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Your Guide to Power Supply

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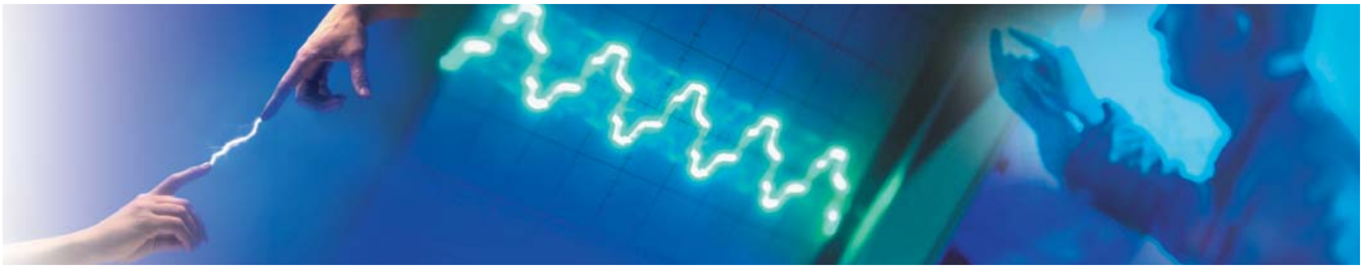

Do you know the difference between AC and DC? Or what is Watt? And who was Ohm? Join us in this crash-course in power supply and check out what these abbreviations and technology terms really mean!

Absolute power

Since the late 19th century, electricity has had a tremendous impact on humankind and life on earth, with inventions like the light bulb, telephone, phonograph, generator, motor, and motion pictures. And that is all thanks to Thomas Alva Edison, inventor in the US and Nikola Tesla, a European scientist who is often seen as the inventor the AC power.

Watt and Voltage and Ampere – how do I know the difference?? In electricity there are some basic units to be aware of; voltage (U), current (I), power (W) and resistance (R).

Power is measured in watts, voltage is measured in volts, current is measured in amps and resistance is measured in ohms.

A common analogy to help understand electricity is water falling in a river. In this case the current **(I)** is like water flow rate, the voltage **(U)** is equivalent to the water fall height, resistance **(R)** is the rugged surface in the flood bed and power is “water fall height” times "water flow rate".

FACTS

Symbols and abbreviations in power supply to remember:

Alternating Current	= AC
Direct Current	= DC
Power	= P
Current	= I
Voltage	= U
Ampere	= A
Watt	= W
Resistance	= R
Ohms	= Ω

DEFINITIONS

First of all, it can be good to know that the total sum of energy is always constant, energy only change its shape. It may change from something moving (electrons or cars or computers), to heat when the object is slowed down. As the sum of energy is constant, the energy that is not used for the purpose is converted to another form, for instance heat. This additional heat must be transferred to a place where it is not doing any harm and this requires more energy. So, cooling something is just an expression for the function of transferring the unwanted heat away from the equipment ultimately to the outside air, where the heat does not cause a problem.

Power & Watts

Electrical power is measured in watt - a unit that tells you what the power output will be, from a 100W light bulb for instance. Watt is used to specify the rate at which electrical energy is dissipated, or the rate at which electromagnetic energy is radiated, absorbed, or dissipated. The watt symbol is **W**.

Examples of amount of Watts required for various applications

- *10's of Watt = power supply for light bulbs or a portable PC's*
- *100's of Watt = Printers, faxes and other small office machines*
- *Kilo Watt = Stoves, telecom systems or other large industry systems.*

Current & Ampere

The more "techy version" of energy is that electricity, or current, is the result of an electrical charge, as electrons moving through a wire, often made of metal such as copper. Current (I) is measured in AMPERES (**Amps** or **A**).

Ampere is a unit to measure the rate of electron flow – the current output – in an electrical circuit. Or to use the water analogy – to measure the amount of water flowing in a river – more force (U) pushes more water (I) faster through to generate more power (P). Ampere is named after Andre Marie Ampere, French physicist (1775-1836).

Voltage & Volts

Voltage is the electrical force that makes current (electrons) flow in a circuit or through a wire. To continue the water analogy, voltage can be compared with the height of a water fall.

