

 Application Note

Crane Aerospace & Electronics Power Solutions



## DC/DC Terminology



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*Although the concepts stated are universal, this application note was written specifically for Interpoint products.*

*This application note defines some of the common terminology used to describe the characteristics and operation of DC/DC converters.*

### ABSOLUTE MAXIMUM

The maximum condition which the power converter can withstand without permanently damaging the device. Usually applied to input voltage, output current/power, or case temperature.

### AGING

The long term change in output voltage of a power supply over time with all other factors held constant, usually accelerated by temperature. Long term aging is most often expressed as a percentage per 1000 hours and short term aging as a percentage over the first 24 hours of operation.

### AMBIENT TEMPERATURE

The temperature in the medium around a component and is measured some distance from the device (usually 0.5 inches) to be considered uniform. Temperature ratings for converters are usually given for case temperatures (Tc). The case temperature for an operating converter is ordinarily higher than the ambient temperature.

### BALUN

An inductor used for impedance matching between a BALanced line and an UNbalanced line. It presents a high impedance to common mode signals and a low impedance to differential mode signals. A balun is sometimes used in series with the input line of switching power converters to suppress common mode noise currents.

### BOOST CONVERTER – TOPOLOGY

The boost circuit is a commonly used building block in converter design. The switch controls energy transfer from the input source, through the inductor, to the load. The output-to-input voltage ratio, is always greater than one and is ideally equal to the inverse of one minus the duty conduction cycle of the switch during continuous operation. The boost topology also requires an output energy storage capacitor to support the load current while the switch is on.

### BUCK CONVERTER – TOPOLOGY

The buck circuit is another commonly used building block in converter designs. In its basic form, without a transformer, the output voltage is always less than the input voltage. When the transistor is switched on, energy is transferred from the input source to the inductor and the output. When the switch is turned off, the inductor current ramps downward and the energy is transferred to the output capacitor and the load. The output-to-input

voltage ratio is ideally equal to the conduction duty cycle of the switch for continuous operation. Since most applications severely limit the amount of pulsating current that can be drawn from the converter's input source, some form of low pass filter is generally inserted on the input side of the switch.

### CASE TEMPERATURE

The temperature of a converter measured at its baseplate. Temperature ratings for converters are usually given for the case temperature (Tc). The case temperature for an operating converter is ordinarily higher than the ambient temperature.

### CLASSICAL CONVERTER – TOPOLOGY

(See Royer converter)

### COMMON

The common input or output terminal of a power supply. It carries the return current for the terminals. Also referred to as "return".

### COMMON MODE NOISE

The component of noise which is common to both the DC input and input return or output and output return with respect to a common reference. The common reference is generally the converter's metal base.

### CONSTANT VOLTAGE POWER SUPPLY

A power supply that regulates its output voltage within specified limits in spite of line, load, and temperature changes.

### CROSS REGULATION

On multiple output power supplies, the change (usually measured in percentage) of the nominal output voltage on one output while the load is varied on another output over specified conditions.

### CROWBAR

An overvoltage protection circuit which monitors the output voltage of a power supply and rapidly creates a low resistance path across the output when a predetermined voltage is exceeded.

### DERATING WITH CASE TEMPERATURE

The specified reduction in output power/current as a function of case temperature above the maximum full load rated case temperature.

### DIELECTRIC BREAKDOWN VOLTAGE

The minimum AC or DC voltage which, when applied across an isolation barrier of a power converter, can cause a direct short to the outputs or the case. Input to output and input/output to case are examples of isolation barriers. Exceeding a converter's

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dielectric breakdown voltage can permanently degrade performance.

### **DIFFERENTIAL MODE NOISE**

The component of noise measured from the DC output or input to the return.

