MICROPOWER DIRECT

TECH NOTE

Glossary Of Power Conversion Terms

MicroPower Direct

MPD, a leading worldwide provider of power conversion products, was founded by a group of industry veterans in 1999. Located in Easton, MA, we are committed to delivering innovative, high quality power converters at the lowest possible prices.

We currently offer over 5,000 low cost standard "off-the-shelf" high performance power converters. Our product lines include DC/DC converters, AC/DC power supplies, high brightness LED drivers, IGBT drivers & controllers, and switching POL regulators.

Component selection and layout are carefully considered at the design stage to optimize product reliability. All manufacturing is in ISO9000 registered factories under strict quality control system guidelines. All products are supported worldwide, and carry a standard three year warranty.

MPD power products have been designed into a wide variety of products and systems by a very diverse customer base. End products range from computer peripherals to test instrumentation to telecommunications equipment to process/industrial controls to medical devices and more.

— A —

Absolute Maximum Ratings: Peak performance ratings for a power supply. If exceeded, permanent damage to a power supply could occur. When specified, these specifications are not given as continuous ratings, and proper operation is not implied.

AC: Abbreviation for alternating current. See Alternating Current.

AC/DC: Abbreviation for alternating current/ direct current.

AC Current: See Alternating Current.

AC Front-End: Part of a distributed power system that will convert ac line voltage to a semiregulated dc voltage level. An AC front-end will typically provide power factor correction and universal (~85 VAC to 265 VAC) ac compatibility. An ac front-end's output voltage is usually 350 VDC to 400 VDC. See Power Factor Correction.

AC Line: The ac power distribution lines. See Alternating Current.

AC Line Filter: A filter placed in the ac line to condition high frequency noise variations.

AC Voltage: See Alternating Voltage.

Accelerated Stress Testing: (AST) See Highly Accelerated Life Testing and Highly Accelerated Stress Screening.

Active Current: The portion of an alternating current that is in phase with the voltage. Active current equals the average power divided by the effective voltage. See Average Power, Effective Voltage, Reactive Current.

Adjustment Range: The range limits over which power system parameters may be varied. Typically used with the output voltage of a power supply. Often called Trim Range.

Aging: The operation of a power supply under tightly controlled conditions (input voltage, output load, ambient temperature, etc.) for a predetermined time. Aging is used in reliability testing to screen out or stabilize marginal units (infant mortality). See Burn-in.

Alternating Current: A periodic current that will symmetrically switch direction of flow from positive to negative values. Over a set period of time, the average value of an AC current, for a pure sine wave, is zero. The time period it takes the current to go from zero to maximum positive and back to zero (the positive alternation), then to maximum negative and return to zero (the negative alternation) is one cycle. The number of cycles per second is the AC frequency.

Alternating Voltage: A voltage that periodically switches direction of flow from positive to negative. The average value of an AC voltage, for a pure sine wave, is zero. One cycle (or period) is the time it takes the voltage to rise to its maximum value in one direction, return to zero, rise to its maximum value in the opposite direction and again, return to zero. The number of cycles per second is the AC frequency.

Ambient Air: The air mass immediately surrounding an operating power supply. Reliable operation of power supplies requires sufficient surrounding air mass and flow to prevent thermal runaway caused by heat dissipated by the supply.

Ambient Temperature: The average temperature of air immediately surrounding a power system. Temperature measurements should be made about 0.5 inches from the body of the power supply. See Operating Temperature and Storage Temperature.

Ambient Temperature Range: The temperature range of air surrounding a power system over which it can be safely operated. Ambient temperature ranges are often extended by using forced air flow or power derating requirements.

American National Standards Institute: (ANSI) A US based organization that develops standards for products, processes, and systems, etc. They also accredit standards developed by other organizations.

American Wire Gauge: (AWG) A standard for sizing wire by cross sectional area. AWG has been used in North America since 1857, it is also known as the Brown & Sharpe wire gauge. The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity.

Ampere: (A) The base unit of current, equal to:

$$I = \frac{E}{R}$$

Where: I = Current
E = Voltage
R = Resistance

Amplifier: See Error Amplifier.

Anode: The "positive" terminal connection to a diode, LED etc. See Cathode.

Apparent Power: The product of input rms voltage times input rms current. High rms values in AC input switch-mode power systems, where the input current is distorted results in high apparent power.

Applied Voltage: The voltage presented to a circuit point or system input, as opposed to the

voltage drop resulting from current flow through an element.

Assembly: The complete power system, power supply or power converter that is fabricated from subassemblies and/or various components.

Asymptotic Breakdown Voltage: A voltage level, that if applied over a long period of time, will break down insulation.

Attenuation: Attenuation typically refers to the loss of power over a length of cable (or board trace), when used regarding power systems.

Automatic Test Equipment: (ATE) Equipment (typically a combination of hardware & software) used to test/stress power conversion products or systems.

Autoranging Input: An ac power supply input circuit that senses the input voltage level and automatically switches the input to the appropriate range (i.e. 90 VAC to 130 VAC or 180 VAC to 264 VAC). Sometimes called an Auto Select Input.

Auxiliary Output: A secondary output that is used to supply low power levels to housekeeping circuits etc. It operates separately from the main output of the supply.

Average Current:: (I_{AVG}) The average value of current flowing in an ac circuit. For a perfect sine wave, the value would be zero. The value of average current is equal to 0.637 times the value of peak current.

$$I_{AVG} = 0.637\ I_{Pk}$$

Average Power: (P_{AVG}) In an ac circuit, the average value of ac power. For resistive circuits, it equals the square of the rms current times the circuit resistance, as given by:

$$P_{AVG} = (Irms)^2R$$

Where: I_{rms} = rms value of the circuit current
R = Circuit resistance in ohms

Average Rectified Current: The average value of current from a full-wave rectifier circuit prior to any filtering. For a circuit with a sine wave input and a resistive load, Ir is equal to:

$$Ir = 0.637\ I_{MAX}$$

Average Rectified Voltage: The average value of voltage from a full-wave rectifier circuit prior to any filtering. For a circuit with a sine wave input and a resistive load, Er is equal to:

$$Er = 0.637\ E_{MAX}$$

Average Voltage: The average value of an AC voltage is equal to 0.637 times the maximum value.

$$E_{AVG} = 0.637\ E_P$$

— B —

Back Ripple Current: See Reflected Ripple Current.

Backup: See Battery Backup.

Backup Battery: See Battery Backup.

Bakelite: A plastic resin used as a case material for power conversion modules. Part of the family phenol-formaldehyde plastics.

Balance Resistors: Resistors connected in series with LED strings to help balance the current in parallel connections. Typically very small values, they are sometimes called Ballast Resistors.

Ballast: In a fluorescent lighting system, the ballast regulates current to the lamp. At startup, it supplies a voltage high enough to start the lamp. Once the lamp is operating, it reduces the voltage and regulates the current to the circuit. This protects the lamp from burning out, and the resultant regulated current output produces a steady light output

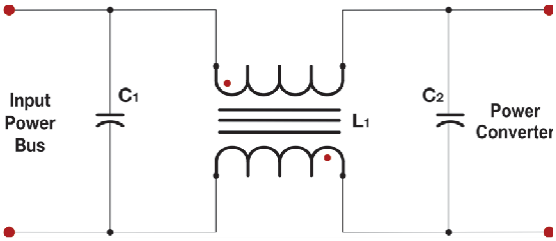


Figure 1 Simplified Balun Filter

Balun Filter: An input line filter that include a differential wound transformer often used within power supplies. They show high impedance to common mode signals and low impedance to differential mode signals. Also called a Common Mode Filter.

Barrier Strip: A connector that includes a protective barrier between adjacent terminals. Often used on moderate/ high power AC power supplies or on applications where a wiring harness is used.

Baseplate: A metal plate or substrate to which circuit components are mounted or the power supply is attached. It is used to draw heat away from critical circuit components and (sometimes) to provide mechanical stability. See Heat Sink.

Baseplate Temperature: See Case Temperature.

Basic Insulation: The level of insulation required for the proper operation of a power system or component and for a minimum level of protection against electrical shock. It is sometimes called Functional Insulation. See also Insulation, Double Insulation, Reinforced Insulation and Supplementary Insulation.

Battery: A multi-cell device that produces DC electricity via an electrochemical action. Battery cells are connected in parallel (to produce a required current) and/or series (to produce a required voltage).

Battery Backup: An electronic equipment subsystem that provides temporary power in case input power to the system is lost. Battery backed systems range from short term options for AC/DC power supplies to high VA Uninterruptible Power Systems. See Uninterruptible Power Supplies (UPS).

Battery Charger: A power supply or power supply output that is used to charge a storage battery or battery system.

Bead: A small ring of ferromagnetic material. When slipped over the power leads to a circuit, the bead acts as a passive electronic choke to suppress high frequency noise.

Beam Angle: The angle between two lines, on either side of the optical axis, at a point where the luminous intensity is 50% of the center beam intensity. It typically ranges from 8° to 160°. High (or wide) beam angle LEDs (>70°), with their broader spread of light, are useful in illumination applications. Low (or narrow) beam angle LEDs are typically used in indicator applications where a higher luminous intensity is required (for improved visibility). Also called View Angle, Viewing Angle or Beam Spread.

Beam Lumens: The total lumens contained within a light beam.

Beam Spread: See Beam Angle.

Benchmark: A performance standard. Used in product, system or component testing.

Bench Power Supply: A cased power supply with displays and controls that are used to precisely adjust operating characteristics. Usually an ac input device, bench supplies are sometimes called Laboratory Supplies.

Binning: LEDs are sorted as part of the manufacturing process. Binning helps minimize operating tolerances in customer shipments. Sort criteria might include intensity, color, forward voltage, etc.

Bipolar Junction Transistor:: (BJT) A three layer, three terminal component whose construction consists of two PN junctions. The two basic types are PNP or NPN (which refers to the arrangement of the N & P type material used). The bipolar transistor acts as a current controlled switch.

Birmingham Wire Gauge: (BWG) A standard used for sizing wire. BWG diameters are larger than corresponding AWG diameters (for a given wire size). Sometimes called the Stubs Gauge.

Bleeder: See Bleeder Resistor.

Bleeder Resistor: A resistor that provides a path for current drain. Often used in filter circuits to provide a discharge path for capacitors. In high-voltage power supplies, they can serve as a safety circuit. Also called a Drain Resister.

Bleeder Power: The power dissipated (as heat) across a bleeder resistor.

Block Diagram: A simplified diagram of an electronic circuit or system. The different components or parts of the circuit are shown as interconnected boxes; making it easier to see the overall system design.

Blocking Capacitor: A capacitor that will stop the flow of DC current while passing AC current.

Blocking Choke:: A choke coil or inductor that will stop the flow of AC current while passing DC current.

Board: See Printed Circuit Board.

Board Mount Power Supply: A power supply or converter that's designed to mount onto a printed circuit board. Typically refers to product that is fabricated in an encapsulated module, but low power open board construction power products are available that mount directly to a PC board.

Bobbin: A spool (typically nonmetallic) used in the winding of transformers and inductors. Bobbins provide a physical frame to support the transformer or inductor windings and keep the windings isolated from the core.

Bode Plot: For a control loop, a plot that shows the relationship of gain and phase vs frequency. The loop stability of a power supply is verified using a bode plot.

Boost Regulator: A basic switching converter topology wherein energy is stored in an input inductor. When the shunt switch is turned off, this energy is transferred to the output. Boost regulators take an unregulated input voltage, and produce a higher, regulated output voltage. Also called a Boost Converter. See Buck Regulator, Bridge Converter, Flyback Converter, Forward Converter, Push-Pull Converter and Resonant Converter.

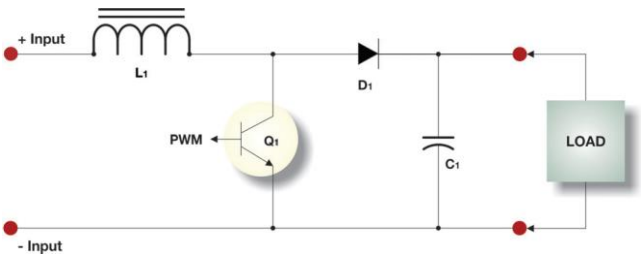


Figure 2 Simplified Boost Regulator

Braided Wire: A length of braid typically used for grounding or shielding.

Breakdown Voltage: The maximum ac or dc voltage that can be applied from the input to output (or chassis) of a power supply without causing damage.

Brick: A packaging standard for DC/DC converters. See Full Brick, Half Brick, Quarter Brick, Eight Brick and Sixteenth Brick.

Bridge Converter: A switching converter topology with a full bridge circuit (four switching elements) or half bridge circuit (two switching elements). This topology is more common in off-line (ac input) supplies than DC/DC converters. Bridge converters can provide high output power and low output ripple, but tend to be more complex than other power converter topologies. The added circuit complexity increases cost and may reduce reliability. See Boost Regulator, Buck Regulator, Flyback Converter, Forward Converter, Push-Pull Converter and Resonant Converter.

British Approvals Board for Telecommunications: (BABT) as established in 1982 by the British government. Now operating as an independent subsidiary of TUV SUD Products Service, they are a notified body for testing and accrediting a number of European telecomm and EMC directives.

British Standards Institution: (BSI) The UK national standards body. They develop standards for a wide variety of organization requirements including health & safety, quality management, IT security and energy management. They also provide training and certification to their standards world wide.

Brownout: A reduction or sag in the ac line or system power bus. If not protected against sags (by an adequate hold-up time or extended input ranges), an ac input power system could inadvertently shutdown.

Brownout Rated: An ac input power supply that is designed to operate within specified limits if a brownout (sag) in the input ac mains or system power bus occurs.

Brute Force Supply: Basic power supply that provides an unfiltered/unregulated output.

Buck Regulator: A basic switching converter topology (see Fig 4) with a series switch (Q_1) to chop the input voltage. The resulting pulses are applied to an averaging LC filter (L_1,C_1). Buck regulators will only produce an output voltage lower than the input voltage level. See Boost Regulator, Bridge Converter, Flyback Converter, Forward Converter, Push-Pull Converter and Resonant Converter.

Buck-Boost Converter: See Flyback Converter.

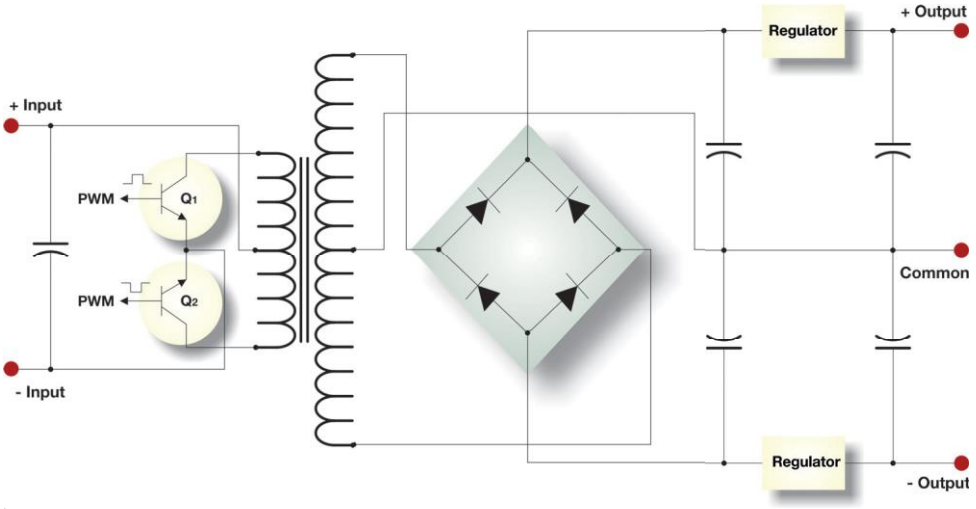


Figure 3 Simplified Bridge Converter

Buck-Derived Converter: See Forward Converter.

Buffer Capacitor: A capacitor placed across the secondary of a transformer to suppress voltage spikes.

Bulb: Typically used in reference to a lamp. An "LED bulb" is a finished lamp assembly that contains LEDs.

Bulk Capacitor: A storage capacitor often used on the input of a distributed power system.

Burn-In: To stabilize power supply operation and eliminate infant mortality, newly manufactured power supplies are often operated for a period of time as part of the production process. This "aging" of the unit is tightly controlled, including the time period, temperature and any special conditions (input power cycling, load switching, etc.).

Bus: The primary conductor path (wires, cables, etc.) used for routing power to various components within a (sub)system.

Bus Converter: A DC/DC converter that provides the isolated intermediate bus voltage in a distributed power system. The intermediate bus is used to power non-isolated point of load (POL) converters. Typically it will be a "brick" type package with a 48 VDC input and a 5 to 12 VDC output.

Bypass Capacitor: A capacitor used in ac circuits to provide a low impedance path around a circuit or component.

Cabinet: See Enclosure.

Cable: A bundle of insulated wires through which electrical signals and /or power are transferred.

Cable Assembly: A set of wires or cables that connect a power system to the power source or output load. The wires are sleeved; or tied together with cable ties, straps, or lacing. Also called a Cable Harness, Wire Harness, or Wiring Assembly.

Cage: A completely shielded box or room. Typically it is covered on all sides with a fine mesh screen that is conductive and well grounded. Often used to test systems or equipment that is sensitive to electromagnetic radiation in the surrounding area. Also called a Faraday Cage.

