusted by controlling the current passing through the pass element, over the active region.

3.4.2. Switching Voltage Regulator

If the pass element operates as an on-off switch (works in the cut-off and saturation regions), the VR is referred to as a switching voltage regulator. The controller performs the duty cycle control (i.e., the time the switch should be on and off) with pulse width modulation technique. The output voltage in the SVR is adjusted by controlling the duty cycle. Duty cycle (D) is the fraction of one period (T) in which the pass element is active

\[
D = \frac{PW}{T}
\]

Where, PW is the pulse active time.
Introduction to Power Supplies and Chargers

3.4.3. Step-Down VR

\[ V_{out} \leq V_{in} \]

3.4.4. Step-UP VR

\[ V_{out} \geq V_{in} \]

3.4.5. Step-up/Step-down VR

\[ V_{out} \leq V_{in} \text{, or } V_{out} > V_{in} \]

3.4.6. Comparison between linear and switching voltage regulators

- Efficiency of LVRs is less than the efficiency of SVRs.

\[ \eta = \frac{P_{out}}{P_{in}} \]

Typical efficiency of LVRs is between 20 to 60%. Whereas, the efficiency of SVRs is between 70 to 95%.

- LVRs can only be used as a step-down, whereas SVRs can be used in both step-down and step-up applications. Due to voltage dropout, the input voltage must be greater than the output voltage for LVRs \( V_{in} \geq V_{out} + V_D \), where \( V_D \) denotes the voltage dropout. In the SVRs, \( V_{in} \) can be greater or smaller than \( V_{out} \).
- Because mains-frequency (60Hz) transformer is sued in LVRs, they are bulky, heavy, and large. Whereas, the high-frequency transformers in SVRs make them small in size.
- The high-frequency operating condition makes the size of the SVR’s elements small.
- LVRs are suitable for applications less than 25Watts.
- Noise of LVRs is less than that of SVRs. For instance, at high frequencies, SVRs lead to electromagnetic inference with other elements.
- The cost depends on the power rating and design.

3.4.7. VR selection

Important factors for the VR selection

- Efficiency
- Output tolerance
- Size and weight
- Power ratings
- Maximum load current
- Cost

Depending on the type of the VR, additional features may be considered. For the LVRs, the dropout voltage, and ground pin (quiescent) current can be important. For the SVRs, the EMI is an important factor.