TDK Power Electronics World

Guidebook of TDK Power Electronics Products

Welcome to Power Electronics World

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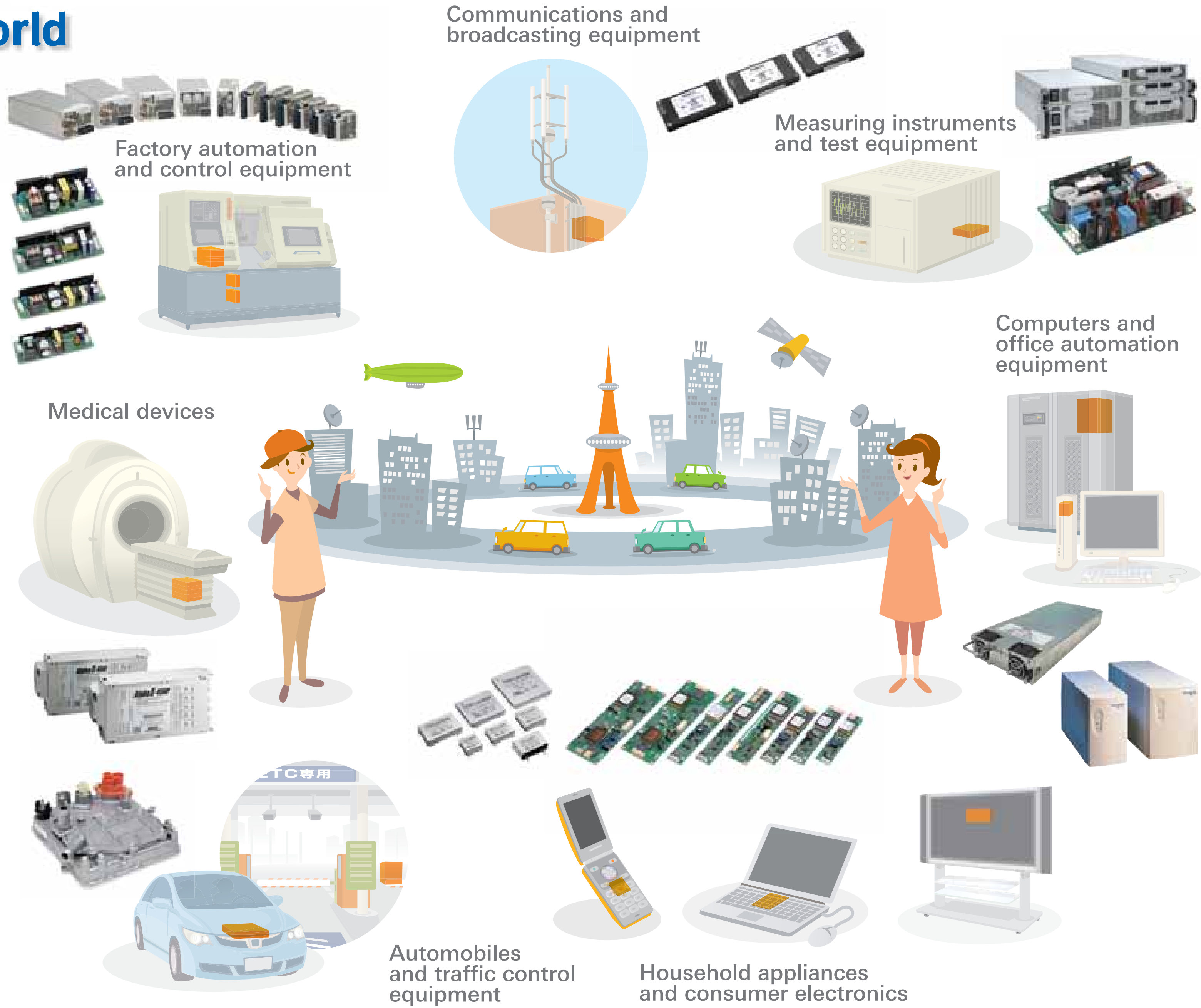
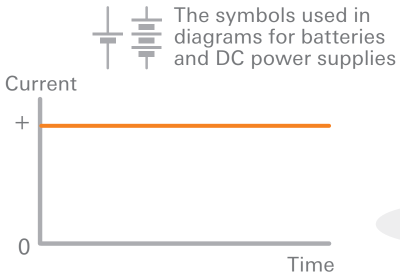


What Is Direct Current (DC)? What Is Alternating Current (AC)?