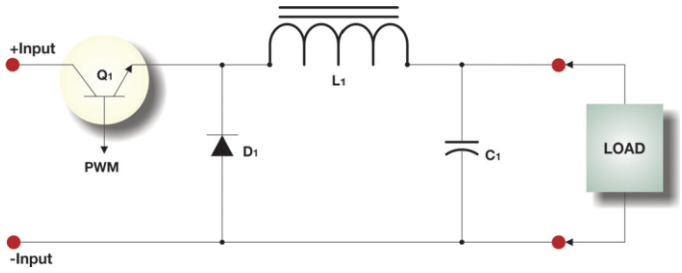


Figure 4 Simplified Buck Regulator

Canadian Standards Association: (**CSA**) Established in 1919, the CSA is an independent organization that sets safety standards (and tests for compliance) for electronic components and systems that are to be sold in Canada. See IEC, UL, TUV and VDE.

Candela: (**cd**) The luminous intensity of a light source in a given direction. At a wavelength of 555 nanometers (green), one candela will have a radiant intensity of 1/683 watt per steradian.

Candle Power: See Candela.

Capacitance: An electrical property that opposes a change in voltage level and stores energy in an electrostatic field.

Capacitive Coupling: The coupling of a signal between two circuits or components caused by discrete or parasitic capacitance.

Capacitive Input Filter: A filter that uses a capacitor as its input component. See Input Line Filter, Choke Input Filter, Common Mode Filter, Pi Filter and Output Filter.

Capacitive Load: The maximum amount of capacitance in the output load circuit that the power supply will drive and is still guaranteed to start and function correctly. Typically specified as maximum capacitive load. If the capacitive load is too high, the power supply could fail on start up and shut down.

Capacitor: A passive electronic component that consists of two metal plates separated by a dielectric (insulator). A capacitor stores energy as an electrostatic field between its plates. The conducting plates are typically made from aluminum, tantalum or silver. The nonconducting dielectric increases a capacitor's charge capacity. Common dielectric materials include glass, ceramic, plastic film, air, paper, mica, etc. Capacitors are widely used in power supplies and other electrical circuits.

Capacitor Leakage: A direct current (DC) that flows through the dielectric of a capacitor, leakage is equivalent to a resistor in parallel with the capacitor. Depending on the capacitance and the applied voltage, an electrolytic capacitor could have several milliamperes of leakage. A non-electrolytic capacitor will typically have less than 1μA.

Case: See Enclosure.

Case Temperature: The temperature of the component or power supply case, when the supply and surrounding system are operating normally. Often used as a specification (as opposed to ambient temperature) for power supplies with extended

temperature ranges or high power densities. It is sometimes called Baseplate Temperature.

Catch Diode: See Free Wheel Diode.

Cathode: The "negative" terminal connection to a device or component (such as an LED). See Anode.

Ceiling: The maximum amount of current or voltage that power supply or circuit can deliver.

Cell: The basic unit used in the generation and storage of electricity. A battery consists of a number of connected cells.

Celsius Scale: A temperature scale based on the freezing point of water (defined as 0°C) and the boiling point of water (defined as 100°c). Sometimes called the Centigrade Scale. See also Kelvin Scale and Fahrenheit Scale.

Center Tap: A connection made to the center point of a coil or transformer winding. Used in simple power supply designs to develop dual outputs.

Centigrade Scale: See Celsius Scale.

Central Power System: A power system in which all the components are contained in one box (or on one card). Often, a central power system consists of a medium or high power switching power supply that takes an ac input and generates multiple, regulated dc outputs. These dc outputs are bused throughout the system (via a wiring harness or backplane) to provide power to various system components.

Certified Europe: (CE) A mark applied to electronic products (including some power supplies) to be sold in Europe. The mark certifies the power supplies meet the applicable EMI/RFI and/or safety directives.

Characteristic: A quantity that defines an operating parameter of a device, component or circuit. For example the output power of a DC/DC given in watts.

Characteristic Curve: A curve or plot that illustrates the relationship between two or more variables with respect to a parameter for a device, component or circuit. For example, a derating curve for a power supply that graphs the relationship between output power and operating ambient temperature.

Charger: A circuit or device that charges a capacitor or battery.

Charging Current: The current flowing into a capacitor when a DC voltage is applied. The current decreases exponentially over time.

Charging Rate: The rate at which current flows into a capacitor or storage cell.

Chassis: See Enclosure.

Chassis Ground: The voltage potential present on the chassis, frame or enclosure surrounding a power supply.

Charge Rate: The rate at which current is applied to a battery cell to restore its capacity. Typically expressed as ampere-hours or milliampere-hours.

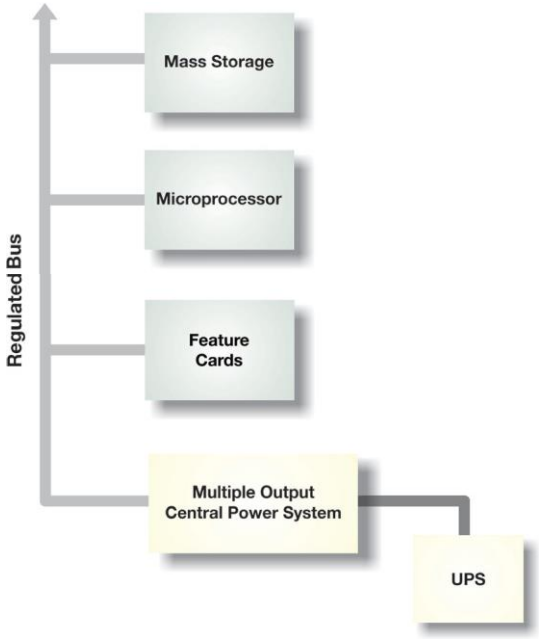
Choke: See Inductor.

Choke Input Filter: A filter that has an inductor as its input component. Often used with a capacitor (as an L/C filter), choke input filters improve line regulation and are more resistant to input variations than capacitor filters. See Input Line Filter, Capacitive Input Filter, Common Mode Filter, Pi Filter and Output Filter.

Chopper: See Inverter.

Circuit Breaker: A fuse like protection device that opens when a circuit is overloaded. Once tripped, circuit breakers can be reset.

Figure 5 Central Power System



Circulating Current: See Ground Loop.

Clamp Diode: A diode found in clipper or clamp circuits. The diode will set the voltage level to a reference point. They are often used as part of a power supply protection circuit.

Clearance Distance: The shortest distance (through air) separating two live conductors or circuit components. See Creepage Distance.

Clock: Timing pulses used in electronic systems to synchronize circuit operation. In a power supply, clock pulses synchronize operation of the pulse width modulator (PWM).

Color Temperature: A measurement that indicates the hue of a specific type of light source. Warm color temperatures tend to enhance red/orange, adding a yellow tint to white. They are typically used in homes, restaurants, etc. Cool color temperatures enhance blue, adding a bluish tint to white. They are often used in offices, hospitals, etc. Given in Kelvins.

Comite International Special des Perturbations Radio-electriques: (C.I.S.P.R.)The International Special Committee on Radioelectronic Interference is an IEC committee that develops standards for EMC (CISPR 22). Requirements are similar to those of the FCC, with significant changes in frequency limits and the specification of "average" limits for testing. See Electromagnetic Compatibility, Electromagnetic Interference, Federal Communications Commission and International Electrotechnical Commission.

Comite pour Europeen de Normalisation Electronic: (CEN/CENELEC) The European Committee for Electrotechnical Standardization) is a technical committee that recommends standards to be adopted by the European Community (EC). Standards cover EMI/RFI interference, intrinsic product safety, immunity, etc.

Commercial Grade: (C-Grade) A power supply rating for products that do not operate below -25°C. See Industrial Grade and Military Grade.

Common: A conductive path used as a return for two or more circuits. When connected to earth, a common is the same as ground. See Ground.

Common Mode Filter: See Balun Filter.

Common Mode Noise: The noise component that is equal and in phase on conductors with respect to a common reference point.

Common Mode Output: Electrical energy that is unintentionally supplied to an external impedance that exists between the output connection of a floating power supply and a system common point (chassis, frame, shield, etc.)

Compliance Range: The range of voltage required to maintain a given constant current output for a specified range of load resistance.

Compliance Voltage: The max dc output voltage of a constant current power supply.

Component: The individual parts (resistors, capacitors, etc) used to assemble an electronic circuit.

Component Density: The quantity of electronic components on an assembled printed circuit board per square area.

Component Failure Rate: The number of components, out of a set group, that are expected to fail over a specified period of time. Typically given as a percentage, however, in some applications it may be expressed as the frequency that a component would be expected to fail.

Component Layout: The physical arrangement of components on a printed circuit board.

Component Stress: The strain that a circuit component is subjected to. Typically the higher the mechanical, electrical or environmental stress is for a component, the higher the failure rate for that component will be.

Conductance: The ability of a circuit or circuit element to conduct electricity. Conductance, measured in mhos (English) or siemens (metric), is the reciprocal of resistivity and is given by the formula:

$$G = \frac{1}{R}$$

Where: G = Conductance
R = Resistance

Conducted Heat: Heat transferred through a material or substance. In power circuits, heat sinks are often used to conduct heat away from critical components to the surrounding ambient air.

Conduction Cooling: The transfer of heat through a solid material. It is used to cool electrical components or sub-assemblies (such as a power supply) by the addition of heat sinking. This will increase the case surface area of the component or subassembly, lowering the thermal resistance. Thermal resistance equals:

$$\theta = \frac{L}{KA}$$

Where: θ = Thermal Resistance
L = Length of material
K = Thermal conductivity of material
A = Cross sectional area of material

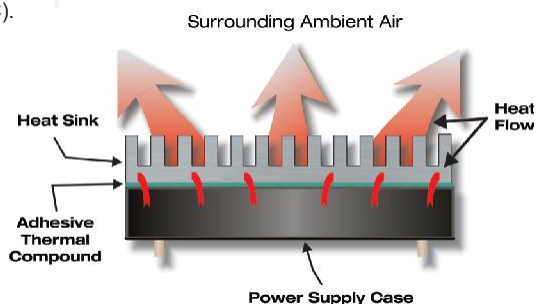


Figure 6 Conduction Cooling

See Cooling, Convection Cooling, Free Convection and Forced Air Cooling.

Conductor: A material that allows the easy flow of electricity, such as metals, electrolytes, etc. See Insulator.

Conformal Coating: A thin, insulating, coating applied to a finished printed circuit board assembly. It provides protection against environmental contaminants (dust, etc,).

Constant Current Load: An electronic load that maintains a constant current drain on a power supply.

Constant Current Power Supply: A power supply designed to regulate output current to within a specified range for changes in output load, input line and ambient temperature. Also called a constant current source.

Constant Voltage Power Supply: A power supply designed to regulate output voltage to within a specified range for changes in output load, input line and ambient temperature.

Continuous Shield: A packaging technique in which the power supply is placed into a metal case. The metal shielding minimizes noise radiation from the switching components of the power supply. A continuous shielded case has the base (or header) welded on, further reducing potential noise leakage. Also called Six-Sided Shielding.

Control Circuit: Circuit that controls certain operating parameters of the power supply. Used to maintain output regulation.

Control Loop: A feedback loop used to control a power supply output.

Convection Cooling: The transfer of heat via a fluid motion (typically air). In power subsystems this is normally accomplished by the forced movement of air over the power supply case and/or heat sink surface area. See Cooling, Conduction Cooling, Free Convection and Forced Air Cooling.

Converter (AC/DC): A device that accepts an ac line input voltage and produces a dc output(s). Often referred to as a "switcher" (although linear converters are available), switching regulated supplies are used in the majority of applications. AC/DC supplies are available in a variety of form factors, power levels and feature/performance envelopes.

Converter (DC/DC): A device that accepts a regulated or unregulated DC input voltage and produces a DCc output that is that is the same or possibly at a different voltage level. They are used to provide load isolation, noise isolation local regulation, etc.

Cooling: The transfer of heat dissipated by an operating power supply into the surrounding ambient air mass. See Convection Cooling and Conduction Cooling.

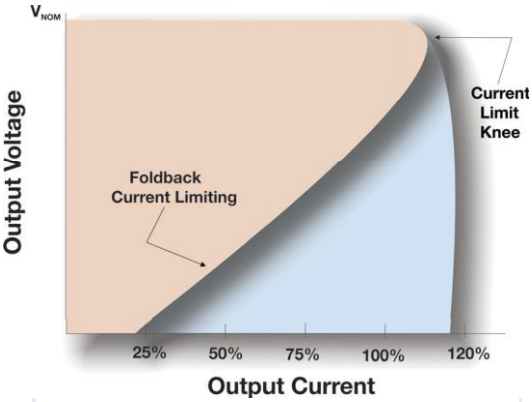
Core: The material that a transformer or an inductor is wound on. In many cases, the core consists of a type of magnetic material (iron, etc.) and provides a path for magnetic flux.

Core Loss: Power dissipated within the core of a transformer/inductor due to eddy currents or hysteresis. Adversely affects the efficiency of a power supply.

COS: For undistorted sinusoidal waveforms, COS is the shift in load current as compared to the ac mains voltage. Equal to the difference between apparent power and true power (for an undistorted sinusoidal waveform). See Apparent Power, and True Power.

Creepage Distance: The shortest distance between two conductors (typically, one primary, one secondary) measured along the surface of the insulation. See Clearance Distance.

Figure 7 Output Current Limiting



Crest Factor: For an ac waveform, the ratio of peak value to RMS value. If the waveform is pure sinusoidal, this value is 2. Crest factor was used to approximate the current stress in an AC mains circuit. Today, the use of power factor is more common. See Power Factor.

Crest Value: The maximum value of a waveform (excluding transients).

Coupling: See Capacitive Coupling.

Cross Coupling: Unwanted coupling between two circuits.

Cross Regulation: In a multiple output power supply, the change in voltage level on one output, caused by a load change on another output, expressed as a percentage.

Crowbar: A protection circuit that rapidly shuts down a power supply's output when a preset voltage level is exceeded. A crowbar circuit places a low resistance shunt across the output when an over voltage condition exists.

CFM: Cubic Feet per Minute is a common measure of the volume of air flowing in a system. The conversion of cubic feet per minute to linear feet per minute is dependent upon the cross-sectional area through which the air flows:

$$CFM = LFM \times Area$$

See Linear Feet per Minute.

Cuk Converter: A "buck-boost" converter variation that produces very low output ripple. Typically used in applications that do not require isolation. See Flyback Converter.

Current Foldback: An overload protection circuit that reduces the output current as the load approaches short circuit. This minimizes internal power dissipation under short circuit conditions. Also called Foldback Current Limiting.

Current Limiting: An overload protection circuit that limits the maximum power supply output current to a predetermined, safe value. See Current Limit Knee.

Current Limit Knee: The point at which current begins to foldback or limit on a plot of output voltage vs current. See Current Limiting, and Current Foldback.

Current Mode Control: A control method used with switching converter topologies. A dual loop control circuit adjusts the PWM operation in response to a measured output current.

Current Sensing Resistor: A resistor that is placed in series with the output load of a power supply. The voltage drop is used to measure load current.

Current Share: To increase system reliability or power, multiple power supplies are often used in parallel. When connected this way, the power supply outputs are strapped together and each unit supplies approximately equal "shares" of the load current. Current sharing can be controlled passively, by synchronizing multiple converters and trimming the outputs to within a tight margin; or actively with internal circuits to monitor and adjust output current. The most popular redundant topology is the "N+1" circuit. See Master/Slave, N+1 and Dual Redundant.

— D —

DC/AC Converter: See Inverter.

DC/DC Converter: See Converter (DC/DC).

DC OK Signal: See Power Good Signal.

Dead Circuit: A circuit that is electrically disabled.

Debugging: A process used to identify and eliminate the flaws in a circuit, process or machine .

Debugging Period: The period of time following the completion of a design during which problems and errors are identified and corrected.

Decay Time: The time required for a pulse to decrease from 90% to 10% of its maximum amplitude (either positive or negative).

Decibel: A decibel (dB) is the fundamental measurement unit used in EMI measurements. Given by the equation:

$$1\ dB = 10\log_{10}\frac{P_O}{P_I}$$

Where: P_O = Output Power
P_I = Input Power

Decoupling: To reduce system noise, it is often recommended that filter components (typically mF capacitors) be connected between the power terminals of the load in a power system. See Figure 8.

Decoupling Capacitor: A capacitor that helps prevent stray coupling between circuits in a system. Decoupling capacitors provide a low impedance path to ground.

Deep Discharge: A cell or battery discharge that is nearly complete. Sometimes a deep discharge is done just prior to recharging.

Density: See Power Density.

Derate: See Derating.

Derating: The reduction in output power, voltage or current required to operate a power supply in an environment beyond that typically specified. Normally used to characterize power supply operation

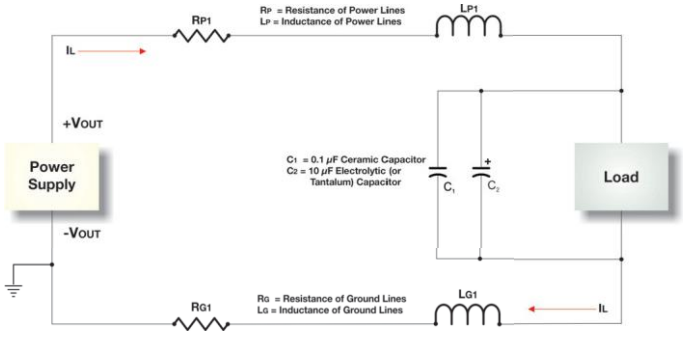


Figure 8 Power System Decoupling

at extended temperatures. See Cooling, Convection Cooling, Conduction Cooling, Forced Air Cooling and Free Convection.