### **DRIVEN PUSH-PULL TRANSFORMER – INTERPOINT TOPOLOGY**

The driven push-pull circuit is derived from the Royer converter. Instead of relying on transformer saturation to provide the switching action, the driven converter uses a multivibrator to drive the switching transistors at a frequency chosen to maximize efficiency and minimize transformer size. Like the Royer, output voltage is directly proportional to input voltage. Efficiencies are typically higher than the Royer due to the non-saturating nature of the transformer switching action. This topology is used in Interpoint's DCH Series of isolated, unregulated converters.

### **DRIFT**

The change in output voltage over a period of time with all other operating parameters held constant.

### **DUAL BALANCED OUTPUTS**

An output voltage regulation scheme for dual opposite polarity output converters in which the absolute sum of the two voltages is held constant.

### **DYNAMIC LOAD REGULATION (OUTPUT IMPEDANCE)**

The ratio of change in transient output voltage to change in load current.

### **EFFICIENCY**

The ratio of power delivered to power consumed, expressed as a percentage.

### **EMI (ELECTROMAGNETIC INTERFERENCE)**

Conducted or radiated noise which is emitted from switching power supplies.

### **EPOXY POTTING**

An inexpensive method of hybrid packaging which consists of coating the substrate with a conformal coating and then submerging it in a potting cup filled with epoxy. Epoxy-potted modules have excellent thermal capacity characteristics but are not as resistant to moisture or as tolerant of temperature cycles as other types of packaging.

### **ESR (EQUIVALENT SERIES RESISTANCE)**

The amount of resistance, in series with an ideal capacitor, required to exactly model a real capacitor.

### **FARADAY SHIELD**

An electrostatic shield between the input and output windings of a transformer. The shield reduces capacitive currents and output common mode noise by shorting capacitive currents to a fixed reference, usually the case ground.

### **FAULT MODE INPUT CURRENT**

The input current of a DC/DC converter with the output terminals shorted.

### **FLYBACK CONVERTER – TOPOLOGY**

In the basic flyback converter when the transistor is turned on, the current increases linearly in the transformer primary. When the switch turns off the decreasing flux in the transformer core causes a current to flow in the secondary, transferring energy to the output capacitor and the load. Since the transformer assumes the roles of both an energy storage device and a transformer, only one magnetic component is needed.

### **FOLDBACK CURRENT LIMITING**

A short circuit protection system which decreases the output current as the overload increases, with the output current reaching a minimum at short circuit.

### **GROUND LOOP**

An unwanted feedback voltage caused by two or more circuits sharing a common electrical ground or return line.

### **HERMETIC SEAL**

A sealing technique sometimes used for microcircuit packages to provide airtight and moisture resistant components. The highest quality hermetically sealed converters have final soldering or welding performed in a dry nitrogen environment and undergo leak testing. Hermetically sealed packaging increases a converter's reliability and extends its life.

### **HI-POT TEST (HIGH POTENTIAL TEST)**

A test performed by applying a high voltage between isolated test points in order to test the minimum specified isolation resistance of a power supply.

### **HOLD-UP TIME**

The length of time a power supply will maintain its output voltage within specifications after loss of its input power.

### **IDLE CURRENT**

See Standby Current.

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### INPUT LINE FILTER

A low pass filter at the input of a power supply which can attenuate input line noise fed into the supply or reflected line ripple current generated by the supply. (See also Pi Filter.)

### INPUT/OUTPUT CAPACITANCE

The effective barrier capacitance from the input pins to the output pins.

### INPUT RIPPLE CURRENT

The magnitude of the AC current generated at the input of a DC/DC converter by the switching operation of the converter, measured in milliamps peak-to-peak or milliamps RMS. Input ripple current is usually measured at full load over a specified bandwidth with a specified source impedance. (See also PARD.)

### INPUT RIPPLE CURRENT FILTER

A filter at the input of a power converter designed to reduce the ripple current generated by the switching action of the converter.

### INPUT RIPPLE REJECTION

The attenuation, in dB, of the output AC signal in response to the injected AC input signal at a particular frequency or as a function of frequency.