The standard unit is Volt, symbolized by a non-italic uppercase letter V. Voltage can be direct or alternating. A direct voltage maintains the same polarity at all times. In an alternating voltage, the polarity reverses direction periodically. The number of complete cycles per second is the frequency, which is measured in hertz (one cycle per second), kilohertz, megahertz, gigahertz, or terahertz.

Resistance & Ohm's Law

To be a full fledge expert in the power ABC, you also have to know about resistance. Resistance can be anything that causes an opposition to the flow of electricity in a circuit, and can be compared with the rugged surface in the flood bed. Resistance is used to control the amount of voltage and/or ampere in a circuit. Resistance (R) is measured in Ohms or (**Ω**).

Ohm's Law

"The amount of current flowing in a circuit made up of pure resistances is directly proportional to the electromotive forces impressed on the circuit and inversely proportional to the total resistance of the circuit" – easy, right?!

Ohm's Law – named after German scientist Georg Simon Ohm - is the mathematical relationship among electric current, resistance and voltage. By using Ohm's Law you can determine one value by knowing the other two, for instance to figure out the Current by using Voltage and Resistance values: **I = U/R**.

If the current in amperes is represented by I, the voltage (or potential difference) in volts is represented by U, and the resistance in ohms is represented by R, then the following equations hold for power in watts, represented by P: **P = U*I**

As mentioned about Resistance, the resistance consumes power in electrical wires, and the power consumed increases as the current going through the wires increases. You can see how this happens by doing a little rearranging of the two equations. What you need is an equation for power in terms of resistance and current.

Let's rearrange the first equation: **I = U/R can be restated as U = I*R**.

Now you can substitute the equation for V into the other equation: **P = U*I substituting for U we get P = I*I*R, or P = I^2R**.

What this equation tells you is that the power consumed by the wires increases if the resistance of the wires increases (for instance, if the wires get smaller or are made of a less conductive material). But it increases dramatically if the current going through the wires increases.

So using a higher voltage to reduce the current can make electrical systems more efficient. The efficiency of electric motors also improves at higher voltages.

AC-DC – Rockband, or...

No, AC and DC is short for Alternating Current (AC) and Direct Current (DC) and the difference is the way the water flows.

DC – Direct Current

Direct Current (DC) is when the current, or water, flows in only one direction, from point A to point B. DC power was the first current technique used, and a common source of Direct Current are DC generators and batteries. DC can be either positive or negative, but it never alternates. Industry applications/areas using DC power are telecom system equipment and automotive applications such as cars and buses. However, DC is today seldom used in household outlets. DC power is used internally in almost all electronic equipment.

AC – Alternating Current

If the current instead moves back and forth – it is called Alternating Current (AC). AC means that both voltage and current alternates.

AC is the electricity we use in our homes, to power our TV and radio, armatures and

The electronic circuit

Through out this guide, "circuits" has been mentioned now and then, and just to straighten out any question marks, a short overview of various circuits.

Circuits

In electronics, a circuit is a path between two or more points along which an electrical current can be carried. (A circuit breaker is a device that interrupts the path when necessary to protect other devices attached to the circuit – for example, in case of a power surge.)

Think of it as a circle. The paths may split off here and there but they always form a line from the negative to positive. Negatively charged electrons in a conductor are attracted to the positive side of the power source.

Simple Circuit

A circuit broken down to it's elementary blocks, contains of:

- *Power Source – eg. battery*
- *Patch – eg. a wire*
- *Load – eg. a lamp*
- *Control – eg. switch (optional)*
- *Indicator – eg. meter (optional)*

Series Circuit

A series circuit is one with all the loads in a row. Like links in a chain. There is only ONE path for the electricity to flow. If this circuit was a string of light bulbs, and one blew out, the remaining bulbs would turn off.

Parallel Circuit

A parallel circuit is one that has two or more paths for the electricity to flow. In other words, the loads are parallel to each other. If the loads in this circuit were light bulbs and one blew out there is still current flowing to the others as they are still in a direct path from the negative to positive terminals of the battery.

Combination Circuit

A combination circuit is one that has a "combination" of series and parallel paths for the electricity to flow. Its properties are a synthesis of the two.