Derating Curve: The curve or graph that illustrates the amount of derating required to operate a power supply in an abnormal environment.

Design Validation Test: (DVT) See Design Verification Test.

Design Verification Test: (DVT) A test program designed to ensure that the initial product design goals are achieved. Testing is done at various points in the development cycle and would include product functionality, reliability, EMC/EMI performance, mechanical conformance and environmental tests.

Designed To Meet: A term used when a circuit or product has been designed to fit the requirements of a safety or performance specification but has not actually been certified by an authorized testing facility.

Destructive Test: A test that destroys the unit under evaluation as part of the process. See Nondestructive Test.

Deutsches Institut fur Normung: (DIN) The German Institute for Standardization, it is the German national association for developing standards. They currently have upwards of thirty thousand standards covering a wide variety of technologies

Dielectric: A material that prevents two points in an electrical circuit from becoming conductively connected. At times referred to as a Dielectric **Barrier**. See Conductor.

Dielectric Breakdown: The sudden, destructive, conduction of current through a dielectric that occurs when the applied voltage exceeds the breakdown value. See Dielectric Withstand and Breakdown Voltage.

Dielectric Strength Test: See High Potential Test.

Dielectric Withstand Voltage: The maximum voltage an insulating material can withstand before suffering punch through or arcing across. See Break Down Voltage and High Potential Test.

Differential Mode Noise: The noise component measured between two circuit points with respect to a common point (minus common mode noise).

Differential Voltage: The difference in voltage levels measured between two points.

Dimmer: A circuit that will adjust the brightness of a lamp or LED.

DIN Rail: A metal rail upon which the user can mount a wide variety of available components (including power supplies). Available in a number of standard sizes, they are typically mounted inside a rack or cabinet.

DIN Rail Power Supply: A power supply that is physically designed to mount on a standard DIN rail. All connections are then made via a wiring harness. Some standard board or chassis mount power supplies offer "kits" that will adapt them for use with a DIN rail.

Direct Current: A current that flows in one direction. See Alternating Current.

Discrete Circuit: A circuit or subassembly comprised of discrete components (resistors, diodes, FETs, etc.) as opposed to an assembly comprised of integrated components.

Dissipation: See Internal Power Dissipation.

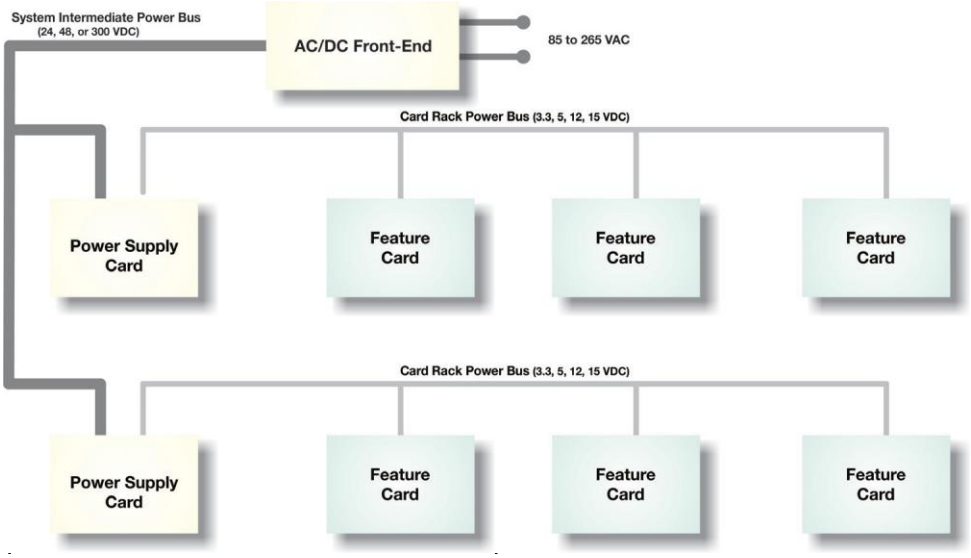


Figure 9 Distributed Power System

Distributed Power: A system level architecture in which a central supply or battery system powers an intermediate power bus (i.e. 24 or 48 VDC). The intermediate bus, routed throughout the system (normally via a backplane), provides the input power to a number of DC/DC converters. These converters in turn provide localized power (and various voltage levels) to individual sub-assemblies and components. The type of power distribution system used depends upon the requirements of a particular application.

Distributed-power Open Systems Alliance: (DOSA) Formed in 2004, DOSA is a global association working to insure compatibility and standardization in the DC/DC board mounted power conversion market. They have developed standards regarding form factors, footprints, pinouts, feature sets and other parameters.

Dominant Wavelength: (d) The wavelength (or color) of an LED as perceived by the human eye. Visible LEDs are typically specified by their dominant wavelength or color. Sometimes referred to as Hue Wavelength or Hue Sensation.

Double Insulation: An insulation barrier made up of two layers of different insulating materials on a conductor. See Basic Insulation, Reinforced Insulation and Supplementary Insulation.

Drift: With all operating parameters (load, line, etc.) held constant, the gradual (and undesirable) change in the output voltage of a power supply over a specified period of time. Typically specified as starting after a warm-up period.

Driver: See Master.

Drop Out Voltage: The minimum input voltage level required to operate a power supply to within specified operating limits.

Dual-In-line-Package: (DIP) Popular package footprint for low power DC/DC converter modules.

Dual-Redundant: A fully redundant power system topology. The circuit consists of two complete power supplies connected in parallel. Power supply #1 runs "hot", supplying all the load current, while power supply #2 runs "cool" (disconnected from the load via oring diodes). If the "hot" supply fails, the oring diodes reverse bias and power supply #2 starts to provide full load current. Dual redundant systems are expensive and not as flexible as other redundant approaches, but they do allow separate input power sources to be used. Sometimes referred to as a "100% Redundant" System. See Master/Slave and N+1.

Duty Cycle: For power supplies, the ratio of "on" time to "off" time of the semiconductor switch (in pulse width modulated "PWM" systems) or clock signal. In LED lighting systems a PWM input is often provided as a dimming control. The user controls the brightness of the LED by varying the duty cycle of a PWM wave.

Dynamic Load: An output load that changes rapidly. Normally specified as a load change value as well as a rate of change.

Dynamic Response: The output overshoot that occurs when the output load of a power supply is either cycled on/off or abruptly changed. This overshoot gives the high frequency output impedance of the power supply. See Output Impedance.

— E —

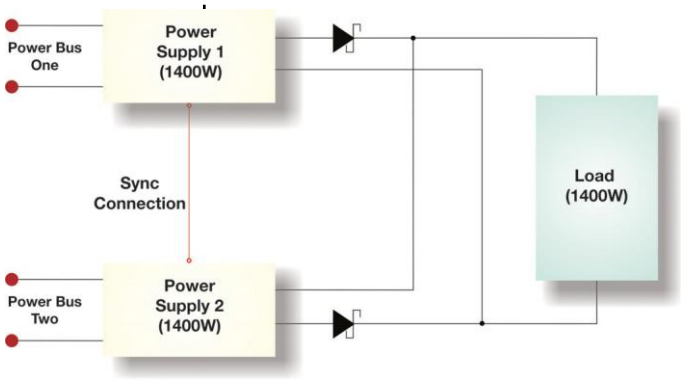
Early-Failure Period: The time period immediately following the production of a product, during which failures may occur due to production errors, equipment failures and/or process issues. See Infant Mortality.

Earth: See Ground.

Earth Leakage Current: See Leakage Current.

Edge Connector: Part of a printed circuit board (PCB) that has traces etched out to an edge that has been formed to fit into a matching socket.

Figure 10 Dual Redundant Power System



Eddy Current: A circulating current induced by variations in a magnetic field.

Eddy Current Loss: The energy losses in a system/component due to eddy currents.

Effective Current: See Effective Value.

Effective Value; (I_{EFF}) The value of an alternating waveform that has an effect on a resistance that is the same as an equivalent value of DC voltage or current. The effective value equals the RMS (Root Mean Square) value. For sine waves this equals:

$$X_{EFF} = \sqrt{2} \times \text{Peak Value}$$

If the maximum current (I_{MAX}) or voltage (V_{MAX}) of the waveform is known, the effective value can be determined by:

$$X_{EFF} = 0.707 \times I_{MAX} \text{ (or } V_{MAX})$$

Effective Voltage: See Effective Value.

Efficiency (r): The ratio of total output power to input power expressed as a percentage. Expressed as a percentage, efficiency is derived by the equation:

$$r\ (\%) = \frac{P_O}{P_I} \times 100$$

Where: r = Efficiency
P_O = Output Power
P_I = Input Power

Efficiency may vary under differing operating conditions, and is normally specified at full rated output power, nominal input line conditions and +25°C. Efficiency has become an increasingly important power supply specification with the rising demand for higher power density systems.

Eighth Brick: A packaging standard for DC/DC converters. Its dimensions are 2.3 x 0.9 inches (57.9 x 22.8 mm). Other established package standards include full, ½, ¼, and 1/16 bricks.

Elastance: (F^{-1}) The opposition of a capacitor to being charged. It's the reciprocal of the Farad and is expressed by the unit "daraf". It is typically referred to as "reciprocal farad".

Electrode: A terminal used to conduct electricity or to which electricity is applied. A positive electrode is typically called an Anode and a negative electrode is typically called a Cathode.

Electrolysis: The process of passing a direct current through an electrolyte, producing a chemical change in the solution and the electrodes.

Electrolyte: A substance that ionizes when dissolved in an ionizing solution. If electrodes are placed into the electrolyte and a voltage is applied, the electrolyte will conduct electricity.

Electrolytic Cell: See Electrolytic Capacitor.

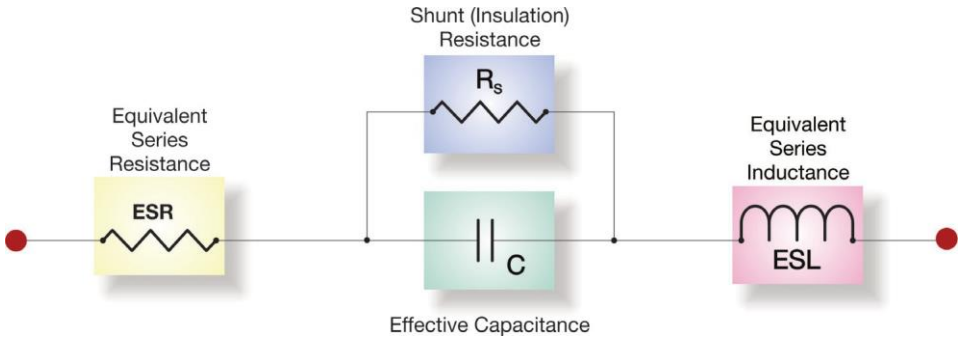
Electrolytic Capacitor: A type of capacitor used in power supplies that consists of two plates (or electrodes) separated by an electrolyte.

Electromagnet: A magnet that uses an electric current to produce a magnetic field. Simply, an insulated coil of wire is wound around a core of ferromagnetic material (such as iron). The strength of the feild can be varied by changing the amount of current in the winding.

Electromagnetic Compatibility: (EMC) Power supplies and systems must be designed to operate within their intended environment without interfering with other components, and without being adversely affected by other components. EMC is divided into two main areas: electromagnetic interference (EMI) and electromagnetic susceptibility (EMS).

Electromagnetic Interference:(EMI) Conducted EMI - Noise generated by a power supply (typically by the switching action of the more

Figure 11 ESL and ESR



popular power conversion topologies) and reflected back onto the input power bus. Improved design techniques (such the use of PFC) have reduced this issue. Acceptable limits for conducted EMI are set by various agencies (FCC, IEC, etc).

Radiated EMI - Noise generated by a power supply that is emitted into the area surrounding a power system. Radiated EMI, consisting of broadband radio frequencies and narrow band emissions is also limited by various agencies (IEC, VDE, etc.). Typically, it is controlled by shielding.

Electromagnetic Susceptibility: (EMS) The tolerance of a power supply, circuit or system to electromagnetic energy that could cause a degradation in performance or failure. Sometimes called Electromagnetic Vulnerability.

Electromechanical: Describes a mechanical device or process that is controlled electrically.

Electronic Breadboard: A board or card that has prepunched holes that allow the quick assembly of electronic circuits. Used to test and evaluate circuits during the development or improvement of products.

Electronic Industries Alliance: (EIA) An industry standards and trade association. Started in 1924, it ceased operations in 2011, splitting into its six divisions. These are the Electronic Components, Assemblies; Equipment & Supplies Association (ECA); the JEDEC Solid State Technology Association (JEDEC once called Joint Electron Devices Engineering Councils); the Government Electronics and Information Technology Association (GEIA); the Telecommunications Industry Association (TIA); and the Consumer Electronics Association (CEA).

Electronic Load: Test equipment which will draw precise current or power levels from a power supply. Often used as part of an ATE setup. See Automated Test Equipment.

Electrostatic Shield: See Faraday Shield.

Electrostatic Discharge: (ESD) Current produced by two objects having a static charge when they are brought close enough to produce an arc or discharge.

Enable: A signal that can turn a power supply on. Often specified as part of a remote ON/Off control capability. See Inhibit and Logic Inhibit/Enable.

Encapsulant: A material into components, or circuits are embedded. Typically a synthetic epoxy resin is used for modular power supplies. Often called Potting Compound.

Encapsulation: The process of embedding a circuit or component into an epoxy resin. The epoxy is typically applied as a thick liquid which is then cured (allowed to solidify) by air or by heating it. Great care must be taken to remove voids, to not to stress components (such as windings, glass diodes, etc) and to insure the epoxy fully cures. Once cured, the epoxy protects the circuitry from the surrounding environment, provides mechanical stability, insulation and helps to draw heat away from internal components to the outer case. Also called Potting.

Enclosure: The case/container used to package a power supply. Enclosures, which range from small plastic shells to sophisticated metal cases, protect internal components from the outside environment; provide mechanical stability and in some applications improve thermal and noise performance. See Open Frame and L-Frame.

Energy Loss: See Power Loss.

Energy Storage Device: See Capacitor.

Environmental Factors: Characteristics of the area immediately surrounding a power supply or system that might affect performance. These might include temperature, moisture, electrical noise or vibration.

Epoxy Resin: See Encapsulent.

Equivalent Series Inductance: (ESL) The inductance in series with an "ideal" capacitor. ESL sources include terminals, electrodes etc.

Equivalent Series Resistance: (ESR) The resistance in series with an "ideal" capacitor. ESR sources include lead resistance, terminal losses, etc. It's an important specification for high frequency applications.

Error Amplifier: An amplifier used in the control feedback loop of a power supply. It produces an error voltage when the sensed output (tapped off a voltage divider network) differs from a reference voltage. The error voltage adjusts the PWM operation to correct the sensed output voltage. Sometimes called a Reference Amplifier.

Eye Sensitivity: A curve depicting the sensitivity of the human eye as a function of wavelength (color).

— F —

Failure: The state or condition wherein a power converter is not operating correctly or not operating at all

Failure Analysis: The process of determining the mode or cause for the failure of a power converter.

Failure Mode: The reason a power supply or system either does not meet or stops meeting specified parameters.

Failure Rate: (**λ**) As used in reliability engineering, it is the rate at which a system, product or component fails, expressed in failures per unit of time. In actual practice, the mean time between failure (MTBF) of a product is typically used instead of failure rate. See Mean Time Between Failure.

Fan Cooled: See Forced Air Cooling.

Farad: (F) The basic unit of capacitance. When a charge of 1V per second across a capacitor produces a current of 1A; that capacitor has a capacitance of 1F.

Faraday Shield: An electrostatic shield that reduces coupling capacitance in transformers. The shield, which reduces output common mode noise, is placed between the primary and secondary windings of a transformer.

Fatigue: The degradation of a component or circuit over time or under repeated stress.

Fault: A device, circuit or component failure.

Fault Mode Input Current: The input current (typically a momentary surge) drawn by a power supply when the output is shorted.

Fault Tolerant: A power system configuration optimized for continuing operation without shutdown. Typically involves the use of a redundant topology (i.e. N+1, etc.) and the ability to remove and replace power modules without disturbing system operation (hot-plug capability). Thus, the failure of any one power module will not cause a system failure.

Federal Communications Commission: (FCC) A US government agency that sets standards for, and governs the testing of conducted and radiated emissions. These are system level standards, but they are often used in specifying power supplies. See Electromagnetic Interference (EMC).

Feedback: The process of returning part of the output signal of a power supply to its input, where it is used to control or regulate the output.

Feed Forward: A method of improving line regulation by directly sensing the input voltage of the power converter. See Line Regulation.

Ferrite: A ceramic compound composed of iron oxide combined chemically with one or more additional metallic elements. Soft ferrite's used in transformer/electromagnetic cores contain oxides or carbonites of metals such as zinc, nickel or manganese. They have low losses at high frequencies and are used extensively in switching power supplies.

Ferrite Bead: A small ring of ferrite that is slipped over a wire or cable to reduce or eliminate radio-frequency noise.