### INPUT TRANSIENTS

Temporary changes in the input voltage to a power converter which may fall outside the minimum/ maximum input voltage range of the converter. Those which exceed the maximum may damage the converter.

### INPUT VOLTAGE RANGE

The input voltage range over which a DC/DC converter is guaranteed to meet its specifications.

### INRUSH CURRENT

The peak instantaneous input current drawn by a power supply at turn-on.

### INVERTER

A DC to AC power converter.

### ISOLATION

The electrical separation between the input, output and case of a power supply. Isolation is usually expressed in megohms.

### ISOLATION VOLTAGE

The guaranteed maximum AC or DC voltage which can be applied from input to output of a power supply while the supply maintains the specified isolation resistance in megohms.

### LEAKAGE CURRENT

The AC or DC current flowing from input to output and/or case of an isolated power supply at a specified voltage and frequency.

### LINE REGULATION

The change in output voltage (expressed in millivolts or percentage of output voltage) as the input voltage is varied over its specified range. Line regulation is usually measured at full load.

### LINEAR REGULATOR - TOPOLOGY

A linear regulator is a circuit which uses an error amplifier to compare a fraction of the output voltage with a voltage reference. The amplifier output drives a series regulator transistor which keeps the output voltage constant. Some linear regulators include a short circuit protection circuit which senses the voltage across a current sampling resistor. When this voltage exceeds a preset level, the circuit reduces the base drive of the transistor and limits the output current. Linear regulators are used in DC/DC converters to regulate output voltages which are not controlled by feedback loops, or to provide tight post-regulation.

### LOAD REGULATION

The change in output voltage (expressed in millivolts or percentage of output voltage) as the load is varied from a specified minimum to full load. Load regulation is usually measured at nominal input voltage.

### LOW LINE DROPOUT VOLTAGE

The low input line voltage at which an operating power converter's output voltage will drop below the specified minimum output voltage.

### MAXIMUM ALLOWABLE VOLTAGE BETWEEN PINS

On power converters with output voltage trim and/or remote sense, the maximum voltage that is allowed at the specified pins due to the combined effects of line drops and voltage trim.

### MAXIMUM OUTPUT CURRENT

The maximum steady-state current a converter is guaranteed to supply while continuing to meet its other requirements.

### MTBF (MEAN TIME BETWEEN FAILURES)

The failure rate of a power supply, calculated using MIL-HDBK-217 for military or aerospace applications. MTBF calculations

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(expressed in hours) vary widely depending on assumptions made about the quality of components and assembly, number of interconnects, packaging methods, case temperature, and operating environment.

### NOMINAL CLOCK SWITCHING FREQUENCY

In a switching power converter, the frequency at which the power switch chops the incoming DC voltage. The frequency is chosen to optimize transformer efficiency and size.

### NON-SATURATING CORE CIRCUIT

A circuit design which controls the switching action of a power converter so as to limit the operation of the transformer to the non-saturating portion of its B (flux density) – H (magnetizing force) curve.

### OUTPUT CURRENT LIMITING

An output protection feature in which the output current is limited to a predetermined maximum value under overload and/or short circuit conditions.

### OUTPUT POWER

The maximum steady-state power (the product of voltage and current) which the converter is guaranteed to be able to deliver to the load while continuing to meet its other specifications.

### OUTPUT TRIM

On adjustable output power converters, the maximum allowable adjustment of the output voltage, often expressed as a percentage of the nominal output voltage. Output trim is used to compensate for resistance drops (Also referred to as “output voltage adjustment”).

### OUTPUT VOLTAGE

The nominal DC voltage at the output terminals of a DC/DC converter.

### OUTPUT VOLTAGE ADJUSTMENT

See Output Trim.

### OUTPUT VOLTAGE RIPPLE

The magnitude of the AC voltage on the output of a converter, measured in millivolts peak-to-peak or millivolts RMS over a specified bandwidth. Usually measured at full load. (See also PARD.)

