AN003

Basic Terms Used for DC Power Supplies

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1 Introduction

DC (Direct Current) power supplies are used in various applications related to automation, telecom, industry, energy management, medical, home automation, etc.
They are converting the AC (Alternating Current) mains to DC, at various power / voltage levels.
The most spread DC power supply technology nowadays is the **switched-mode power supply**, also known as an **SMPS** or a **primary switched-mode regulator**.

There are many different circuit topologies for this power supply, such as **forward converters, flyback converters, half-bridge converters, full-bridge converters, push-pull converters and resonant converters**.

Generally, on the **input** side, the mains voltage is rectified and filtered first in the case of SMPS. The capacitance of the filter electrolytic capacitor determines the **buffer (hold-up) time** of the unit in the event of a power failure on the input side. The filtered DC voltage is interrupted periodically by a specific circuit and a static switch (usually a MOSFET) 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 switching frequencies are normally between **20 kHz and 250 kHz**. Where high clock frequencies are used there is a risk that the switching losses will become too high. In this case, a reasonable compromise between high efficiency and the highest possible clock frequency has to be reached.

On the **secondary side**, the voltage is rectified and filtered again. The control deviation of the output voltage is fed back to the primary circuit through electrical isolation (other feedback configurations are also possible). 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 (**Pulse Width Modulation -PWM-** method; others are also possible).

The benefits

- Small magnetic components (transformer, storage choke, filter) due to high operating frequency
- Highly efficient thanks to switching technique
- Compact, light design
- No forced cooling necessary (exceptions possible)
- Wide-range input and output of the voltage possible

The drawbacks

- Complex circuits, lots of live parts
- High levels of interference (EMI – Electro Magnetic Interference)

2 Important Terms for Power Supplies

2.1 Output related terms

2.1.1 Overload and short circuit protection

Behavior of the power supply when operated outside the specified output values, as overload or short-circuit.
The most important output limitation characteristics are:

- **Hiccup 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, supplying high peak currents for short time. When the over load has been removed, the power supply will resume standard operation automatically.
- **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.
- **Switch-off (latch) mode:** when overloaded, the power supply will switch off. It has to be switched on manually after removing the overload.

2.1.2 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.

2.1.3 Response time

The time the power supply needs after a defined load change (usually 10% to 100%) until the output voltage will be back within the specified tolerances. This parameter is in conjunction with overshoot / undershoot define the dynamic behavior of the power supply.

2.1.4 Overshoot / undershoot

Short duration increase / decrease of the output voltage due to the quick changing of the load or input voltage. This parameter is in conjunction with the response time define the dynamic behavior of the power supply.

2.1.5 Load regulation

Changes in the output voltage due to a defined change of the load (usually 0% to 100%) at the nominal output voltage. It is normally expressed in % of the nominal output voltage.

2.1.6 Line regulation

The change at the output voltage with a defined change of the input voltage, while all other parameters stay constant. It is normally expressed in % of the nominal output voltage.

2.1.7 Start-up time

The time the power supply needs to reach the output voltage regulation after applying the input voltage. It is normally expressed at nominal input voltage and maximum output current.

2.1.8 Hold-up time

The time while the output voltage is still regulated, though the input voltage has disappeared. It is normally expressed at nominal output voltage and maximum output current.

2.1.9 Ripple and noise

Residual oscillation present on the power supply output due to the switching action. It is normally expressed in mVpp at nominal output voltage and maximum output current.

2.1.10 Output over-voltage protection

A circuit added on the output side of the power supply to limit the maximum output voltage in case of an internal failure.

2.2 Input related terms

2.2.1 AC-DC Converter

A power supply used to convert an AC input voltage (usually the mains voltage) to a regulated DC output voltage

2.2.2 DC-DC Converter

A power supply used to convert a DC input voltage to a regulated DC output voltage

2.2.3 Nominal input voltage

Input voltage which is specified for the power supply (AC or DC). The power supply parameters are normally expressed at nominal input voltage. For AC-DC converters usually also the frequency is specified, normally 47…63Hz

2.2.4 Input over-voltage protection

A circuit added on the input side of the power supply to make it able to withstand transient input voltage above the specified limit.

2.2.5 Power factor (PF)

The ratio of real power to apparent power. Due to the non-sinusoidal shape of the input current, the power factor of switch mode power supplies is <0.8 unless a dedicated PFC circuit is used.

2.2.6 Power Factor Corrector (PFC) circuit

Circuitry applied to obtain a PF close to 1 with sinusoidal shape of the input current. Power supplies provided with PFC circuit have normally less input current requirement for a given output power with respect to power supplies without PFC circuit

2.2.7 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. Higher efficiency brings smaller size and less power consumption.

2.2.8 Dissipated power

It is the power lost in heat during the energy conversion process. It is the difference between the input power and the output power. Higher efficiency brings lower dissipated power

2.2.9 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 source.

2.2.10 Isolation voltage

Isolation voltage is the maximum allowed voltage between two isolated circuits.
Normally it applies to **Primary to Secondary** and **Primary or Secondary to PE** (Protective Earth).

2.3 Environment related terms

2.3.1 Operating temperature

The specified temperature range within which the power supply is allowed to be operated, with or without derating.

2.3.2 Derating

The recommended decrease of performance (e.g power decrease) in order to accommodate specific operating conditions (environmental or load type related).

2.3.3 Storage temperature

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

2.3.4 Ambient temperature

Temperature of the air in which the power supply is operated.

2.3.5 Drift

Changes of output voltage or other parameters (e.g. current limit threshold) due to the ageing or the temperature.

2.3.6 Cooling

The removal of the heat which is produced by the losses in the electronic parts. It is to distinguish between **natural** and **forced** - by a fan or by liquid cooling.

2.3.7 Lifetime expectation

Theoretical calculation of the product lifetime based on ambient temperature and input / load conditions.

2.3.8 Radio interference emission

Undesired high frequency energy, produced by the switching elements of a power supply. A distinction should be made between **conducted** (on input/output wires) and **radiated interference.**

2.3.9 Radio interference immunity

Ability of a power supply to operate correctly in an environment with strong radio interference.