Ferroresonant Transformer: A transformer in which part of the core is driven into saturation by a resonant tank circuit. The output of the transformer, taken from the saturated portion, is relatively immune to variations in input voltage. Used in ferroresonant power supplies.

Field Angle: Similar to "Beam Angle", but given at a point where the luminous intensity is 10% of the center beam intensity. See Beam Angle.

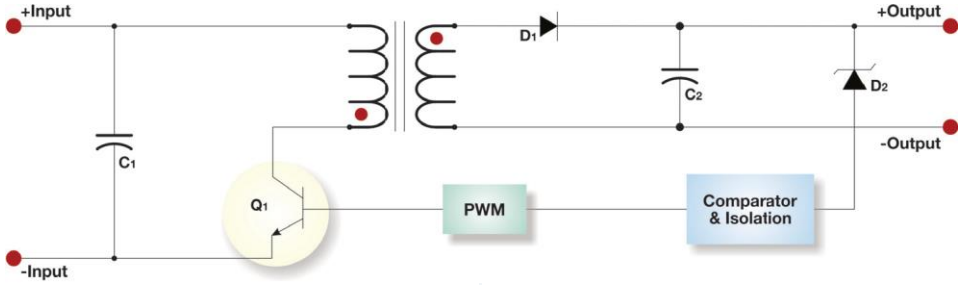
Field Effect Transistor: (FET) A transistor that uses a high impedance gate to control the flow of current through a thin "channel" of semiconductor material (typically silicon). FETs have four connections, gate, source, drain and body. A voltage applied to the gate regulates the conductivity (via an electric field) of the channel. A depletion FET is normally OFF and an enhancement FET is normally ON.

Filter: A circuit that passes one frequency or band of frequencies while blocking others. See Input Line Filter, Common Mode Filter, Pi Filter and Output Filter.

Filter Capacitor: A common component in power supply circuits, filter capacitors are used to pass AC noise to ground. They are typically connected across the input/output of a supply.

Filter Inductor: A common component in power supply circuits, inductors are used to block AC noise. They are typically connected in series with the power line being filtered. They are often used with capacitors to form an LC, Pi or T filter.

Figure 12 Simplified Flyback Converter



Finned Surface: This refers to "fins" added to a heat sink. The fins increase the surface area of the heat sink, thus increasing its effectiveness.

Fixed-Frequency: For a power supply, this typically refers to the switching frequency of the unit. For many power supplies, the switching frequency will vary with changes in the load. A "fixed frequency" supply will operate over a wide range of load conditions with little or no change.

Flag Signal: A status or alarm signal generated by a power system. Often displayed as a front panel LED or provided as output logic signals (normally TTL/CMOS compatible). Typical signals would indicate "Power Good", "Power On", "Over temperature", etc.

Floating Output: A power supply output that is ungrounded and not referenced to another output. Typically, floating outputs are fully isolated and may be referenced positive or negative by the user. Outputs that are not floating share a common return and as such, are referenced to one another.

Flyback: The voltage spike that occurs across an inductive load when the supply voltage is reduced suddenly or removed. See Flyback Diode.

Flyback Converter: Sometimes called a "buck-boost" converter, this topology minimizes the required components by using a single transistor switch and eliminating the need for an output inductor. During the first half of the switching period, when the transistor switch is "ON", energy is stored in the transformer primary. During the second half or "flyback" period when the switch is "OFF", this energy is transferred to the transformer secondary and load. This technique is cost effective because of the minimum number of components required. See Boost Regulator, Buck Regulator, Bridge Converter, Forward Converter, Push Pull Converter and Resonant Converter.

Flyback Diode: A diode connected across the transformer secondary to reduce voltage spikes caused by the switching action of the power transformer. Sometimes referred to as a Snubber Diode, Freewheeling Diode, Suppressor Diode, Clamp Diode or Catch Diode.

Foldback Current: See Current Limiting and Current Limit Knee.

Foot-candle: The illumination on a one square foot surface set one foot from a one candela light source. Equal to one lumen per square foot.

Forced Air Cooling: The use of a fan (or other air moving equipment) within a (sub)system to move air across heat producing components in order to reduce the ambient temperature. See Convection Cooling, Free Convection and Forced Convection.

Forced Convection: An operating environment in which air movement induced by a fan, blower, etc. is used to maintain power modules within operating limits. See Convection Cooling, Free Convection and Forced Air Cooling.

Forward Converter: Like the flyback circuit, a forward converter uses a single transistor switch. However, in the forward converter, energy is transferred to the transformer secondary while the transistor switch is "ON", and stored in an output inductor. Also called a Buck-Derived converter. See Boost Regulator, Buck Regulator, Bridge Converter, Flyback Converter, Push Pull Converter and Resonant Converter.

FR-4: A grade designation for laminate sheets used to produce printed circuit boards. FR-4 is a fire resistant, composite material consisting of woven fiberglass cloth with an epoxy resin binder. See Printed Circuit Board.

Free Convection: An operating environment in which the natural movement of air (unassisted by fans or blowers) is sufficient to maintain the power module within its' operating limits. Also called Natural Convection. See Convection Cooling, Forced Air Cooling and Forced Convection.

Free Wheel Diode: See Flyback Diode.

Forward Current: (IF) The current that flows through a semiconductor junction (such as an LED) when it is forward biased.

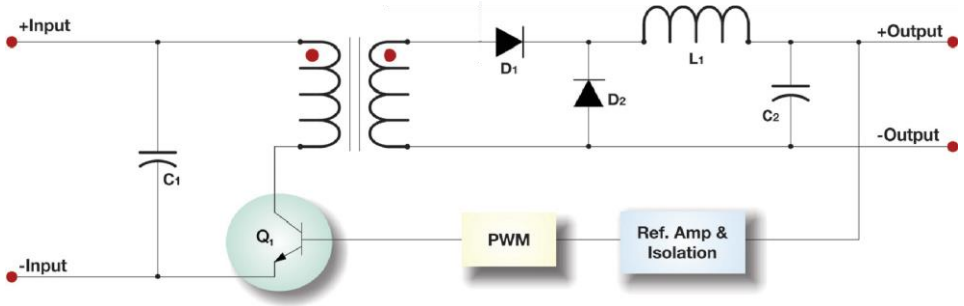
Forward Voltage: (VF) The voltage drop across a semiconductor junction (such as an LED) when it is forward biased.

Frequency of Operation: See Switching Frequency.

Front End: See AC Front End.

Full Brick Converter: A standard package size for high power density DC/DC converters. A full brick typically measures about 4.6 x 2.4 Inches (116.84 x 60.96 mm). There is some variance between manufacturers. Other established package standards include ½, ¼, ⅛, and 1⁄16 bricks.

Figure 13 Simplified Forward Converter



Full Bridge Converter: A power supply topology, typically configured as a forward converter, that uses a bridge circuit, consisting of four switching transistors, to drive the transformer primary. See Bridge Converter.

Full Load: The maximum value of output load specified for a converter under continuous operating conditions.

Full-load Current: The output current from a source when the load is maximum (that is, the load resistance is minimum).

Full Load Power: The power drawn from a supply when it is operating at maximum rated load.

Full Load Voltage: The output voltage of a supply when it is operating at maximum load.

Full Wave Rectifier: A circuit (bridged or center tapped) that rectifies both halves of an ac waveform.

Fuse: A circuit protection device, consisting primarily of a low melting point wire. If current passing through the wire exceeds a set level (as in the case of a fault condition), the wire melts and the circuit opens.

Fusible Resistor: A resistor used to protect all, or parts of a circuit. The resistor (typically low value) will open up if it's current rating is exceeded.

— G —

Gate: A circuit or component that has no output until it is triggered by a control signal (or level).

Galvanic Isolation: Two circuits which have no significant ohmic connection are "galvanically isolated" from each other. Galvanic isolation (separation) is achieved by using a transformer, opto-coupler, etc.

Gauge: An instrument or device used to measure the magnitude of a circuit parameter. Also used to describe the standard thickness of wire. See Wire Gauge.

Generator: A piece of equipment that produces electricity.

Go-No-Go Test: A test that indicates only pass or fail. No other information is provided.

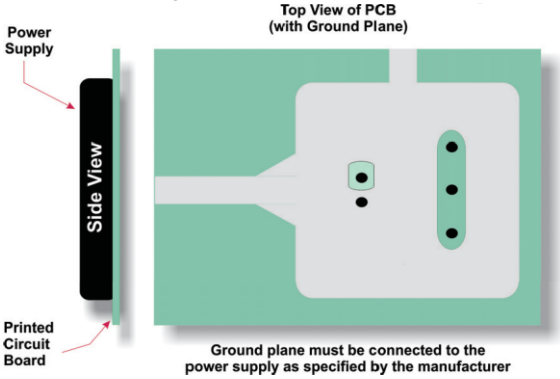
Gram: (g) A unit of mass a weight. It is equal to 0.001 kilogram or 0.0353 ounce

Ground: An electrical connection that is made to earth (or a conductor that is connected to earth). A power converter "common" is not actually ground unless it is somehow connected to earth. See Common.

Ground Bus: A grounded conductor or circuit trace to which various system components are connected.

Ground Connection: A low resistance connection to earth.

Figure 14 Ground Plane



Ground Fault: Circuit failure caused by the loss of a ground connection.

Ground Loop: When two or more system components share a common ground line, a feedback (ground) loop is induced. This can cause unwanted voltage levels within the system.

Ground Noise: Circuit noise caused by a faulty ground connection.

Ground Plane: A conductive pad on the printed circuit board, set at ground potential, upon which a power supply is mounted. Shields system components from possible RFI noise generated by the supply.

Ground Potential: Potential of the ground point in a circuit as referenced to other circuit voltage levels.

Ground Resistance: The DC resistance of a connection to ground or earth.

Ground Return: The circuit point or path used as a return to ground either to compete a circuit, or for safety.

— H —

Half Brick Converter: (½ Brick) A standard package size for high power density DC/DC converters. A half brick typically measures about 2.4 x 2.3 Inches (61 x 58 mm). There is some variance between manufacturers. Other established package standards include full, ¼, ⅛, and 1/16 bricks.

Half-Cycle: One half (180° of phase) of a complete AC wave.

Half Bridge Converter: A power supply topology that uses a bridge circuit, consisting of two switching transistors, to drive the transformer primary. Half bridge converters are typically configured as a forward converter. See Bridge Converter.

Half Wave Rectifier: A single diode circuit that rectifies one half of an AC waveform.

Hardware: The mechanical & electromechanical components of a circuit or system.

Harmonic: (H) A component whose frequency is an integer frequency of the fundamental system frequency. For power supplies, harmonics are caused by nonlinear loads. See Harmonic Distortion.

Harmonic Distortion: For sinusoidal AC current waveforms, the load current distortion caused by the presence of multiple harmonics of the fundamental frequency (the frequency of the AC mains voltage).

Head Room: For a series pass regulator, refers to the difference between the input and output voltages.

Heat: A form of energy that is transferred between two bodies having different temperatures. The transfer (from a hot body to a cooler one) is done by conduction, convection, or radiation. The amount of heat transferred is expressed in degrees, British thermal units (BTU's), calories, joules, or kelvins

Heat Aging: See Burn In.

Heat Exchanger: A device or system that draws heat from a hot component and transfers it to another component or into the surrounding air. See Heat Sink.

Heat Flux: The flow rate of heat across or through a material. Given in units of W/cm^2.

Heat Loss: Power lost as a result of heat dissipation in a power supply.

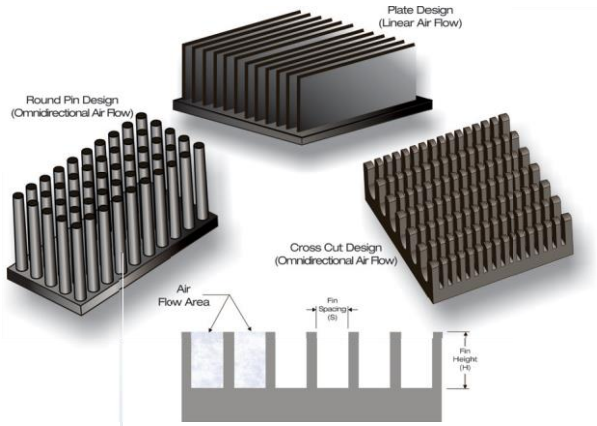


Figure 15 Heat Sinks

Heat Rise: The increase in component/subassembly temperature caused by self-heating or heat absorption.

Heat Sink: A metal extrusion plate etc used to transfer heat away from sensitive components or circuits. See Baseplate.

Heat Sink Resistance: The resistance to heat flow within a heat sink.

Heat Sink Temperature: The average temperature of a heat sink attached to a power system component during normal operation. Under typical operating conditions, heat sink temperature will be lower than the component case (or baseplate) temperature.

Heat Transfer: The movement of heat from one part of a system or circuit to another. The transfer is typically made by conduction, convection, or radiation.

Henry: (H). The standard unit of inductance. The inductance of a circuit is one Henry when 1V is produced by a current that is changing at 1 A/S. Typical values of inductance used in circuitry are micro henry (μH) and millihenry (mH).

Hertz: (Hz) The standard unit of frequency. The Hz is equivalent to cycles per second. One Hertz is equal to 1 cycle per second.

Hiccup Mode: An operating mode in which an output fault condition (short-circuit) causes the power supply to cycle on and off. The duty cycle of the on/off cycle is set to maintain the internal power dissipation at a safe level until the fault condition is corrected.

High Line: The maximum input line voltage specified for normal power supply operation. See also Low Line and Input Voltage Range.

High Potential Test: (Hipot Test) A test that determines whether a power supply passes its minimum break down voltage specification. See Breakdown Voltage.

Highly Accelerated Life Testing: (HALT) A process in which a product is stressed by a variety of environmental factors (temperature cycling, power cycling, vibration. etc). Stresses are applied until the product fails. The product is repaired and the testing continues until the stress levels are significantly beyond what the product is expected to see in actual use. The HALT process is used to identify design defects before a product is released.

Highly Accelerated Stress Screening: (HASS) A process in which a product is stressed by a variety of environmental factors. Unlike HALT testing, the stresses are over the specified limits of a product, but within the safe operating limits of the design (product life is not reduced). HASS testing is used to identify potential problems with product design and/or production. It is applied to 100% of production.

Hipot Test: Abbreviation for High Potential Test.

Hold-up Capacitor: A capacitor on the input of a distributed power system. The hold-up capacitor will maintain or "hold-up" the input voltage to the power system in the event a fault causes a loss of the input bus voltage. The capacitor has to be selected to have sufficient capacity to maintain the input until the fault condition is removed (typically the time required for a fuse to blow).

Hold-Up Time: Following a loss of input power, the period of time an AC/DC power supply output will remain operating to within specification.

Hot Line: The line or bus that provides the AC current to a circuit. See Ground and Neutral Line.

Hot-Plug: A fault tolerant feature that allows power supplies to be inserted or removed from a system while it is powered and operating. Power supplies must be specifically designed for this feature to avoid causing damage to the power supply or disturbing other modules and sub-assemblies connected to the system power bus.

Hot-Swap: See Hot-Plug.

Hybrid: See Hybrid Circuit.

Hybrid Circuit: A circuit in which two or more dissimilar technologies are used.

Hysteresis: The tendency of a magnetic material that is subjected to an alternating magnetic field, to saturate and retain some of its magnetism when the field reverses polarity.

Hysteresis Loss: The power loss caused by hysteresis in a magnetic material exposed to an alternating magnetic field. The loss (as heat) depends upon the volume & grade of the core, the frequency of the magnetic field and the value of flux density.

— I —

IGBT Driver: A hybrid component used to simplify the design and control of high power IGBT circuits. Typically they include circuitry to control the gate drive; provide safety circuits; isolate power sources; and optimize circuit timing.

Impedance: The total opposition offered by a circuit/component to the flow of ac current.

Incoming Inspection: The examination and testing of components and materials as they are received. In this way, faulty components can be identified and separated before reaching production.

In-Circuit Tester: A test system that allows components to be tested without removing them from the circuit in which they are wired.

Inductance: An electrical property that opposes the flow of current in a circuit when a voltage is applied (or a change in an established current). It is measured in Henries.

Inductive Load: A load that is inductive in nature, such as electric motors.

Inductor: A coil or winding with inductive properties.

Inhibit Signal: A signal that can shut a power supply off. Often specified as part of a remote ON/Off control capability. See Logic Inhibit/Enable.

Input Capacitor: The first capacitor in a capacitor-input filter.

Input Current: The current drawn from the input power bus by a power converter when operating under nominal conditions.

Input Line Filter: A low-pass or band-reject filter on the power supply input (internal or external) that attenuates noise from the system power bus. See Common Mode Filter, Filter and Pi Filter.

Input/Output Isolation: See Isolation.

Input Power: (Pi) The power present at the input to a circuit or component.

Input Protection: A component or circuit that protects the input of the power supply from damage in the event a fault occurs on the input bus (surge, transients, short, etc). Protection circuits can range from a simple fuse to a full EMC/protection module.

Input Reflected Ripple Current: The AC component (typically generated by the switching circuit) measured at the input of a power supply. Given as a peak to peak or rms value.

Input Surge Current: See Inrush Current.

Input Transient: A spike in the input line to a power supply. Input circuits/components are used to absorb or clip transients, shielding sensitive components from possible damage.

