Direct current power supply

General
Nowadays, practically all systems and machines use an electrical control system. This control system requires a reliable power supply in order to ensure that the system or machine can operate safely.

The direct current power supply is a static device that converts an existing input voltage (DC or AC voltage) into a defined, required level of electrical output energy (DC voltage and current). There are different DC power supplies for different uses and applications. These are listed briefly below:

Unregulated DC power supply
In this case, the mains AC voltage is transformed into the required voltage using a transformer and then filtered and smoothed with a rectifier and capacitor. The output voltage fluctuates with the input voltage from the mains as well as with the load applied; in other words, the output voltage is not set to a fixed value.
Furthermore, the output voltage is not fully smoothed. The output DC voltage is superimposed by a slight fluctuation, the value of which changes depending on the load and the input voltage. This fluctuation is known as ripple and is normally specified as a percentage proportional to the level of the output DC voltage.
Unregulated DC power supplies are robust and simple in design, incorporating only the bare essentials. Devices of this kind are an adequate choice for controlling contactors, relays, valves and solenoid switches.

Regulated DC power supply
In this case, the output DC voltage is monitored by an electronic regulating circuit and is held at a preset value in the event of fluctuations in the input voltage or a different output load.
A certain residual ripple is present for this DC power supply too, but – unlike cases involving unregulated DC power supplies – it is very low and is, as far as possible, only dependent on the load at the output.
The most commonly used types of circuits that can be implemented using regulated DC power supplies are:
• Voltage controllers
• Magnetic voltage stabilisers
• Secondary switched-mode power supplies
• Primary switched-mode power supplies

The following short descriptions of each circuit principle under consideration are designed to help you find the best and most affordable power supply for your application.
Direct current power supply

**Voltage controller**
As with unregulated DC power supplies, in this case the mains AC voltage is also transformed into the required secondary voltage using a transformer, and is then rectified and filtered. This voltage is converted into a regulated voltage at the output in a control unit. During this process, the filtered voltage upstream of the actuator and the control unit must be higher than the required output voltage. The output voltage is monitored and corrected immediately in the event of a deviation. In this case, the actuator acts like a rapidly variable resistor. The product of the difference between the unregulated filtered voltage and the regulated output voltage and the output current in heat losses is also implemented at the actuator.

The advantage of this system is that several regulated output voltages can be implemented without much effort as the transformer is supplied with an additional secondary winding for each additional output voltage. Some applications can only be implemented using this circuit principle, particularly when excellent control accuracy, a quick settling time and low residual ripple are required.

The voltage controller is only used for low levels of power due to the power loss, which is dependent on the output current. Furthermore, it is large, heavy and inefficient. The consumer also requires protection since, in the event of a defect in the voltage controller transistor, the higher, unregulated voltage of the filter electrolytic capacitor is present at the output.

**The benefits**
- Circuit principle is simple and proven
- The output voltage has very good regulation properties
- Short settling time
- Several electrically isolated output voltages can be implemented easily thanks to additional secondary windings

**The drawbacks**
- Low efficiency and bridging time
- Complex heat dissipation
- Relatively large size and weight
Direct current power supply

**Magnetic stabilisers**
In this case, the primary winding and secondary winding are wound on a core, as with a transformer. However, these windings are largely decoupled by an air gap. The windings can assume different values due to the separation. As the converter itself is operated in the ferromagnetic saturation range, the magnetic voltage stabiliser provides a well-stabilised and constant output voltage. To obtain a rectified voltage, a voltage controller or a secondary switched-mode regulator is often connected in series at the output of the magnetic stabiliser. The reliable, robust technology used for the magnetic stabiliser does not require any maintenance; however, the equipment involved is large and heavy, and therefore relatively cost-intensive.

**The benefits**
- Voltage fluctuations, interference voltage spikes and voltage dips at the input are corrected or bridged quickly
- The output voltage has very good regulation properties in conjunction with a downstream voltage controller
- Significantly more efficient than a voltage controller

**The drawbacks**
- Large and heavy power supply due to magnetic component
- Very expensive power supply

**Secondary switched-mode power supply**
In this case, a transformer is connected upstream on the input side. This transforms the mains voltage into the required secondary voltage, which is then rectified and filtered. Following this, a switching transistor transfers the energy in the form of pulses to an additional filtering and memory circuit at the output. The output voltage is regulated by the duty cycle. The system perturbations are very low thanks to the transformer connected upstream on the input side. This circuit is highly efficient and is especially beneficial for power supplies with several output voltages.

As with the voltage controller, however, the consumer must be protected on the output side so that the full, unregulated DC voltage of the filter electrolytic capacitor cannot be present in the event of a defect in the switching transistor.