### OUTPUT VOLTAGE TOLERANCE

(Total Error Voltage) The maximum deviation, in percentage of nominal, of the output voltage under all specified minimum or maximum conditions.

### OVERLOAD PROTECTION

An output protection feature which limits the output current of a power supply under overload conditions so that the supply will not be damaged.

### OVERVOLTAGE CLAMP

See Overvoltage Protection.

### OVERVOLTAGE PROTECTION

A feature which limits the output voltage or inhibits a power supply when its voltage exceeds a specified level.

### PARD (PERIODIC AND RANDOM DEVIATIONS)

The sum of all ripple and noise components measured over a specified bandwidth.

### PI FILTER

A filter consisting of two parallel capacitors (line to line) and a connecting series inductance which is used at the input of a switching power supply to reduce ripple current, or at the output to reduce ripple voltage.

### POST-REGULATION

Use of a linear regulator on the output of a switching power supply to improve regulation and reduce ripple voltage.

### POWER DISSIPATION

The Sum total of all internal power losses defined as the difference between input power and output power.  $P_D = (P_{in} - P_{out})$

### POWER FOLDBACK

A power supply feature in which the input power is reduced to a low value under overload conditions.

### PRE-REGULATION

The regulation at the input side of a power supply, usually by a type of switching regulator or a linear regulator.

### PULSE WIDTH MODULATION

A method of controlling the power switches in a switching power supply by varying the duty cycle of the switches while holding the switching frequency relatively constant.

### PUSH-PULL DC TRANSFORMER – TOPOLOGY

The push-pull DC transformer is a commonly used switch, transformer, and diode topology. Its name is derived from the alternate conduction actions of the two primary side switches and the secondary side rectifier elements. The alternate switching actions of generate a symmetrical alternating voltage across

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the primary of the transformer. A corresponding AC voltage will appear across the secondary which, when rectified, results in a DC voltage at the output such that:

$$V_o \text{ is approximately } V_s \times (N_s/N_p)$$

### QUASI-SQUAREWAVE CONVERTER – TOPOLOGY

The quasi-squarewave converter is derived from the combination of a buck converter and a push-pull DC transformer. The operation is similar to that of the buck converter with switches alternately closing to transfer energy from the input through the transformer to the output inductors. As in the buck, the output-to-input voltage ratio is proportional to the duty cycle of the switches.

### REFERENCE

A stable voltage, generally supplied by a voltage reference IC, which is used for comparison to control a regulated output voltage.

### REGULATED/UNREGULATED

A power converter's output voltage is said to be regulated if its value is constant within specified limits, regardless of input voltage and load variations. An unregulated output voltage varies in relation to changes in input voltage and load.

### REMOTE SENSING

A method of regulating the output voltage of a power supply at the load by using sensing leads which carry very little current, thereby compensating for voltage drops in the load leads.

### RESOLUTION

For an adjustable power supply, the smallest change in output voltage which can be realized by the adjustment.

### RETURN

The common input or output terminal of a power supply. It carries the return current for the terminals. Often referred to as "common."

### REVERSE VOLTAGE PROTECTION

A feature which protects a power supply against damage from a reverse polarity voltage applied at the input or output terminals.

### RIPPLE AND NOISE

The magnitude of the AC voltage on the output voltage of a power supply. This is the result of conducted line noise, internal switching transients and other random noise.

### ROYER (CLASSICAL) CONVERTER – TOPOLOGY

The Royer circuit is a self-oscillating, push-pull topology. The transistors are driven from auxiliary windings on the transformer. When the input voltage is applied, the bias circuit causes one of the transistor switches to turn on. This switch remains on until the transformer core saturates, thereby removing the base drive from the conducting transistor. Residual energy in the core then changes the polarity of the voltage across the windings which turns on the opposing transistor. The circuit continues to self-oscillate at a frequency proportional to the input voltage, which produces an output square wave of voltage which is rectified and filtered to produce the output. Line regulation is not provided by this circuit and the output voltage is directly proportional to the input voltage. The primary advantage of the Royer circuit is its simplicity, which keeps component and assembly costs down. Its use is limited, however, to low power applications due to its inherent low efficiency (typically less than 65%). Core magnetic losses are especially large at the high oscillation frequencies needed for small transformers.