Conductor

A conductor is a material, usually a metal such as copper, that allows electrical current to pass easily through. The current is made up of electrons. This is opposed to an insulator which prevents the flow of electricity through it.

computers. In a standard household outlet the electrical current changes direction, from positive to negative and back, 50 (in Europe) or 60 times (in USA) each second.

POWER SUPPLIES & SYSTEMS

Let's talk hardware

To make use of all this current and power and electricity, there is however a need for hardware too.

Rectifiers – AC/DC

A rectifier is a power supply unit that is used to convert the AC input to lower DC voltages. Typical applications for rectifiers are in telecommunications, industrial and medical areas as most of these systems run on DC power, and you have to "rectify" the incoming alternating (AC) current.

Inverters – DC/AC

A power inverter can be described as a "reversed rectifier", as it is typically used for converting direct current (DC) into alternating current (AC). They are also known as DC to AC converters. To illustrate this, imagine that you need to use a regular car battery (DC output) to power your drill (AC input). Then you need a DC/AC inverter between the drill and the battery to make it work. Inverters are used in telecoms, medical and other industrial applications to provide AC power which can be powered from a backup battery.

Converters – DC/DC

DC/DC converters convert a DC input voltage to one or more output voltages. The output voltages can be either regulated or not, all depending on what kind of application it's used for.

UPS

Uninterruptible power supply (UPS), three-phase, is a device that operates in conjunction with existing electrical system to provide power conditioning, back-up protection and distribution for electronic equipment loads. UPS power tends be used in server rooms and mission critical applications.

A single phase uninterruptible power supply (UPS) is a device that sits between an AC outlet (i.e. a wall outlet or power strip) and an electronic device (such as a computer, server, or phone equipment) to provide power conditioning, back-up protection and distribution for electronic equipment loads.

Transformer

The AC transformer is a way to easily change the voltage to electricity, something that can't be done with DC electricity. This invention gave AC a tremendous advantage over DC as a source of our electricity, because of the ability to easily transform voltage up or down.

If you take an iron rod and wrap a wire around it, make it electromagnetic by using AC electricity, the magnetic field will alternate at the same rate as the electric current changes.

If another wire is wrapped around the rod, the changing magnetic field will create an AC current in that wire. What is especially interesting about this phenomenon is that the voltage created in the second wire depends not only on the voltage in the first wire but also on the ratio of the number of turns around the iron rod. This type of AC electro-magnet with two sets of wires is called a transformer.

Units vs systems

A unit is a single piece of product - which together with other units makes a system. However, it takes a lot of experience and know-how to design and create systems out of bits and pieces. Just to compare a complex system – such as medical or telecom applications - with a Domino game; If one crucial component is touched, it may effect the whole system – that is why system knowledge and understanding is so critical.

COST DRIVING PARAMETERS

Volume – height, width and length

Depending on how and where the power supply shall be used, the physically dimensions need to be specified. A product that is very small versus its output power, is harder to design (high density) than a product with lower density. Also the maximum height of components is of importance since a lower maximum height makes the design more costly than if more flexibility is allowed.

Efficiency

Measures or describes how effective the energy conversion is, presented as the relation between output power and input power. The efficiency varies in different converters depending on input and output voltage, or input and output power. For instance, if you have 100W input power, and the efficiency of the output power is 90W, the "missing" 10W disappears as heat, which means that the efficiency is 90%.

Cooling

All power supplies emits more or less heat. There is a need to cool it down, which can be done by either forced cooling with fans, or cooling by using the self-convection principle. The cooling of certain "hot" components is also a challenge and may require additional heat dissipation mechanics.

Packaging – enclosures

Depending on the application, the physical design of a power supply unit differs. Some applications require a closed covering, to withstand water for instance. While others requires an open frame design. The different packaging requirements affects the total cost.

Environment

Usually specified in the following subgroups:
Temperature
Temperature limits are set to define what the product should be able to handle during operation and storage, e.g. 0 to +40ºC for indoor office applications, –40 to +70ºC for outdoor applications.
Humidity
Defines the humidity conditions expressed as RH %, can be non condensing, or condensing. Important factor when power supply units have to be "water proof", as some power units are placed outdoors.
Altitude
Defines altitude above sea level at which the power unit must be able to operate. The height is affecting the cooling of the power unit, which becomes harder the higher you get.