**The benefits**
- Simple design
- Several electrically isolated output voltages can be implemented easily thanks to additional secondary windings
- Fewer interference problems (EMC) than with a primary switched-mode power supply
- Less power loss than with a voltage controller

**The drawbacks**
- Large and heavy power supply due to the transformer
- Output ripple (spikes) corresponds to that of a primary switched-mode power supply
Direct current power supply

Primary switched-mode power supply
This switched-mode power supply is also known as an SMPS or a primary switched-mode regulator. There are many different circuit variations for this power supply, such as single-ended forward converters, flyback converters, half-bridge converters, full-bridge converters, push-pull converters and resonant converters.

Generally, the unregulated mains voltage is rectified and filtered first in the case of primary switched-mode power supplies. The capacitance of the filter electrolytic capacitor determines the buffer time of the power supply to a large extent in the event of a power failure on the input side. The filtered DC voltage is interrupted periodically with a timer circuit and the primary energy is transferred at a high switching frequency. The power loss at the switching transistor is low and the efficiency therefore ranges from > 70% to over 90% depending on the output voltage and current. Due to the high switching frequency, the transformers in the primary switched-mode regulator are relatively small, which means that the entire power supply can be smaller and lighter. The clock frequencies lie between 20 kHz and 250 kHz depending on the output power. Where high clock frequencies are concerned, however, there is a risk that the switching losses will become too high. In this case, you have to make a reasonable compromise between high efficiency and the highest possible clock frequency.

On the secondary side, the voltage is rectified and filtered again. The control deviation of the output voltage is reported back to the primary circuit with electrical isolation. The energy is transferred over the pulse width to the secondary side and the level of the output voltage is regulated by the ratio between the on and off periods of the pulse voltage. During this process, only the energy drawn at the output is transferred.

The benefits
- Small magnetic components (transformer, storage choke, filter) due to high operating frequency
- Highly efficient thanks to pulse width regulation
- Compact, light design
- No forced cooling necessary
- Adjustable power failure bridging time thanks to the capacity in the intermediate circuit
- Wide-range input of the voltage possible

The drawbacks
- Complex circuits, lots of live parts
- Very high levels of interference (EMC)
- High switching frequency; mechanical design therefore based on HF criteria
Important Terms for Power Supplies

Output behaviour
Behaviour of the power supply when operated outside the specified output values. The most important characteristics are:

• **Constant current mode**
  When exceeding the nominal output current, the unit will turn into the constant current mode. The current will be constant, while the voltage decreases.

• **Fold-back mode**
  When exceeding the nominal output current, the voltage and the current will decrease.

• **Hicc-up mode**
  The unit will switch off, when the current exceeds the nominal value. It will try to switch on periodically to check if the overload still remains. When the overload has been removed, the power supply will switch on automatically.

• **Switch-off mode**
  When overloaded, the power supply will switch off. It has to be switched on manually after removing the overload.

Drift
Changes of output voltages due to the time or the temperature.

Inrush-Current
The peak current while switching on the power supply due to the charging current of the capacitors. Can be limited by the use of special electronic limiters, without this, it is only limited by the impedance of the input current.

Radio interference
Undesired high frequency energy, produced by the switching elements of a power supply. A distinction should be made between conducted and radiated interference. Conducted interference can be reduced down to allowable values by the help of filters, radiated interference can be minimised with a suitable PC-board as well as by the means of shielding.

Isolation voltage
Isolation voltage is the maximum allowed voltage between two isolated circuits.

Cooling
The removal of the heat which is produced by the losses in the electronic parts. It is to distinguish between radiation and convection (natural and forced with a fan).

Short circuit protected
The protection of a power supply against overload and short circuit. There are different methods, —> Output behaviour.
Important Terms for Power Supplies

**Load regulation**
Changes in the output voltage due to a defined change of the load at the specified output.

**Hold-up time**
The time, while the output voltage is still regulated, though the input voltage has disappeared.

**Storage temperature**
The temperature range, in which the power supply can be stored, not operated, without damaging the unit.

**Overshot**
Increase of the output voltage over due to the changing of the temperature.

**Power factor cos φ**
The ratio of real power to apparent power. Due to the non-sinusoidal shape of the input current, normally the power factor of switch mode power supplies is below one.

**Power derating**
The necessary reduction of the output power under specified conditions, e.g. when exceeding a specified temperature.

**Line regulation**
The change at the output voltage with a defined change of the input voltage, while all other parameters stay constant.

**Over current protection**
Protection against overload of a power supply due to a too high output current. —> Short circuit protection

**Ambient temperature**
Temperature of the air in which the power supply is operated. Normally it is measured about 10 mm beneath the operating unit.

**Efficiency**
The ratio of the output power to the input power, expressed as a percentage. Normally specified at maximum load and nominal input voltage. The efficiency is one of the most important specifications of a power supply. The difference between input power and output power is converted into heat. The improvement of the efficiency therefore means less heat and an improvement of the power losses and therefore a reasonable reduction of the heat.

**Nominal output voltage**
Output voltage which is specified for the power supply. The voltage may be adjusted in specified limits below and above the nominal value.

**Temperature coefficient**
Changing of the output voltage over the specified value, due to a rapid load change.