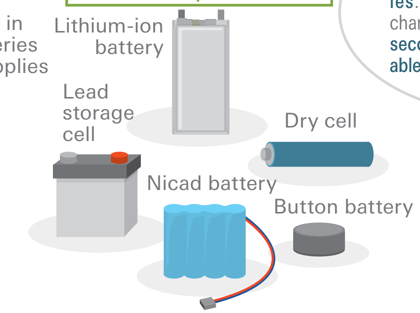
Electric current can be **direct current (DC)** or **alternating current (AC)**. Direct current such as the power from dry cells is characterized by a uniform direction of flow and amount (voltage) of electricity. Alternating current is characterized by direction of flow and amount of electricity that changes cyclically over time. Long ago, static electricity was the only type of electricity known, but when batteries were invented, it became possible to use DC electricity. Generators were later invented, and it became possible to use AC as well.

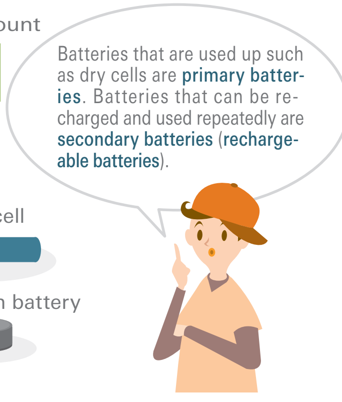
DC is an abbreviation for direct current.

Direct Current Direct current has uniform direction of flow and amount (voltage) of electricity.



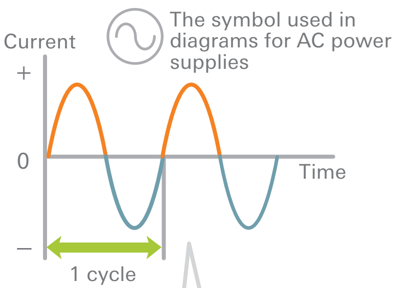
Primary Batteries and Secondary Batteries





AC is an abbreviation for alternating current.

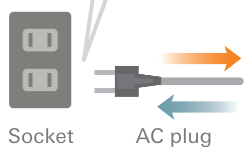
Alternating Current Alternating current has direction of flow and amount (voltage) of electricity that change cyclically.



The waveform of the **commercial AC power** supplied by electric power companies is called a sine wave.

* Not all AC electric power has a sine wave. There is also AC with a pulse waveform.

The direction of the electric current that comes from the two holes of the electric socket alternates.



AC Frequency

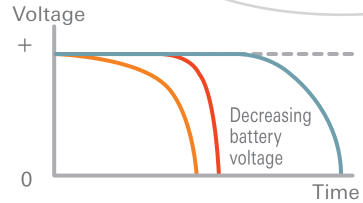
How many times the direction of AC changes each second is called the frequency. The unit of frequency is Hertz (Hz).The frequency of commercial AC is **50 Hz in eastern Japan** and **60 Hz in western Japan**.

Low Frequency and High Frequency

AC with a relatively low frequency is referred to as low frequency, and that with a high frequency is referred to as high frequency, but generally, high frequency means **AC with a frequency in the kilo-Hertz, mega-Hertz, or higher range**.

There Is No Such Thing as Perfect DC or AC

When the power of a battery (dry cell or rechargeable) falls, electric and electronic devices stop working. This is because the voltage of a battery falls over time. In recent years, the **driving voltage of integrated circuits has declined**, so even small changes in voltage are a problem.

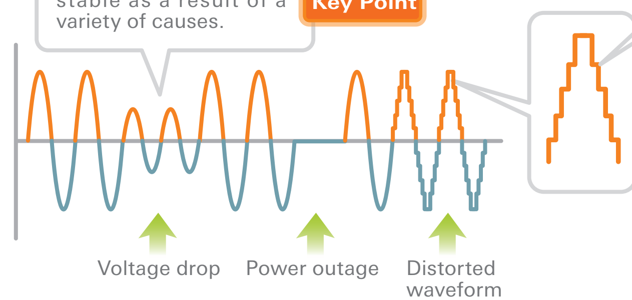


The voltage of AC from the outlet is not constant and can vary by 10 V more or less than 100 V.

The commercial AC from outlets is not stable. **Commercial AC can become unstable** depending on the load (electrical devices and so on) connected to the distribution network. For example, when all the houses in a neighborhood are using the air conditioning during the afternoon in the middle of the summer, the voltage drops. There are also **momentary stoppages in distribution and distortion to wave forms** caused by the addition of noise.

<Cases of instability in commercial AC>

Commercial AC is not stable as a result of a variety of causes. **Key Point**



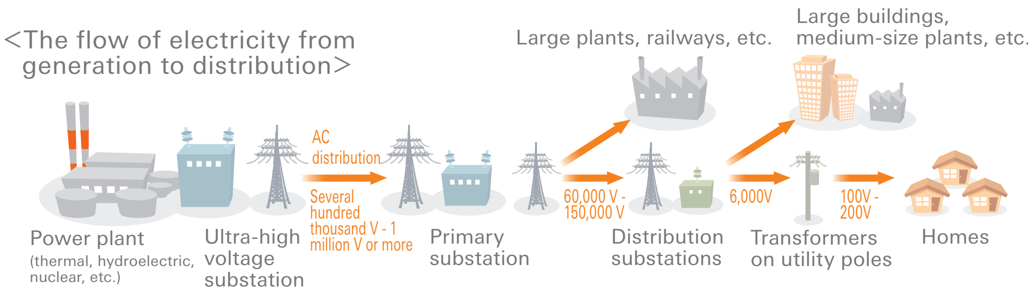
When high-frequency AC is added in the form of noise, the waveform can become jagged like this.