### SERIES REGULATION

A method of linear regulation in which the control device is in series with the supply and the load.

### SHORT-CIRCUIT PROTECTION

A feature which limits the output current of a power supply under short circuit conditions in order to prevent damage to the supply.

### SHUNT REGULATION

A method of linear regulation in which the control device is in parallel with the load.

### SOFT START

A feature which limits the start-up current of a switching supply and causes the output voltage to rise gradually to its normal value.

### SOLDER SEALING

A method of attaching a metal cover to a metal package base which uses a low temperature alloy to fuse the cover-to-base interface. Hermetically sealed converters are often solder sealed in a dry nitrogen atmosphere.

### SPLIT BOBBIN WINDING

A method of winding a transformer in which the primary and secondary are wound side by side on a bobbin with an insulation barrier between the two windings.

### STANDBY CURRENT

The no-load or shutdown input current of a power supply.

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### START-UP OVERTHOOT

The maximum deviation of the rising edge of a power supply from its final, steady-state value following a release from inhibit condition.

### START-UP TIME

The maximum time required for the output voltage of a power supply to reach a specified percentage of its final, steady-state value, following a release from inhibit condition.

### SWITCHING REGULATOR

A circuit which chops and re-rectifies an input DC voltage, and then uses a feedback control loop to regulate the output voltage of a power supply. The feedback loop controls the pulse width and/or frequency of the switching action.

### SYNCHRONIZATION

A switching power supply feature in which the internal switching frequency can be synchronized with an external clock within specified limits.

### TEMPERATURE COEFFICIENT (OF VOLTAGE)

The maximum percent change in nominal output voltage per degree centigrade change in case temperature over a specified temperature range.

### TEMPERATURE RANGE, OPERATING

The temperature range within which a power supply can be operated while meeting specified performance characteristics. The operating temperature range is specified for case temperature rather than ambient temperature.

### TEMPERATURE RANGE, STORAGE

The ambient temperature range within which a power supply can be stored with no subsequent degradation of its operating specifications.

### THERMAL IMPEDANCE

Thermal resistance. The measure of opposition to heat flow for a particular material or materials ( $^{\circ}\text{C}/\text{W}$ ).

### THERMAL PROTECTION

A power supply safety feature which shuts the device down in the event of excess internal temperature.

### THICK FILM HYBRID TECHNOLOGY

A method of microcircuit manufacture in which one or more integrated circuits are combined with discrete components and screen printed passive elements and interconnections to form

a packaged module. The smallest and most reliable DC/DC converters are made with thick film hybrid technology.

### TOPOLOGY

The basic configuration of a circuit.

See also the following basic topologies:

Boost Converter

Buck Converter

Flyback Converter

Linear Regulator

Push-Pull DC Transformer

Quasi-Squarewave Converter

Royer (Classical) Converter

And Interpoint topologies:

Driven Push-Pull Transformer

Feedback Controlled Flyback Converter

Pulse Width Modulated (PWM) Quasi-Squarewave Converter

### TRACKING

A characteristic of multiple output power supplies in which one or more output voltages follow another with line, load, and temperature.

### TRANSIENT RECOVERY

The peak change in the output voltage of a power supply following a step change in a load or line condition.

### TRANSIENT RESPONSE

The time required for a converter's output to return to within its specified regulation range following a step change in line or load.

### UNDERSHOOT/OVERTHOOT

The time required for a converter's output to return to within its specified regulation range following a step change in line or load.

### VOLTAGE BALANCE

In a dual, opposite polarity, power supply the difference in magnitude (in percentage) between the output voltages which are nominally equal at equal load.

### WARM-UP DRIFT

The initial change in output voltage of a power supply from turn-on until it reaches thermal equilibrium.