Mechanical – shock and vibration

To ensure that a power supply unit can manage the mechanical wear in an application, shock tests are used by the designer and manufacturer. The product is then exposed to mechanical shocks and vibrations to guarantee that it withstand the specific application. An example of a demanding application is power equipment externally mounted on a train that hauls more than 200 km/hour.

PFC

Power Factor Correction, PFC, is a circuitry that is used to lower the amount of overtones that is fed back to the main source from an AC/DC or AC/AC converter. There are international standards that regulate this; one of them is the EU standard EN 60552.

Current Limiting

Current limiting is required if the application involves charging of batteries or if the output needs to be short circuit safe. This means adding components in the output circuitry.

Other Bells & Wistles, examples

- *Alarms and status information of the unit can be provided either in by means of software or additional circuitry*
- *Surge protection on the input can be added dependent on the application and location of installation*
- *Instruments or displays can be added to offer information to the user when looking at the unit*
- *Self-test and manufacturing information can be provided if software is designed-in to the product*

Redundancy

In a system, redundancy means there is an over dimensioning of the power supply, to ensure that a single fault will not cause the application to stop functioning. There are different types of redundancy:

- *The most usual is N+1. This means that the system is dimensioned with one additional unit, so that if one unit is failing the system is still functioning without degradation of its performance. This principle is commonly used in Telecom Power Systems used in Telecom applications.*
- *A second type is N+N, which means that the system consists of twice as many units as the load needs. This increases the availability but at the same time the cost is increasing*

Availability

Availability requirement defines the amount of time, out of the total time, that the power supply function should be available. Some people are talking about the number of 9's when discussing availability. This means how many decimals there is after 99%. 99% availability means that the product or solution is unavailable 87.6 hours per year.

Availability in %	Unavailability in hrs & min/year
99%	87 hrs 36 min
99.9%	8 hrs 45 min
99.99%	53 min
99.999%	5 min
99.9999%	32 sec
99.99999%	3 sec

Of course will higher availability drive costs compared with lower availability.

Reliability

Defines how reliable the power supply should be, and is calculated as a MTBF figure (Mean Time Between Failure). The calculations are done according to one of the different standards that are available. This value gives a statistical value on how many units that will fail when used under the defined circumstances. The result is stated in years, example 100 years, or hours, example 1 000 000 hours, meaning that based on a given population in service, ex. 5 000, statistically X number of units will fail during a given period. Let's make calculations on the example information given above.
Example 1:
5 000 units in services divided by 100 years MTBF means that 50 units will fail every year.

Did you know

....electricity was first introduced to New York in the late 1870s.

....the residents of Brooklyn became so accustomed to dodging shocks from electric trolley tracks that their baseball team was called the Brooklyn Dodgers.

....in spite of the perils, wealthy New Yorkers rushed to have their homes wired, the most important being the banker, J.P. Morgan, who had invested heavily in Thomas Alva Edison.

....both Tesla and Edison shared a common trait of genius in that neither of them seemed to need much sleep. That's where the similarity ended.

....Tesla relied on moments of inspiration, perceiving the invention in his brain in precise detail before moving to the construction stage.

....Edison was a trial and error man who described invention as five percent inspiration and 95 percent perspiration.

....Edison was self-taught. Tesla had a formal European education.

....with high frequencies, Tesla developed some of the first neon and fluorescent illumination. He also took the first x-ray photographs. But these discoveries paled when compared to his discovery of November 1890, when he illuminated a vacuum tube wirelessly-having transmitted energy through the air.

....at age 28, Nikola Tesla arrived in New York City.The Serbian immigrant had four cents in his pocket, some mathematical computations, a drawing of an idea for a flying machine, and a letter of introduction from Charles Batchelor, one of Edison's business associates in Europe.

....Edison executed the first of his 1,093 successful U.S. patent applications on 13 October 1868, at the age of 21.

....Nikola Tesla one of the most important scientist of the 19th century with respect to electricity is given the credit for inventing AC. However, in the late 19th century, a Swedish scientist named Wenstrom first discovered alternating current (AC).