Input Voltage Range: The minimum and maximum input voltage limits within which a power supply will operate within specifications. For DC/DC converters, it is typically given as a percentage or ratio of high line to low line (i.e. a range of 18 VDC to 36 VDC is 2:1 and a range of 9 VDC to 36 VDC is 4:1). For operation in railway systems and PV systems, much wider ranges are available. For AC/DC power supplies, operation in Europe and North America requires an input range that accepts nominal levels of 110 VAC & 220 VAC and it is normally specified as "universal" (90 VAC to 264 VAC), auto-ranging or user selectable. Some supplies now have inputs that accept up to 305 VAC for use with a 277 VAC bus.

Inrush Current: At turn on, the maximum, instantaneous input current drawn by a power supply. Also called Input Surge Current.

Inrush Current Limiting: A protection circuit that limits the current a power system draws at turn on.

Insulated Gate Bipolar Transistor: (IGBT) The IGBT combines features of the bipolar transistor (BJT) and the metal oxide field effect transistor (MOSFET). It has the voltage controlled gate drive of the MOSFET and the high current conduction channel of the BJT. This combination has made the IGBT the preferred device for high power switching applications.

Insulation: A non-conductive material used to protect & separate electronic components or circuits.

Insulation Breakdown: The rupture or breech of an insulating material due to high voltage stress, that allows the flow of current.

Insulation Resistance: The resistance offered by an insulating material to current flow.

Insulator: A material that stops the flow of electricity.

Internal Power Dissipation: The power dissipated as heat within the power supply during normal operation. Primarily a function of the power handling capability and efficiency of the power supply. Internal power dissipation is normally given as a maximum specification that cannot be exceeded without risking damage to the power supply.

International Commission on Illumination: (CIE) The international standardization body on light, lighting, illumination, color, and image technology. Established in 1913, it based in Vienna, Austria

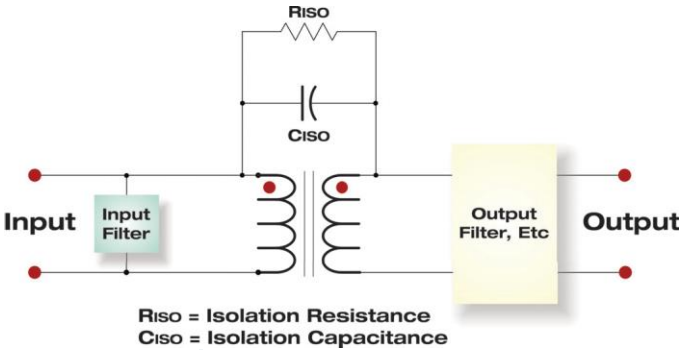


Figure 16 Isolation

International Electrotechnical Commission: (I.E.C) An organization based in Switzerland that sets standards for electronic products and components. IEC does not conduct any testing, however, their standards have been adopted by many of the national safety/standards agencies.

International Organization for Standards: (I.S.O.) Established in 1947, the I.S.O is a worldwide federation of standards bodies that works to promote the harmonization of international standards. Thousands of companies now comply with ISO 9000 and ISO 14000 standards.

Inverter: A circuit that converts DC power to AC power.

Iluminance: A measure of the intensity of light on a surface. Measured in foot-candles or lux, it is inversely proportional to area.

Isolated Output: See Floating Output.

Isolating Diode: A diode used to pass a signal or voltage level in one direction, but block them from the other direction.

Isolation: The electrical separation between the input and output of a power converter. Normally determined by transformer characteristics and component spacing, isolation is specified in values of VDC for DC/DC converters and VAC for AC power supplies. Isolation resistance (typically megohms) and capacitance (typically picofarads) are also common specifications.

Isolation Voltage: The maximum voltage (ac or dc) that can be continuously applied between isolated circuits without a breakdown occurring. For power supplies, it is normally specified as input-output or input-case isolation. Minimum isolation voltage levels must be maintained to meet most safety regulations. Typical isolation levels range from 1 kV for low power DC/DC's to 3 kVAC for AC power supplies. See Breakdown Voltage, High Potential Test and Isolation.

— J —

Joule: (J) The standard unit of work or energy. It is equal to the work performed by a force of one newton when its point of application is moved a distance of one meter in the direction of the applied force.

Joule Effect: The heat released by a current flowing through a resistance. Also called Resistive Heating or Ohmic Heating.

Joule's Law: The rate at which current flowing in a constant-resistance circuit produces heat is proportional to the square of the current.

Jumper: A piece of wire (typically flexible & insulated) used to temporarily connect two points in a circuit.

Junction Diode: A semiconductor diode created by forming a P-N junction. The diode will conduct in one direction.

Junction Field Effect Transistor: (JFET) See Field Effect Transistor.

— K —

Kelvin: (K) The standard unit of thermodynamic temperature. The kelvin is based upon an absolute thermodynamic temperature scale with a null point of absolute zero. It's defined as 1/273.16 of the thermodynamic temperature of the triple point of water (0.01 °C or 32.018 °F)

Kirchhoff's First Law: In a DC circuit, the sum of the currents flowing out of a point will equal the sum of the currents flowing into that point.

Kirchhoff's Second Law: In a DC circuit, the algebraic sum of all the voltage drops around the circuit (including supply voltages) is always equal to zero.

— L —

L-C Filter: A low pass filter consisting of a series inductor followed by a shunt capacitor. Often used as an input filter in low power converters.

L-Frame: A type of power supply construction in which the assembled power unit is mounted onto an "L" shaped metal frame (see Figure 18). This frame is used as heat sinking for critical components and gives mechanical stability to the entire power supply assembly. In the application, the L-frame is typically attached directly to the users equipment chassis. See Open Frame and Enclosure.

Lagging Load: An inductive load (current lags voltage).

Lamp: A device that converts electrical energy into visible light. Many different types of lamps are available including, incandescent, fluorescent and neon. Increasing lamps consisting of LED arrays are being used. See LED.

Lead Frame: A metal frame that holds the pins or components of a power supply in place during encapsulation (after which it is cut away). Very common in the manufacture of semiconductors, lead frames are now used on low power DC/DC converters. Also called a Pin Frame.

Leading Load: A capacitive load (current leads voltage).

Leakage Current: At a set voltage level, the current flowing from input to output or input to case of an isolated power supply. For an ac input power supply, the current that flows from the primary circuit to earth ground. Excessive leakage current may pose a hazard to system operators if the earth ground is disconnected. For this reason, safety agencies regulate allowable levels of leakage current.

LED: (Light Emitting Diode) A diode that emits photons (as light) when forward biased.

LED Driver: A power supply with a constant current output. LED's are current controlled semiconductors and most power supplies have voltage controlled outputs. There are an increasing number of constant current power sources available specifically designed to power LED arrays.

LED Strip: LEDs that are attached to a flexible PC board up to about 16 feet long and put on reels. The user can then trim the strip to the size required.

Life: The time period over which electronic components, equipment or systems will operate before they fail.

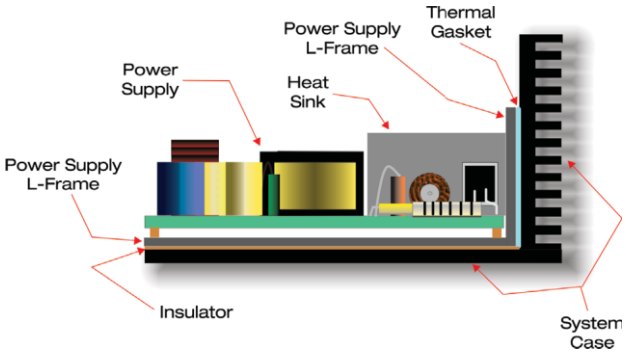


Figure 17 L-Frame Construction

Life Test: A power supply reliability test in which units are operated (typically under accelerated conditions) over some period of time in order to approximate life expectancy.

Light Load: A power supply load that is a small fraction of its normal level.

Limit: The lowest or highest level of a power supply specification. Often refers to specification levels that could potentially damage a power supply if exceeded.

Line: Bus used to deliver power to the input (terminals, pins, etc.) of a power supply. See Bus, High Line, Mains and Low Line.

Line Cord: A two or three wire insulated conductor used to connect equipment to the power line.

Line Current: The ac input current to a power system, taken off the mains.

Line Drop: The voltage drop across a line supplying power to a component or system.

Line Effect: See Line Regulation.

Line Frequency Regulation: The change in output voltage caused by a variation in input line frequency, all other factors remaining constant. In switching and linear power supplies, this is not significant, but it is an important specification in ferroresonant power supplies.

Line Regulation: The change in output voltage caused by varying the input voltage over a specified range (with output load, temperature, etc remaining constant), expressed as a percentage.

Line Transient: See Input Transient.

Line Voltage: The ac input voltage to a power system, taken off the mains.

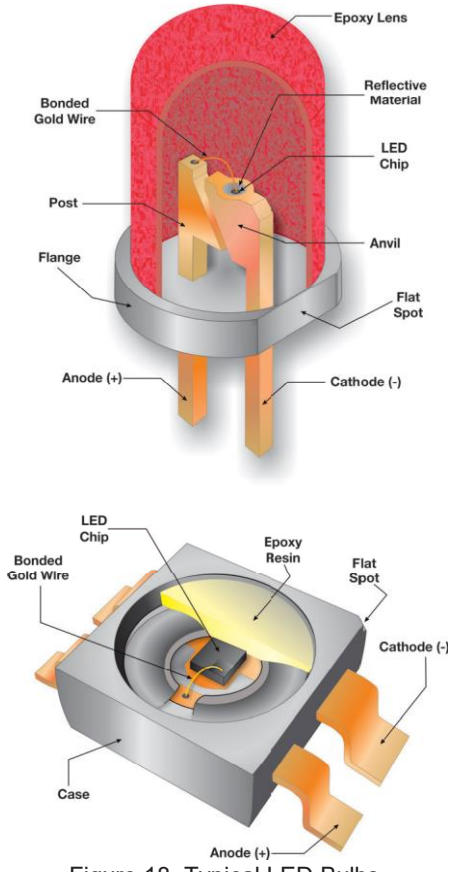


Figure 18 Typical LED Bulbs

Linear Feet per Minute: (LFM) A measure of the velocity of air. Often used in power systems to give the air flow over a baseplate or heatsink surface area required to meet specified operation. LFM is equal to:

m/s multiplied by 196.8

Where: m/s = meters per second

Linear Power Supply: A power supply that uses linear regulation. Linear's provide excellent regulation, low output noise and fast transient response. However, they are typically much heavier, larger and less efficient then "switchers", which are now much more popular. See Switchers.

Linear Regulation: A regulation technique in which the regulating device (typically a transistor) is placed in series or parallel with the load. Voltage variations across the load are then controlled by changing the effective resistance of the regulating device to dissipate unused power. See Series Regulator, Shunt Regulator and Post Regulation.

Linear Regulator: A voltage regulator that utilizes a transistor or other device (zenor diode, etc) to control the output voltage. This method is inherently inefficient, as the regulating component is dropping the difference between the input voltage and the regulated output voltage. For low power applications, this power loss may not be significant, and in these cases linear regulators can be a cost effective solution. See Linear Regulation, Switching Regulation, Switching Regulator.

Line Filter: A circuit that is put on the input lines to a power supply to suppress noise and interference. Line filters can range from simple Pi or LC filters to more complex circuits that meet EMC/EMI standards.

Line Noise: Random fluctuations (noise) on the input line to a power supply. See Line Filter.

Live: A wire, circuit trace, etc that is connected to a power source and has a potential that is different than earth ground.

Load: The electronic components or circuitry powered by a power system. The load characteristics (resistance, reactance, etc) determine the amount of power drawn from the power supply.

Load Capacitance: The capacitance present in the output load of a power supply. Most power supplies are tested & specified for the maximum capacitive load that they can drive. Adding too much capacitance to the load circuit of a power supply could cause start up issues. At start up, load capacitors draw high current levels as they charge. If it this current level is too high or if it takes too long to charge, the over current protection (built into most power supplies) could trip; shutting the unit down.

Load Decoupling: See Decoupling.

Load Effect: See Load Regulation.

Load Regulation: The change in output voltage caused by varying the output load over a specified range (with input line, temperature, etc. remaining constant). It is expressed as a percentage.

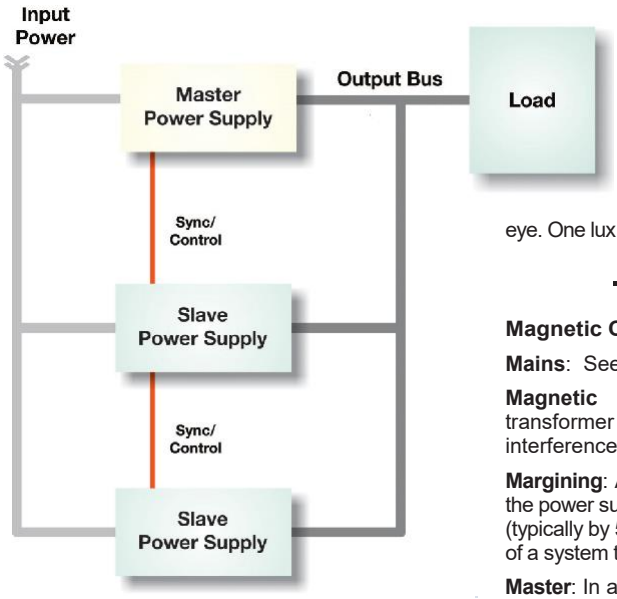


Figure 19 Simplified Master Slave Connection

Load Sharing: See Current Sharing.

Local Sensing: Using the output terminals of the power supply to provide feedback to voltage regulation circuits. See Remote Sensing.

Logic Inhibit/Enable: A signal (typically TTL/CMOS compatible) used to turn a power supply output on/off. Also called a Remote On/Off.

Long Term Stability: The change, over time, in the output voltage of a power supply with all other factors (line, load, temp, etc.) remaining constant, expressed as a percentage. This output change is primarily due to component aging.

Low Line: The minimum input line voltage specified for normal power supply operation. See High Line and Input Voltage Range.

Low Voltage Directive: (LVD) An EU directive that covers all electrical equipment with a voltage (at the input/output terminals) of 50 to 1,000 VAC or 75 to 1,500 VDC.

Lumen: (lm) A lumen is the luminous flux of light produced by an LED that emits one candela of luminous intensity over a solid angle of one steradian (sr).

Lumen Maintenance: The ability of an LED light to maintain intensity over time. A high power LED will typically retain 70% of its intensity for up to 50k hours.

Luminance: The luminous flux emitted or reflected from a source; in this case an LED. Given in candelas per square meter (cd/m^2).

Luminosity Function: Established by the CIE, this function approximates the average visual sensitivity of the human eye to light of different wavelengths. Two functions are defined. The photopic luminosity function is used for everyday light levels; while the scotopic luminosity function is used for poor light levels. Also called the Luminous Efficiency Function.

Luminous Efficacy: A measure of the effectiveness of a light source in converting electrical energy into light. It's the ratio of luminous flux to power & is expressed as lumens per watt (lm/W).

Luminous Flux: (F) A measure of the total perceived power of a light source in all directions. The measurement factors in the sensitivity of the human eye by incorporating the luminosity function. Expressed in lumens. Sometimes called luminous power. See Luminosity Function.

Luminous Intensity: The perceived power emitted by a light source in a single direction. It is the luminous flux per unit solid angle steradian (sr). Expressed in candelas (cd).

Lux: (lx) The measure of light intensity, as perceived by the human eye. One lux equals one lumen per square meter.

— M —

Magnetic Core: See Core.

Mains: See Ac Line.

Magnetic Shielding: Enclosing a power transformer with conductive material to reduce interference caused by the magnetic field.

Margining: A system performance test, in which the power supply output is adjusted up and down (typically by 5%). It is used to verify the resilience of a system to power supply voltage fluctuations.

Master: In a master/slave system, the intelligent power supply. The master supply contains the feedback loop for the power subsystem, and thus controls output regulation. Sometimes called a Driver.

Master/Slave Operation: The connection of two or more power supplies in which one (master) controls the operation of the others (slaves). Master/slave configurations provide higher output power, wider input voltage ranges, synchronized operation, etc.

Maximum Current: When in current limiting mode, the highest value of output current delivered by a power supply.

Maximum Load: When running under continuous operating specifications, the highest amount of output load allowable for a power supply.

Maximum Operating Temperature: The maximum temp. at which a power supply will operate to within specified operating parameters. Normally specified as either ambient or case.

Maximum Power: (Pmax) The highest level of output power that a supply can safely operate at.

Maximum Rating: See Absolute Maximum Ratings.

Mean Time Between Failure: (MTBF) A unit of measure, that gives the relative reliability of a power supply. MTBF data is either calculated per the conditions of MIL-HDBK-217F or demonstrated using actual operating data. MTBF is expressed in hours.

Mean Time To Repair: (MTTR) For a repairable power supply, MTTR refers to the average time required to perform the repair work. Encapsulated power modules are typically not repaired.

Metal-Oxide Field-Effect Transistor: (MOSFET) Power MOSFET's are used in most power supplies as the "switch" that chops the input signal at very high speeds. They operate at high speeds, are efficient and can handle high power levels.

Minimum: (min) The lowest value for a given specification.

Minimum Load: The minimum output load required to maintain the normal continuous operating specifications of a power supply. Usually associated with PWM (Pulse Width Modulation) controlled power supplies.