Load

Things that are connected to power supplies and consume energy are referred to as "loads." Specifically, loads include resistors, circuits, connection devices, and so on.

Why is electricity distributed as high-voltage AC?

<The flow of electricity from generation to distribution>



When electricity is distributed at high voltage, the electric power losses (thermal losses resulting from the resistance of the power lines) are lower.

AC has the advantage of being easy to change to a different voltage using a **transformer** (**DC distribution** is used for some portions of the distribution route).

The difference between DC and AC is fundamental knowledge concerning power electronics.

AC can easily be converted to a different voltage using a transformer.

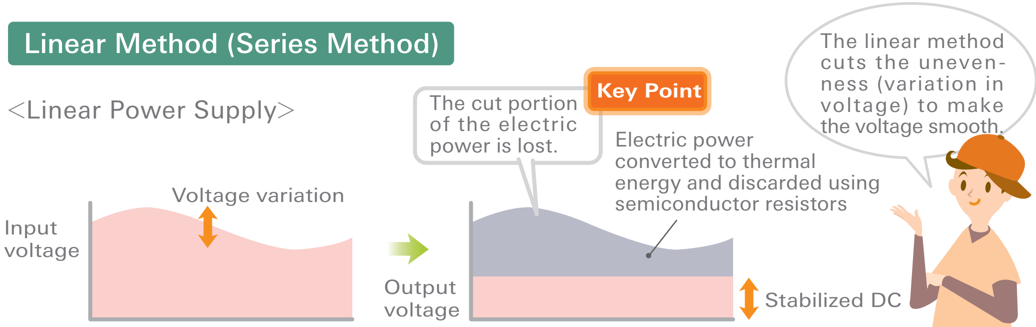
▶ Why Are Stabilization Circuits Needed?

The DC from a battery or converted from commercial AC using an adaptor still has unstable variations in voltage. Changes in voltage can cause sensitive electronic devices to malfunction, so **stabilization circuits** are used to create DC with stable voltage. Two methods of doing this are the **linear method** (also called **the series method** and **dropper method**) and **switching method**.

The principle of the linear method is simple, but it is inefficient and has high thermal losses.

Linear Method (Series Method)

<Linear Power Supply>

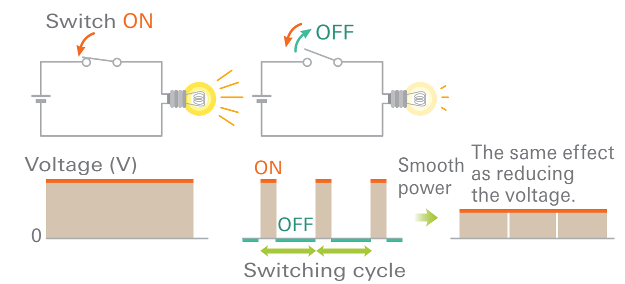


The switching method achieves stable power supply with compact, lightweight, and high-efficiency devices.

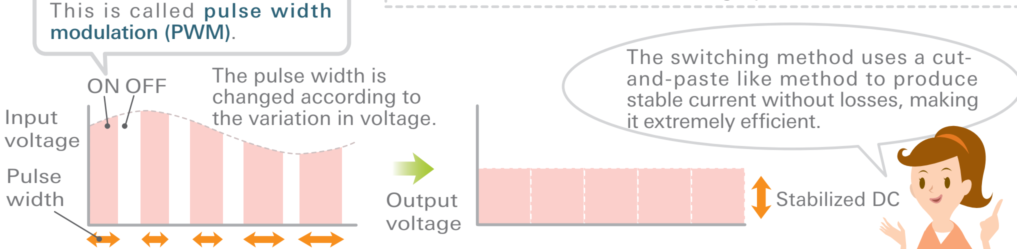
Switching Method

If the circuit shown to the right is used and the switch is turned ON and OFF quickly, the brightness of the lamp will decrease as if the voltage dropped. Switching power supplies achieve this effect using semiconductor elements.

<The idea behind a switching power supply>



Key Point
This is called **pulse width modulation (PWM)**.



The current is pulsed at high frequency by switching (ON/OFF) a semiconductor element and is sent to a transformer that changes the voltage.