Example 2:

5 000 unit in services divided by 1 000 000 hours MTBF means that 0.005 units will fail every hour, e.g., one unit per 200 hours of operation. Of course will higher reliability drive costs compared with lower reliability.

Design Life

The expected life time of a unit or component, depends on the application – a mobile phone is expected to last for 5 years, and a car for at least 10-15 years. When designing, a long design life means selecting longer life components or adjusting the design limits that is used for the unit or application, downwards, which in turn means larger margin in the design. This is a factor that also adds more cost.

Wide input

Wide input voltage range is a dominant demand regarding the input voltage. This is due to the global differences regarding mains voltages. However, a wide input range will drive cost since the input stages needs to be designed for both the high input voltages and the high currents that will be the result at low input voltage. When deciding on input voltage demand, one of the deciding factors is of course where the in the world the final product is to be sold and used.

Outputs – Single or Multiple

Power supplies can have different outputs. Some have one and some other have two or more. The different outputs can have demands on cross regulation – how one output is affecting the other – and the outputs can be specified with individual current limiting or other different specific demands. As a general rule, the simpler the lower cost.

Quantity

In all production and manufacturing, the basic rule is that the more you buy, the less will each unit cost you. For a custom designed product the quantity is therefore of major interest, since this is the base to spread the cost of the design.

Lead-times – development and manufacturing

The lead-time for development is related to the complexity of the product as well as the level from which the design can get started. Or simply, the more detailed a specification is and/or the more similar the design is to previous products or experiences, the faster can the actual design be made.

The lead-time for manufacturing depends basically on the component lead-times. When short lead-times is requested different types of means needs to be put in place all aiming for faster availability on resources and components. Such as forecasts, consignment stocks, pre-ordering, pre-manufacturing of certain units.

STANDARDS

EMC

All electric equipment is surrounded by an electro-magnetic field, which can cause interference with other electronic products. With the extended use of electronic systems in every aspect of our daily lives, there inevitably comes the problem of compatibility.

To avoid this electro-magnetic interference, manufacturers of all kind of electronic equipment - from consumer products like the razor to industrial product such as telecom systems – has to follow the EMC regulations. EMC, Electro Magnetic Compatibility, is a worldwide governmental regulation, to prohibit electronic products from emitting or being susceptible to electro magnetic interference.

Translated into an everyday situation, it must be possible to listen to the news on the radio while shaving with an electric razor. A more industry related example, the power supply of radio telecommunications equipment that also has to meet the tough EMC requirements, as the power supply must never interfere with the radio network.

Isolation

Defines the amount of barrier between input and output, or between different outputs or between in/output and ground. Different safety standards stipulate different isolation voltages by default.

Safety

Safety standards describe how a product needs to be designed to be safe for use in a certain application. There are a number of test laboratories, which are testing products for safety and give the manufacturer a certificate of conformity that allows the product to be marked with a certain safety mark, e.g., UL, CSA, CE, etc.

Product safety standards

	Europe	USA
Medicine	EN 60601	UL 2601
IT, General	EN 60950	UL 60950
Marine	EN 60945	
Industrial	EN 60335 EN 60558	UL 1012 UL 1310

Above table shows safety standard for different market segments in Europe and USA. The standards are not totally harmonized, but the harmonization work is constantly ongoing.

Little business case

By knowing the numbers of two out of the three units Watt's and Amp's and Voltages, an expert in engineering can tell you how to get more power effect out of less current in.

Or to speak plain market economy – how to get the most cost effective solution for each business opportunity.

The equation they are using is power equals the voltage multiplied by the current, symbolized by ***P=U/I***

In an electrical system, increasing either the current or the voltage will result in higher power. Let's say you have a system with a 6-volt light bulb hooked up to a 6-volt battery. The power output of the light bulb is 60 watts. Using the equation above, we can calculate how much current in amps would be required to get 60 watts out of this 6-volt bulb.

You know that P = 100 W, and U = 6 V. So you can rearrange the equation to solve for I and substitute in the numbers for I=P/U: ***60W / 6V = 10 amps***

What would happen if you use a 12-volt battery and a 12-volt light bulb to get 60 watts of power? Let's see: ***60W / 12V = 5 amps***

Well, look at that - this system produces the same power, but with half the current!

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