Minimum Operating Temperature: The minimum temp. at which a power supply will operate within specified operating parameters. Normally specified as either ambient or case.

Modification: Changing the configuration, packaging or specifications of a power supply to meet a specific customer demand.

Modular: Term used to describe the physical construction of power systems that consists of separate sub-assemblies. Modular construction tends to lower the design turnaround for custom products, but increases cost and lowers MTBF.

Modulator: See Pulse Width Modulator.

Module: An encapsulated or potted power supply.

Mold: The container used in the injection molding process. Power supply circuits are placed in the mold (typically on a pin frame). Then liquefied epoxy is forced into the mold under pressure. After the epoxy cools and solidifies, the individual modules are separated.

Molded: A component or subsystem that is completely enclosed in an insulating material (such as plastic). Some low power converters are now available as molded units.

Mylar: A plastic material (polyethylene terephathalate) often used as an insulator in the design and assembly of power supplies. A registered trademark of EI Dupont DeNemours & Co.

— N —

N+1: A redundant power system topology used to achieve high reliability levels. The circuit consists of a number of power supplies connected in parallel, sharing the load power. One more supply than is necessary to provide full load current is used (i.e. for a 1200W load, three 600W power supplies are used). Thus, if any single power supply fails, the remaining units will continue to power the load. See Master/Slave and Dual Redundant.

N+x: An "N+1" redundant circuit in which more than one extra power supply is used (i.e. N+2, N+3, ...N+x).

Nanometer: (nm) A unit of length in the metric system, equal to one billionth of a meter. Used as a measure of the wavelength of light.

Natural Convection: See Free Convection.

Negative Temperature Coefficient: A function (voltage, resistance, etc.) that decreases as temperature increases.

Neutral: In an AC circuit, the neutral line is the return path for the current provided by the hot wire. The neutral line is often connected to ground. See Ground and Hot Line.

Noise: Undesirable variations in the power supply output that are unrelated to the switching frequency. Noise is typically specified as "Ripple

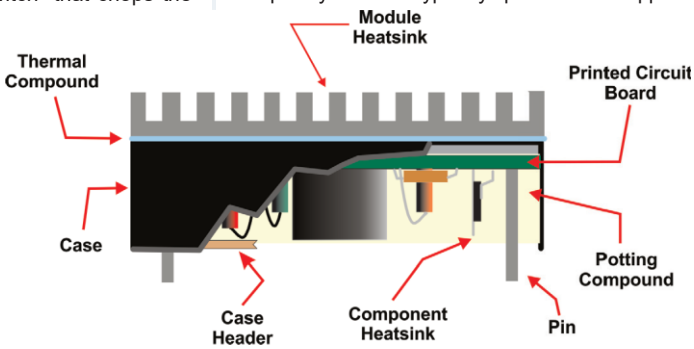


Figure 20 Modular Construction

and Noise" and given as a peak to peak value with a specified bandwidth. See Electromagnetic Interference, Ripple and Periodic and Random Deviation.

No Load Voltage: The voltage level present at the output of a power supply when 0% load is applied.

Nominal Value: An ideal value that is used as a reference point. Typically it is not the same as the value actually measured.

— O —

Off Line Power Supply: A power supply (linear or switching) that operates directly off the ac line. The input voltage is rectified and filtered prior to any isolation transformer.

Ohm (Ω): The unit of measurement for resistance.

Ohm's Law: First discovered by the German physicist George Ohm in 1827, the law gives the relationship between the voltage, current and resistance in a circuit.

$$I = \frac{V}{R}$$

Where: I = Current
V = Voltage
R= Resistance

Open-Circuit Voltage: See No Load Voltage.

Open Frame: A power supply that is made without an enclosure. Very common in low/medium power ac switching supplies, the power supply is typically constructed on a printed circuit board which is then mounted in the end-user application. See Enclosure and L-Frame.

Operating Life: The number of hours an LED is expected to be operational. For illumination applications where light output is considered critical, output degradation to 70% lumens is typically used. For applications where light output is not as critical (such as decorative lighting), 50% is typically used. Typically given in hours.

Operating Temperature Range: The temperature range over which a power supply can be safely used within specified operating limits. May be specified as ambient, case or base plate temperature.

Optical Coupler: A passive optical component that passes electronic signals using light waves. They are commonly used in power supply circuits to provide very high isolation for feedback lines. signals. Also called opto-isolator, opto-coupler, opto-isolator or photo-coupler.

Oring Diodes: Diodes, typically placed externally in the output circuit of two power supplies connected redundantly to a load. The diodes isolate each power supply from the other, insuring that one supply provides load power at a time.

Outage: A loss of power to a circuit or system.

Output Capacitance: When a power supply is off, the capacitance present between the output terminals.

Output Current: (Io) The current provided by a power supply to the load. See Input Current.

Output Current Limiting: See Current Limiting.

Output Filter: A circuit that attenuates noise and ripple current present on a power supply output. Normally, a power supply will include internal output filtering. For critical applications, external filter components may be added.

Output Device: See Load.

Output Efficiency: See Efficiency.

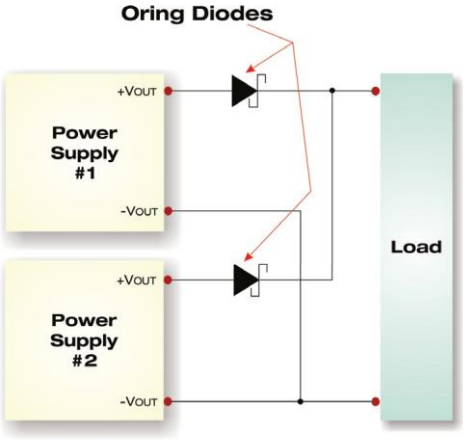


Figure 21 Oring Diodes

Output Good: A status (or housekeeping) signal that indicates that the power supply output is present and within a set tolerance. Typically available on higher power AC/DC power supplies or distributed power systems.

Output Impedance: The ratio of change in output voltage to a change in output load current. Sometimes referred to as Dynamic Response.

Output Load: See Load.

Output Power: The maximum output power a power converter is designed to provide.

Output Range: A power supply specification that gives the limits over which the output voltage may be adjusted and still meet specified performance.

Output Ripple & Noise: See Noise and Periodic and Random Distribution.

Output Voltage: DC voltage level measured at the power supply output pins.

Output Voltage Accuracy: The maximum deviation (from the ideal or nominal value) allowed in the DC output voltage of a power supply. Also called Output Voltage Tolerance, it is expressed as a percentage of output voltage.

Output Voltage Range: The minimum and maximum output voltage limits within which a power supply will operate within specified limits.

Output Voltage Tolerance: See Output Voltage Accuracy.

Over Current: A current that exceeds the specified level of a power supply.

Over Current Protection: See Current Limiting.

Overload: A condition under which excessive power is drawn from the power supply. May lead to a fault condition. See Current Limiting.

Overload Protection: See Current Limiting.

Overshoot: A momentary change in output voltage that exceeds specified limits. A transient overshoot will typically occur when a power supply is turned on/off; or with a step change in output load or input line.

Over Temperature Protection: A fault protection circuit that reduces the output power or shuts down the power supply if the operating temperature exceeds a set limit. Typically available on higher power AC/DC power supplies.

Over Temperature Signal: A status (or housekeeping signal) that indicates the power supply has shut down due to an over temperature condition. Typically available on higher power AC/DC power supplies or distributed power systems.

Overvoltage: An output voltage that exceeds the specified limit of the power supply.

Overvoltage Protection: (OVP) An output monitoring circuit that activates whenever a preset output voltage level is exceeded. Differing OVP circuits are used, with features that will shut the power supply down, "crowbar" the faulty output or switch the supply to a different operating mode.

— P —

Package: The enclosure for a power supply. A very wide range of packages are available, ranging from encapsulated modules to large fan-cooled metal cases.

Parallel Operation: A power system in which the output currents of two or more power supplies are connected together to provide a higher level of output power. A power supply must be designed to share output loads to be used in a parallel connection. Although parallel circuits are used in redundant systems; power system redundancy is not necessarily achieved through a simple parallel connection. See Redundant Operation.

Parameter: A specified characteristic or feature of a power supply.

Parasitic Capacitance: An unwanted capacitance that can introduce undesirable coupling into a circuit. It exists between the components in a circuit due to their proximity to one another. Also called stray capacitance.

Passive Component: A component that is static. For example, resistors, capacitors diodes, etc.

Peak Power: (P_P or P_{PK}) The maximum instantaneous power level that a power supply can handle without damage.

Peak-to-Peak: (P-P or Pk-Pk) For an AC waveform, the difference between the maximum positive and the maximum negative amplitude of a waveform.

Period: (T) The duration of a complete AC cycle. It is given by the formula:

$$T = \frac{1}{f}$$

Where: T = Time
f = frequency in H

Periodic and Random Deviation: (PARD) The noise & ripple voltage superimposed on the output of a power supply. It is typically expressed in peak to peak or rms volts over a given bandwidth at full load.

Photovoltaic Cell: A semiconductor diode that converts visible, infrared, or ultraviolet light into electric current. The diode consists of a flat P-N junction in a transparent package so that radiant energy can will fall on the P type silicon. Also called a Solar Cell.

Pi Filter: A filter consisting of two capacitors connected in parallel with a series inductance. Often used in DC/DC converters to reduce input reflected ripple current.

Pin-Out Diagram: A diagram that shows the pin location and functionality for a power module.

Plate: See Base Plate.

Point of Load Regulators: See Switching Regulators.

Post Regulation: A power supply output circuit that uses a linear regulator to reduce output ripple and noise and improve line/load regulation. On the negative side, post regulation adds expense and degrades power supply efficiency.

Potentiometer: A variable resistor used as an output voltage trimmer. Some power supplies allow the output voltage to be trimmed (typically by about ±10%). The trimmer may be built into the power supply (typical for AC/DC supplies), or it may have to be added as an external circuit by the user (typical for DC/DC modules.

Potting: See Encapsulation.

Potting Material: See Encapsulant.

Power: See Output Power.

Power Cycling: A quality assurance test sometimes applied to power supplies. For the test, power supplies are operated at full load, at an elevated temperature. The power to the units under test is then cycled on/off. This test will stress the power supply at significantly higher levels than the more typical burn in. For commercial grade power devices a burn-in at full load is more common.

Power Density: The ratio of power supply output power to the volume of the power supply, expressed as watts per in^3.

Power Derating: See Derating.

Power Dissipation: (PD) See Internal Power Dissipation.

Power Factor: For an ac input power supply, the ratio of true input power to apparent input power. A measure of the input current that is in phase with the input voltage (and thus contributing to the average power).

Power Factor Correction: (PFC) A power supply feature in which the ac input current is forced to be approximately in phase with the input voltage. This reduces the harmonic distortion of the power system and increases the useful power drawn from the mains. PFC circuits can be active or passive. See Power Factor.

Power Fail Signal: An output signal (typically TTL compatible) that indicates the DC input to the power supply has failed. This housekeeping signal is typically used to trigger the execution of an orderly shutdown during the hold-up time of the power supply.

Power Good Signal: A status (or housekeeping) signal that indicates the primary DC output of a power supply is still present. Often brought out to a system front panel as an LED indicator.

Power Ground: For a system or circuit, the power supply ground.

Power Loss: See Internal Power Dissipation.

Power Rating: The specified power available at the power supply output pins.

Power Source: A device or system that supplies electrical power. This could be a generator, PV system, battery, power supply, etc.

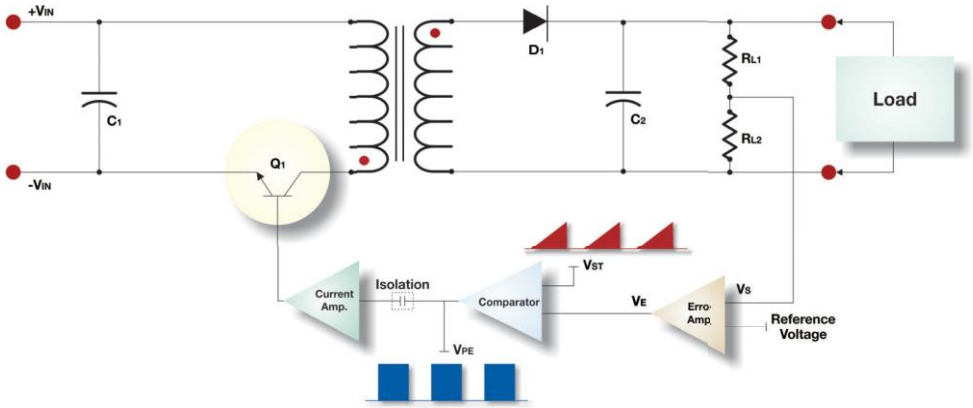


Figure 22 Simplified PWM Circuit

Power Supply: See Converter (AC/DC) and Converter (DC/DC).

Power Surge: See Surge.

Power Transformer: See Transformer.

Primary Circuit: The input side of an isolated power supply. See Secondary Circuit.

Primary Current: The current flowing in the primary winding of the power transformer of a power supply. Also called Transformer Input Current. See Secondary Current.

Primary Voltage: The voltage across the primary winding of the power transformer. Also called Transformer Input Voltage. See Secondary Voltage.

Primary Winding: The input winding of the power transformer. See Secondary Winding.

Printed Circuit Board: (PCB) A "board" made up of copper layers (sheets) that are laminated onto a non-conductive substrate. For power supplies, the substrate is typically rigid and uses FR4 glass epoxy to provide insulation. A pattern of conductive tracks (traces) and pads are etched onto the board to provide the wiring interconnections required by the circuit. If the complexity of the power supply design requires it, the board can be made with multiple levels of conductive connection patterns. The vast majority of power supply designs require this type of circuit board. Some low power products are available deigned without a PCB. In these designs the circuit components are mounted onto a pin frame.

Process Control: The use of specific, well defined and testable steps to design, manufacture and store products. The use of continuously tested controls results in products that have a consistently high level of quality; mechanically and electronically. Industry standards, such as ISO 9000 are often used to insure that the repeatable quality output of a process is achievable and maintained.

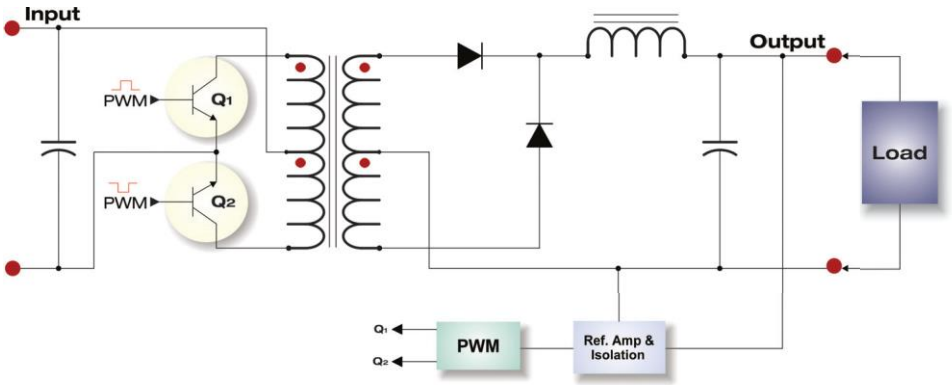


Figure 23 Simplified Push Pull Circuit

Pulse Width Modulation: (PWM) A circuit used in power supplies to regulate output voltage. Regulation is achieved by varying the conduction time of the transistor switches.

Puncture Voltage: See Breakdown Voltage.

Push Pull Converter: A power supply circuit that uses two transistor switches and a center tapped transformer. Normally configured as a forward converter, the transistor switches turn on and off alternately. See Boost Regulator, Buck Regulator, Bridge Converter, Flyback Converter, and Resonant Converter.

— Q —

Qualification Testing: Testing done on components to insure they meet the requirements of the product design.

Quality: The degree to which a power supply conforms to it's specifications.

Quality Assurance: (QA) A systematic method of monitoring the material, production, testing and packaging of a power supply to insure that quality requirements have been achieved and maintained.

Quality Control: (QC) The inspection of incoming material, manufacturing processes, and product testing operations to ensure that a product conforms to it's specifications.

Quasi-Regulation: Auxiliary outputs on a multiple output power supply that are regulated via the primary output (which is controlled by a direct feedback loop). Auxiliary output voltages are set by the turns ratio of the isolation transformer. Quasi-regulated outputs are significantly affected by variations in the primary output. Sometimes referred to as semi-regulation.

Quarter Brick Converter: A standard package size for high power density DC/DC converters. A quarter brick typically measures about 1.45 x 2.3 Inches (37 x 58 mm). There is some variance between manufacturers. Other established package standards include full, ½,⅛, and 1⁄16 bricks.

— R —

Rack: An upright frame for holding electrical equipment or systems. They are typically paneled to create an enclosure that can then be used to provide the mechanical support, power distribution, temperature control, and cable management required for complex systems.

Radiation Cooling: The transfer of heat between two materials at different temperature levels. Radiant heat does not play a significant role in the cooling of distributed power systems.

Radio Frequency Interference: (RFI) See Radiated EMI (under Electromagnetic Interference).

Random Noise: See Noise.

Range Capacitor: See Trimmer Capacitor.

Range Resistor: See Trimmer Resister.

Rated Output Current: The maximum output current that can be continuously drawn from a power supply under specified conditions.

Reactance: (x) The opposition to the flow of alternating current or voltage due to the presence of inductance and/or capacitance in the circuit or component. Inductive reactance causes the AC voltage to lead the current, while capacitive reactance causes the voltage to lag the current. Reactance is specified in ohms.

Reactive Current: That portion of alternating current that is not in phase with the voltage.

Reactive Load: A load that is primarily capacitive or inductive, rather than resistive.

Reactive Power: (Q) Measured in volt-amperes reactive (var), the reactive power of a circuit is equal to apparent power multiplied by the sine of the phase angle (*cp*) between the circuit voltage and current. It is given by the formula:

Q = Irms x Vrms x (Sine *cp*)

Rectification: The conversion of alternating current into pulsating DC by using diode rectifiers as switching elements. See Bridge Converter.

Rectified AC Current: The unfiltered DC output of a rectifying circuit. It consists of the unidirectional half cycles passed by the full or half bridge rectifiers. There is one pulse/cycle for a half wave rectifier and two pulses/cycle for a full wave circuit. For an illustration of a full wave rectifier, see Bridge Converter.

Rectifier: A circuit that converts alternating current into pulsating direct current. Used on the front end of AC power supplies (typically a full wave rectifier). See Bridge Converter.

Recovery Time: The time required for a measured parameter to return to within specified limits following an abnormal variation.

Redundant Operation: Power system configuration used to increase system reliability. Often used in distributed power systems, to achieve redundancy, power supplies are connected in parallel (typically configured in an "N+1", dual redundant or master/slave architecture).

Reflected Ripple Current: See Input Reflected Ripple Current.

Regulated Power Supply: A power supply whose output is held to within a tight error band regardless of changes in line and load.

Regulation: The ability of a power supply to maintain an output voltage to within specified limits under varying conditions of input line and output load. See Linear Regulation.

Regulator: A circuit or component with a varying input voltage that maintains a tightly controlled output voltage. They are often used to provide tighter regulation on power lines to critical portions of a circuit or to components sensitive to power line fluctuations. They are sometimes called point of load (POL) regulators. See Linear Regulator, Switching Regulator, and Voltage Regulator.

Regulator Diode: A semiconductor diode, typically a zener, used as a two-terminal voltage regulator.

Regulatory Agencies: Organizations (both independent and government supported) that develop specifications and/or test power supplies to specifications that define product performance or intrinsic safety.

Reinforced Insulation: Insulation that by itself, provides the same degree of protection from shock as double insulation. See Basic Insulation, Double Insulation, and Supplementary Insulation.

Relative Humidity: (rh) The ratio of the amount of moisture in the air to the amount the air could contain at a given temperature, expressed as a percentage. A common environmental specification for power supplies is the ability to withstand high levels of relative humidity.

Relative Power: A power level that is specified with respect to a reference power level.

Reliability: The dependability of a power conversion product to operate to specified conditions.

Reluctance: (*R*) The opposition to the set up of a magnetic field in a magnetic circuit. It is comparable to resistance in electronic circuits.

Remote Sensing: An external output connection wherein sense leads connected to the output load provide feedback to a power supply. Used to compensate for voltage losses caused by the resistance of long leads or traces to the load. See Local Sensing.

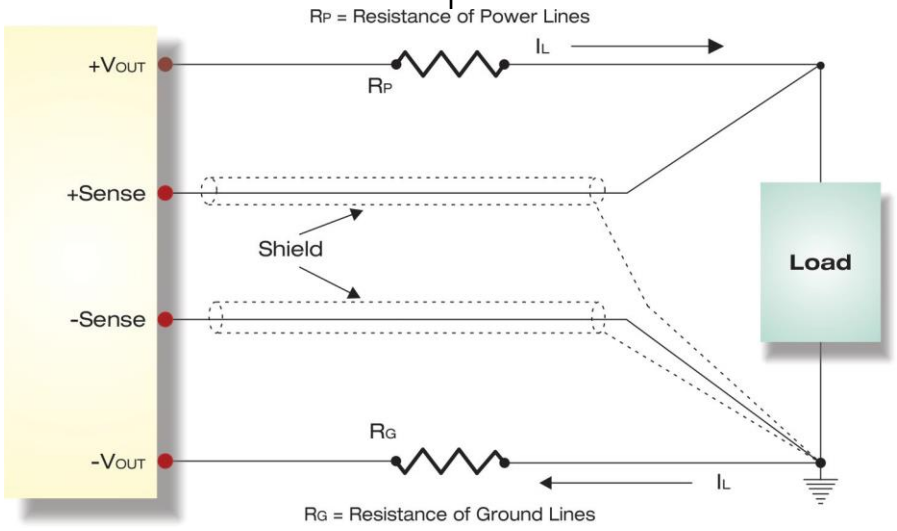


Fig 24 Simplified Remote Sensing Circuit

Remote Shutdown: See Logic Inhibit/Enable.

Reset: After a fault condition has shut down a power supply, power supply has been shut down by a fault condition, the manual operation or the automatic signal that will restart it.

Resin: A natural or synthetic organic substance that's polymeric in structure. Epoxy resins are used extensively in electronics for potting/molding compounds, PC boards, insulators, etc.

Resistance: (D) The opposition to current flow. Resistance is given in ohms and is equal to:

$$R = \frac{E}{I}$$

Where: I = Current
E = Voltage
R = Resistance

Resistance Drop: The voltage drop across a resistor,or the inherent resistance of a component.

Resistive Load: A power supply load that exhibits the characteristics of a pure resistance.

Resistive Losses: Losses resulting from the resistance of a circuit or component. Typically, they are lost as heat.

Resistor: A very common component, that presents resistance to current flow and lower voltage levels in a circuit, as well as a variety of other uses. Resistors are passive components, typically having two terminals. They are fabricated from a number of materials including carbon, metal film, wire and foil. They are available over a wide range of resistance values and power ratings. Variable resistors are also available in a range of values and physical configurations.

Resonant Converter: A power supply topology in which a resonant tank circuit operating at very high frequencies is used to transfer energy to the output. Often found in higher power DC/DC converter applications.

Response Time: See Transient Recovery Time.

Restriction of Hazardous Substances: (RoHS) A European directive that sets limits on the concentration levels of 6 substances. They are Mercury, Lead, Cadium, Chromium VI, polybrominated biphenyls (PBB), and polybrominated dihenyl ether (PBDE).

Return: The common terminal on the output of a power supply. It is the return current path for the output. See Common.

Reverse Current: See Leakage Current.

Reverse Voltage Protection: A power supply feature that protects internal components from damage in the event a reverse voltage is accidentally applied to either the input or output terminals.

Ripple and Noise: See Periodic and Random Deviation (PARD).

Ripple Voltage: The periodic AC component imposed on the output voltage of a power supply. Typically specified as part of "Ripple & Noise" and given as a peak to peak value over a specified bandwidth. See Periodic and Random Deviation (PARD).

Room Temperature: A term sometimes used to describe a benign operating environment. Although it typically implies a temperature of about 77°F (25°C), room temperature has no actual quantitative meaning.

Root Mean Square: (rms) For a sine wave, the rms value is equal to:

rms = 0.707 x I_{PEAK}

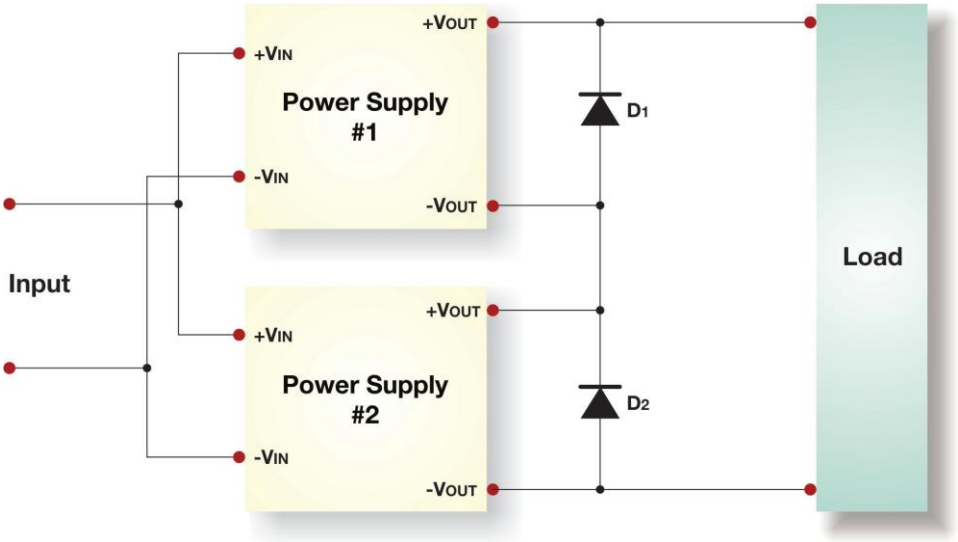


Fig 26 Simplified Series Connection

Royer Converter: A self-oscillating push-pull switching topology often used in low cost, low power DC/DC converter designs. Also called the classical converter.

— S —

Safety Compliance: Certification that a power supply (or family of power supplies) has been approved by a safety agency such as UL, TUV, CSA, VDE, etc.

Safety Extra Low Voltage: (SELV) A term used by safety and regulatory agencies to describe the highest voltage level that can be contacted by a person without causing injury. It is currently defined as 60 VDC (42.4 Vpk).

Safety Ground: A conductive path to earth ground designed to protect equipment operators from potential electrical shocks.

Sample: A quantity of products, components, etc taken from a larger group for the purpose of verification testing. The sample size is set at a number high enough to statistically represent the larger group for the parameter under test.

Schematic (Diagram): A diagram that illustrates an electronic circuit. It will show components and interconnections. Components are typically with an abbreviation of their type and a number (R_1, C_3, etc). Sometimes component values are also given. Also called a Wiring Diagram.

Secondary Circuit: The output side of an isolated power supply. See Primary Circuit.

Secondary Current: The current flowing in the secondary side of the isolation transformer of a power supply. Also called Transformer Output Current.

Secondary Output: See Auxiliary Output.

Secondary Power: The power in the secondary circuit of a transformer. Also called Secondary kVA (or VA).

Secondary Voltage: The voltage across the primary winding of the power transformer. Also called Transformer Output Voltage. See Secondary Voltage.

Secondary Winding: The output winding of the power transformer. Sometimes called Secondary Coil. See Primary Winding.

Sense Line: An input to the power supply that "senses" the output voltage level at the load. Used in remote sensing connections to compensate for line losses incurred when powering a load some distance from the power supply. See Remote Sensing and Local Sensing.

Sense Resistor: A resistor used to sense the current flowing in a circuit. The voltage drop across the resistor is measured and the circuit current (which is proportional to the measured voltage) is derived from this measurement. Care must be taken not to cause significant power losses. So typically the sense resistor will be small.

Sensor: A circuit or device that detects a system or environmental phenomena and produces a current or voltage that is proportionate to this measurement. This output is then used to display the current state of the phenomena (current temperature, flow rate, etc) and/or start some type of alarm or control action.

Series Operation: A power system configuration in which multiple isolated power supplies are configured to obtain a higher output voltage level (inputs connected in parallel) or wider input voltage range (inputs connected in series) than that obtainable from one power supply.

Series Regulator: A linear regulator placed in series with the load to achieve a constant voltage across the load. This is the most popular method of linear regulation. See Linear Regulation, Post Regulation and Shunt Regulator.

Set Point Accuracy: The ratio of the actual output voltage of a power supply to its specified output voltage.

Setting Accuracy: See Set Point Accuracy.

Shelf Life: The longest period of time that a power supply could be stored before deterioration of the components or operating performance occurs.

Shock Hazard: A condition that presents the danger of electric shock to a person.

Short Circuit: A power supply fault condition in which the positive rail of the output becomes directly connected to the negative rail. If the power supply has "Short Circuit Protection", it will immediately limit the output current to prevent damage to the supply. If there is no protection, a short of more than one or two seconds would likely damage the supply. See Current Limit and Foldback Current Limit.

Short Circuit Current: The current that flows when the output is directly shorted.

Short Circuit Protection: A circuit that limits or reduces the output current of a power supply if the output is shorted. See Current Limit and Foldback Current Limit.

Shunt Regulator: A linear regulator placed in parallel with the load to achieve a constant voltage across the load. See Linear Regulation, Post Regulation and Series Regulator.

Sine Wave: See Alternating Current and Alternating Voltage.

Single Ended Circuit: A circuit that has one end grounded. Also called an Unbalanced Circuit.

Single Ended Input: A power supply input that has one side grounded. Also called an Unbalanced Input.

Single Ended Output: An output circuit with one line grounded. Also called an Unbalanced Output.

Sink: A circuit (or device) into which current drains.

Six-Sided Shielding: A packaging technique in which the power supply is placed into a metal case. The metal shielding minimizes noise radiation from the switching components of the power supply. A continuous shielded case has the base (or header) welded on, further reducing potential noise leakage from the power supply or preventing circuit noise from interfering with the supply.

Slave: A power supply that has no internal feedback loop. The output regulation of a slave unit is controlled by a master power supply to which its' operation is synchronized. Sometimes called a "booster" See Master.

Slow-Blow Fuse: A fuse that uses a wire that breaks apart slowly. The time delay allows the fuse to withstand transient current surges that would not damage the circuit. A fast blow fuse would open, shutting down the circuit needlessly.

Snubber: A component or network that reduces the voltage rise and potential voltage overshoot in a power supply switching circuit.

Socket: A connector or slot (typically female) fixture into which a power supply or component inserted. It allows easy connection/removal of systems or components to a circuit.

Soft Start: A power system input circuit that limits the inrush current at turn on.

Solar Array: A complete, power generating unit. An array consists of any number of Solar panels. Panels can be added or subtracted to fit the needs of the installation.

Solar Cell: See Photovoltaic Cell.

Solar Energy: Energy derived from the sun. Typically refers to energy captured over a given period of time within a specific surface area.

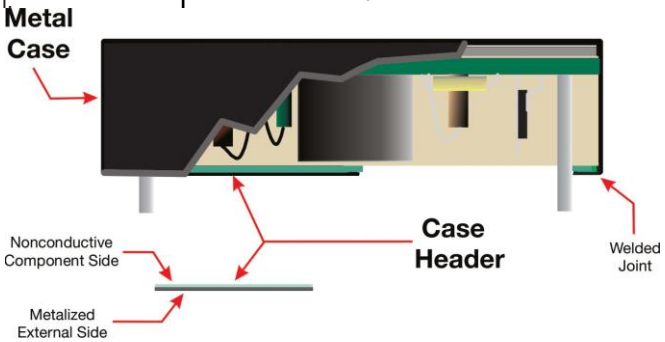


Fig 27 Shielding

Solar-Energy Conversion: The process of changing solar radiant energy into electric power.

Solar Module: A number of solar cells that have been connected in series or parallel and then encapsulated into a weatherproof module. The module typically includes a tempered glass cover and aluminum frame.

Solar Panel: A panel that consists of a number of solar modules connected together. A panel is a field installable unit.

Solar Power: The usable electricity generated by solar cell based systems.

Solder: A metal alloy that is melted to join two other metals electrically and mechanically. Originally, most solders used combinations of lead and tin. In 2006 the European Union prohibited the use of excess lead in consumer electronics. Since then, lead free solders have typically been used in electronics.

Solderless Connection: An electrical connection made without using solder. Typically it is a connection between two leads made by crimping, splicing, or wire wrapping. Also called Wire Wrapping.

Source: The battery, generator, power mains, etc, that provides the input power to a power supply.

Source Effect: See Line Regulation.

Spacing: See Clearance Distance and Creepage Distance.

Specific Power: See Power Density.

Specification: A listing of a products' performance capability (and limitations) for a variety of parameters. Usually given as minimum, typical and/or maximum limits in a "datasheet" format.

Spike: A sharp current or voltage pulse (or transient) of very short duration. Often, a power supply will require protection on the input line to prevent damage from transients.

Split Bobbin Winding: A transformer winding technique in which the primary and secondary windings are wound on a bobbin side by side with an isolation layer in between. See Bobbin.

Stability: See Long Term Stability.

Standard: An industry wide specification that details the performance characteristics, physical size, operating environment, and testing requirements that must be passed to meet a particular level of performance. to meet a specific level of etc of a device or system. Often a standard will define a subset of a device or system performance, such as EMI/EFI or the requirements to meet various levels of safety.

Standby Current: The input current drawn by a power supply when it has no load and has been shut down by a remote ON/OFF signal.

Standby Power: The power dissipated by a power supply when it has no load and has been shut down by a remote ON/OFF signal.

Stand-Off: A mechanical support post (typically an insulator) used to hold a wire, component or PC board away from a chassis or base.

Start-Up Delay: After input power is applied to a power supply, the delay that occurs before the output voltages are within regulation.

Static Load: A load that remains constant for a specified period of time. Typically specified as a percentage of full load.

Status Signals: See Flag Signal.

Step Change: A sudden change in a power supply parameter. Normally used when referring to changes in output load or input line during power supply testing.

Stiff Line: A condition wherein there is no significant impedance present on the AC input mains. The input voltage to the power supply under these conditions will not change appreciably with load.

Still Air: A power supply operating environment in which the surrounding air restricted. Often occurs in small enclosures (sometimes sealed) where air cannot move freely. Because it does not have sufficient mass or flow, still air is prone to thermal runaway caused by the thermal output of the power system.

Storage Life: See Shelf Life.

Storage Temperature Range: The range of ambient temperatures over which a power supply can be safely stored. See Operating Temperature Range.

Stress: A mechanical or electrical strain or tension on a component or circuit.

Subassembly: A complete circuit or assembly that is part of a larger unit.

Supplementary Insulation: Insulation applied in addition to (and independent of) basic insulation. Supplementary insulation provides protection against electric shock in case the basic insulation fails. See Basic Insulation, Double Insulation, and Reinforced Insulation.

Surface Mount Devices: (SMD) Components (including some power supplies) designed to be assembled using surface mount technology.

Surface Mount Technology: (SMT) An automated manufacturing process in which components are designed for mounting on the surface of a substrate or PC board. Often used in the design/assembly of low power DC/DC converter modules.

Surge: A sudden rise in the flow of current or voltage. This often happens when power supplies are initially turned on as circuit capacitors charge. Some fault conditions could also cause a surge. A significant surge could cause damage to a power supply if proper protection is not placed on the input (such as an MOV).

Surge Current: See Surge.

Surge Suppressor: A semiconductor device that will block or short to ground potentially destructive transients or voltage spikes on the input line to a power supply. Sometimes called a Surge Protector.

Surge Voltage: See Surge.

Switch: A circuit or device used to open or close a circuit. For instance, in a power supply, semiconductor "switches" (typically MOSFET's) are used to chop the the input into pulses.

Switching Frequency: The rate at which the input voltage is switched or "chopped" in a power supply. Sometimes called Frequency of Operation.

Switching Power Supply: A power supply that uses switching regulation. Switchers are typically smaller, more efficient and lighter than linear supplies.

Switching Regulator: A circuit (typically a pulse width modulator) that uses a closed loop design to regulate the output voltage.

Symmetrical Wave: A wave with positive and negative half-cycles that are identical in shape and amplitude.

System: A set of components, hardware and/or software that operate together to meet an end purpose.

— T —

Tail: Typically used to describe the current that continues to flow in a circuit when a semiconductor switch has been closed. Dealing with tail current is very important consideration in the design of very high power/high speed switching circuits. Also called Current Tail.

Tantalum: (Ta) A material used in some electrolytic capacitors (rather than aluminum). Tantalum capacitors are widely available, have high reliability and high efficiency. The primary drawback of tantalum's is expense.

Technischer Uberwachungs-Verein: (T.U.V.) A group of independent companies that provide safety testing (and project management & consulting) in a number of industries. For the power supply industry they are mainly used to validate product design and operation to VDE and DIN standards.

Temperature: (T) See Ambient Temperature.

Temperature Coefficient: The average change in power supply output voltage per degree centigrade. Expressed as a percentage over a specified temperature range.

Temperature Derating: See Derating.

Temperature Effect: See Temperature Coefficient.

Temperature Range: See Operating Temperature Range and Storage Temperature Range.

Temperature Scale: The scale graduated in degrees, from which a temperature is read. The different scales include centigrade, Fahrenheit, Rankine, absolute, reamur and kelvin. The kelvin scale is the same as the absolute scale. For the power supply industry, the Celsius or centigrade

Fig 28 Surface Mount DC/DC Converters

and Fahrenheit scales are used. Also called the Thermometer Scale.

Temperature Shock: See Thermal Shock.

Tertiary Winding: A third winding on the power supply. It is typically used in a forward converter configuration to "reset" the transformer at the end of each cycle. Occasionally tertiary windings are used to provide a third, independent output voltage. Sometimes called an Energy Recovery Winding.

Terminal: A connection point on a power supply consisting of a screw terminal. These come in strips with multiple connections (typically two to ten).

Terminal Block: A group of several terminals, mounted on a solid insulating block with a solid between each pair of terminals. Typically used on medium to high power AC/DC power supplies and chassis mount DC/DC converters. Sometimes called a Barrier Strip.

Test: A procedure during which the performance, or a particular part or the performance, of a power supply is verified.

Test Instrument: A device, such as an oscilloscope or voltmeter, used for checking the operation of a power supply.

Test Point: A terminal, pad, etc that is used to connect test equipment o various measurement points within a circuit.

Test Probe: A thin pencil-like instrument with a pointed metal tip. When connected to a meter or scope, etc, it is used to take readings at various points within the power supply circuit.

Thermal Adhesive: An epoxy (rather than oil) based thermal joint compound. When cured, thermal adhesives provide a mechanical bond

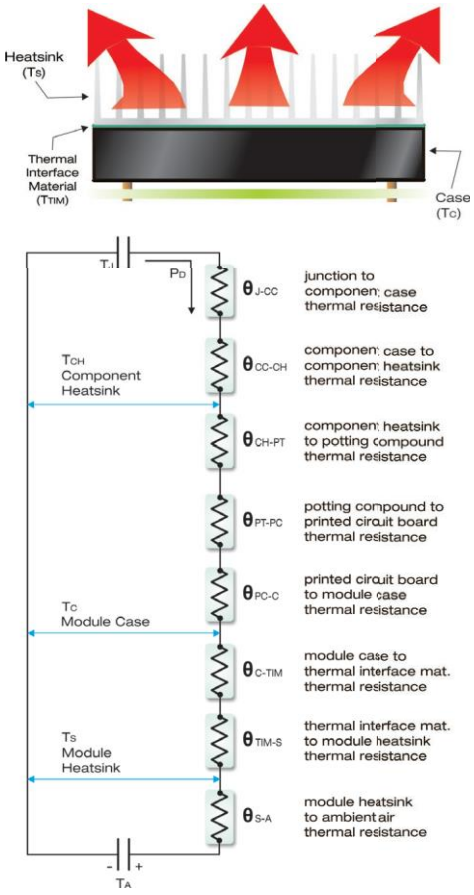


Fig 30 Thermal Resistance

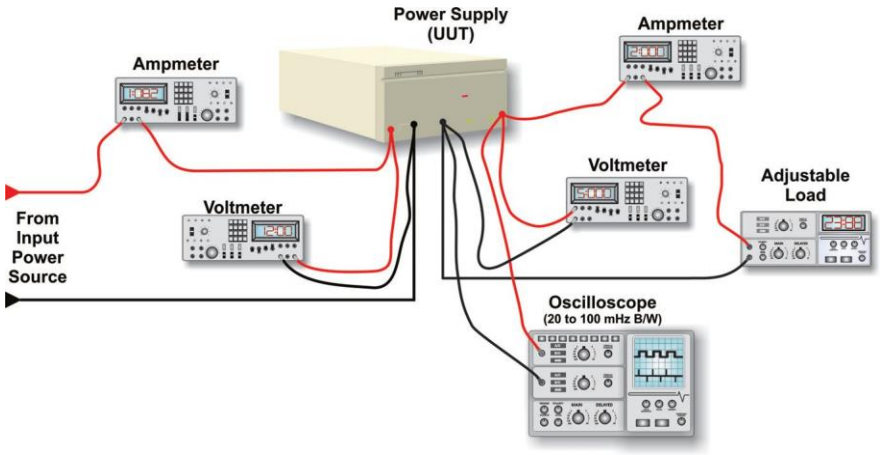


Fig 29 Typical Bench Test Set-Up

between the base plate/chassis of a power supply module and heatsink as well as insuring high thermal conductivity across the junction. See Thermal Joint Compound.

Thermal Conductivity: For a given material, the time required for heat to transfer (via conduction) across a unit material thickness of 1 meter when the temperature differential of the two opposite faces is 1K. Given in joules per second per square centimeter.

Thermal Gasket: A flexible pad or wafer that is placed between a power supply baseplate/ chassis and a heatsink. Thermal gaskets have a very low thermal resistance, insuring high thermal conductivity across the junction. Use of a 'dry' gasket may eliminate some problems associated with thermal joint compounds (inconsistent coating, contaminants, etc.). Gaskets are available in a number of standard pre-cut forms.

Thermal Grease: See Thermal Joint Compound.

Thermal Joint Compound: A fluid or paste that is spread between a power supply baseplate\chassis and a heatsink. Normally, compounds consist of a silicon or synthetic oil that carries a low thermal resistance filler (aluminum, etc.). The compound fills the voids caused by irregularities in the mating surfaces insuring high thermal conductivity across the junction.

Thermal Resistance: (0) A measure of the opposition a material will have to the flow of heat. Used to calculate the temperature drop that occurs when power flows through a material or across the junction of two materials. Given in units of degrees Celsius per watt (°C/W).

Thermal Resistivity: (p) A measure of the ability of a material to impede the flow of heat. Typically given in units of (°C)(T)/W, where T equals the thickness of the material and W equals the power flowing through the material in watts.

Thermal Runaway: A circuit condition in which an increase in the ambient temperature surrounding a power supply causes an increase in the internal power dissipated. This increases the case temperature, which in turn increases the ambient temperature of the surrounding air. The spiraling effect of these temperature increases will eventually lead to failure of the power system. This condition occurs when inadequate measures (air flow, system venting, power derating, etc.) are taken to get heat away from critical components.

Thermal Protection: A protection feature that shuts a power supply down if its internal temperature exceeds a preset limits. Also called thermal shutdown.

Thermal Shock: A test to identify the effects of applying heat or cold to a power supply very rapidly. The rapid temperature change causes different parts of the supply to expand and contract differently. These changes could be catastrophic if the supply has not been designed correctly.

Thermistor: A component that changes resistance with temperature. They are available with either a positive or negative temperature coefficient of resistance. In power supplies, they are often used (ones with a negative temperature coefficient) in inrush current limiting circuits.

Thermocouple: A sensor that is used to measure temperature. Essentially, it consists of two wires welded together at one end. The wires are different metals, so when the junction area is exposed to a change in temperature, a voltage is produced. Using reference tables, the temperature at this point v=can be calculated.

Three Terminal Regulator: A linear regulator packaged in a standard 3-terminal transistor package. These devices can be configured as either a shunt or series regulator.

Tin: (Sn) A metallic element used in solder and (in foil form) as the the plates of a capacitor.

Tolerance: The amount of variation that is allowed in the specifications of a power supply or component.

Topology: The layout and circuit inter connections that make up the characteristics of the different types of a power supply. Major power supply topologies include Flyback, Forward, Buck, Boost, etc.

Toroid: See Toroidal Coil.

Toroidal Coil: A coil wound on a donut shaped core. The core is made of powdered-iron or ferrite. Widely used in power supplies, toroidal coils have certain advantages including a higher Q factor and better isolation properties. A disadvantage is that an air core is not practical.

Tracking: For a multiple output power supply, the parameter that gives the change in one output voltage caused by a change in the voltage level or load on another output.

Transformer: A device that uses electromagnetic induction to transfer electrical energy from one circuit to another, without a direct connection between them). A transformer includes a common core with separate primary and secondary coils wound on it. When an alternating current is applied to the primary winding, the resulting magnetic flux in the core induces an alternating voltage across the secondary winding. The induced voltage in the secondary will cause a current to flow in an external circuit.

Transformer Coupling: The inductive coupling of energy through a transformer.

Transient: A spike or step change in a power supply parameter. Commonly used in describing input line and output load characteristics.

Transient Recovery Time: The time required for a power supply output to return to within specified limits following a step change in output load current. Expressed as a percentage of rated value.

Transient Response: A power supply's ability to return to a constant output voltage level following a step change in output current.

Transistor: See Bipolar Junction Transistor.

Trim: To make a fine adjustment. Trim circuits are typically used to vary power supply outputs by a small amount (typically ±10%.

True Power: The actual power consumed by an ac circuit.

Turn-Off Time: The time required for the operation of a power supply to completely cease after input power is removed. Also applies to the time it takes to stop after a remote off signal has been received (on power supplies that have remote On/Off capability.

Turn-On Time: The time required for the operation of a power supply to start after input power is applied. Also applies to the time it takes to start after a remote on signal has been received (on power supplies that have remote On/Off capability.

— U —

Undershoot: A transient change in a power supply output voltage that does not meet the lower limit of the voltage accuracy specification. Typically occurs at the power supply turn on/off or with some step change in output load or input line. See Voltage Accuracy.

Underwriters Laboratories: (U.L.) An independent, organization that conducts safety testing of products to established standards.

Undervoltage Protection: A protection circuit that shuts a power supply off if the output voltage falls below a preset level. Sometimes used as an input protection circuit in wide input range power supplies (AC and DC) to prevent overheating if the input voltage sags below a predetermined level. Sometimes called Undervoltage Shutdown or Undervoltage Lockout.

Uninterruptible Power Supply: (UPS) A power supply that will continue to operate after the loss of ac input power. A UPS normally uses some type of automatic battery backup system.

Universal Input: An AC input to a power system that accepts all the standard voltage levels available from AC mains. Typically specified at 85 VAC to 265 VAC.

Unregulated Power Supply: A power supply whose output will rise and fall with the input line voltage. The output voltage regulation is typically specified as a percentage of the percentage change in the input voltage (%/%V_{IN}). Low power DC/DC converters (1 & 2W) are often unregulated designs.

Unshielded Cable: A cable that does not have a shielding jacket. These cables are susceptible to interference from stray circuit noise. They could also radiate noise into the surrounding circuits.

Unshielded Transformer: A transformer that does not have a protective cover or shielding.

Unbalanced Circuit: See Single Ended Circuit.

Unbalanced Input: See Single Ended Input.

Unbalanced Output: See Single Ended Output.

Unipolar Transistor: See Field Effect Transistor.

— V —

Variable Resistor: See Potentiometer.

Varistor: A component with a nonlinear resistance that varies with the applied voltage. Typically, the varistor has a very high resistance at low voltages. The resistance decreases as the voltage increases. They are often used in power supply input circuits to protect against excessive transient voltages. They are sometimes called a Voltage Dependent Resistor (VDR).

Verband Deutsher Electrotechniker: (V.D.E.): A German association that sets standards for product safety and noise emissions; and tests and certifies products to those standards.

Vibration: A continuous shaking or oscillating movement. Industrial power supplies are sometimes tested for their ability to withstand the stress of sustained vibration without damage.

Voltage Balance: For a multiple output power supply, the percentage difference in voltage level between two outputs with opposite polarities and equal nominal values.

Volt Ampere: (VA) The product of the circuit voltage (in Volts) and current (in amperes). It is the unit for expressing the apparent power in an AC circuit. See Apparent Power.

Voltage Clamp: See Clamp Diode.

Voltage Divider: A resistor network (or ladder) that divides a voltage applied to it by a desired amount.

Voltage Doubler: A power-supply circuit that takes an AC input voltage and supplies a DC output voltage of about twice the peak value.

Voltage Drift: See Drift.

Voltage Limit: The specified maximum or minimum values of a voltage range.

Voltage Regulation: See Regulation.

Voltage Regulator: A circuit or device that provides a steady output voltage despite variations in the output load or the input line. They are readily available as linear or switching regulators. As the names imply, they use linear or switching regulation circuits. They are also called Point Of Load regulators because they are often used very close to the load they are powering.

— W —

Warm-Up Drift: See Drift.

Warm-Up Time: The time required for a power supply to operate to within specifications after turn-on. This time normally precedes a long-term drift specification.

Watt: (W) The unit of electric power. A one ohm resistor with a current of one ampere flowing through it will dissipate one watt.

Wattage Rating: The specified output power of a power supply. Typically given as a maximum.

Wave: a single cycle of an AC waveform.

Weight: The force of the gravitational pull upon a power conversion product. Typically given in ounces and grams.

Winding: A wire coil wound around a magnetic core. Used in the fabrication of inductors and transformers.

Wire: A metal strand or thread used as a conductor.

Wire Bonding: A method of using very fine wires to make interconnections between a semiconductor device and it's packaging. The wires are welded (the process is also called bonding) at both ends using a combination of pressure, heat and ultrasonic energy. This fabrication method is also used in the manufacture of some high reliability power products that use hermetically sealed hybrid cases.

Wire Gauge: See American Wire Gauge and Birmingham Wire Gauge.

Withstand Voltage: The maximum voltage level that can be applied between circuits or components without causing a breakdown. See Breakdown Voltage and Isolation.

— X —

X-Axis: The horizontal axis on a chart or graph.

X Capacitor: In an EMI filter, x capacitors are placed across the input line. If an x-capacitor fails, the risk is equipment damage and even fire. X capacitors come in three categories that reflect their impulse test ratings. These are X1, X2 and X3. See Y-Capacitor.

— Y —

Y-Axis: The vertical axis on a chart or graph.

Y Capacitor: In an EMI filter, y capacitors are connected from the input line to the chassis. If a y-capacitor fails, there is a shock risk to the user. Y capacitors come in four categories that reflect their impulse test ratings. Y1, Y2, Y3 and Y4. See X-Capacitor.

—Z —

Zener Breakdown: A condition that occurs in a semiconductor junction when the reverse bias voltage exceeds a certain value (this value varies with different diodes). If the electric field at the junction becomes strong enough, current will flow in the opposite direction. Some diodes are fabricated to avalanche at precise voltages. Also called Avalanche Breakdown.

Zener Diode: A diode specially fabricated to conduct in both directions. It conducts in the forward direction like a normal diode, and once a set voltage level is met, it will conduct in reverse In power supply circuits they are typically used as voltage regulating devices. Also called an Avalanche Diode or Zener.

Zener Knee: The transition point on a graph of the voltage characteristics of a Zenor where the diode goes into avalanche breakdown. For voltage regulation circuits, the knee should be as sharp as possible.

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