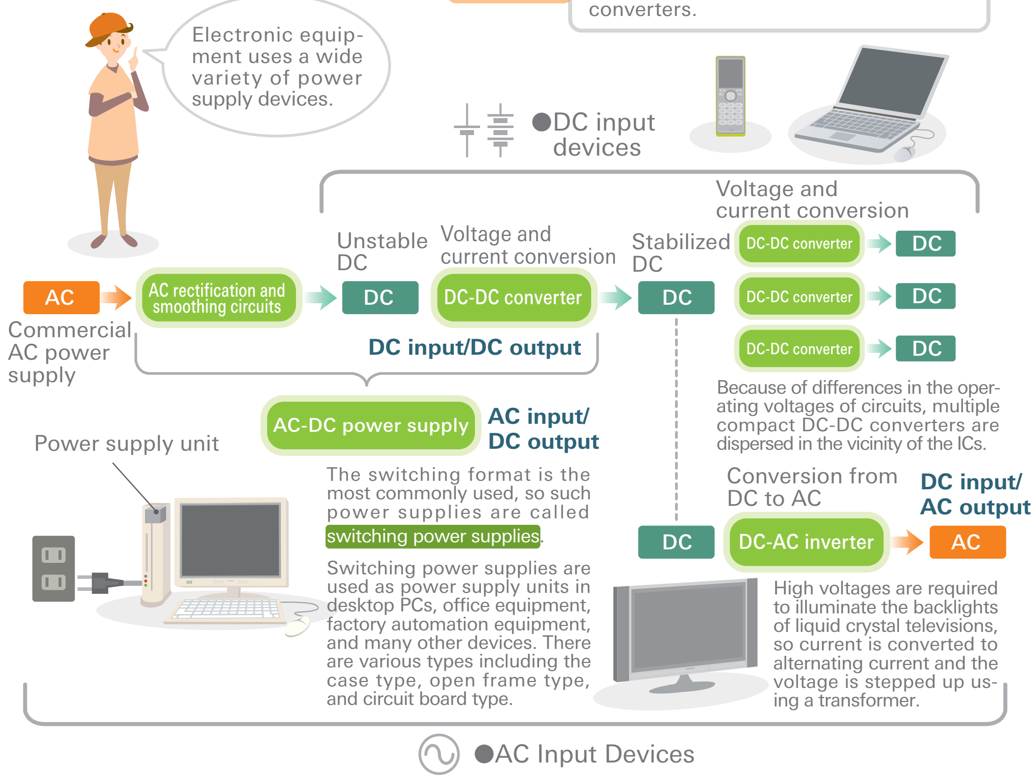
The pulses are controlled so the area of each is the same, producing stable current with uniform voltage.

▶ Power Supply Devices Play a Variety of Different Roles

Most electronic devices operate on direct current. After commercial AC is rectified (the DC is still unstable), a **DC-DC converter** is used to change the power (change the voltage or current) and stabilization circuits are used to produce extremely stable DC.

<Power Conversion Devices Inside Electronic Equipment>

Key Point
The different circuits of electronic equipment use different operating voltages, so they contain multiple DC-DC converters.



Strengths and Weaknesses of Linear and Switching Power Supplies.

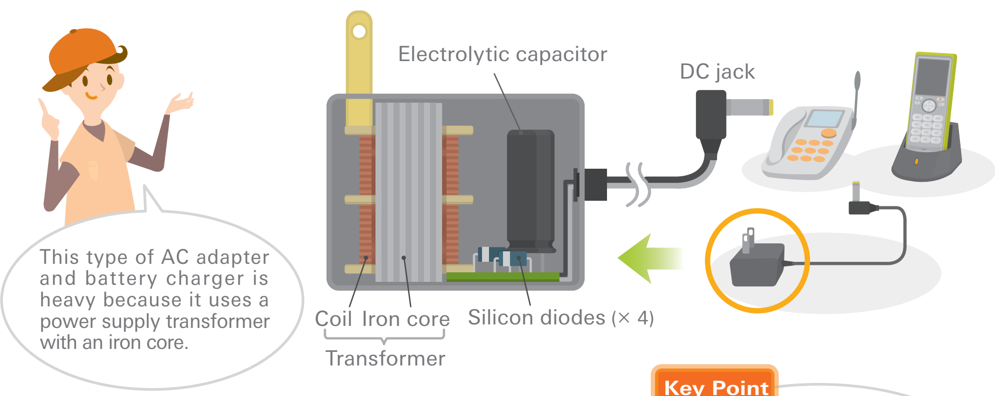
	Linear Power Supplies	Switching Power Supplies
Efficiency	Low (30%–60%)	High (70%–90% or higher)
Radiated heat	High	Low
Size and weight	Large and heavy	Compact and lightweight
Degree of stability	High	Ordinary
Radiated noise	None	Noise countermeasures are necessary

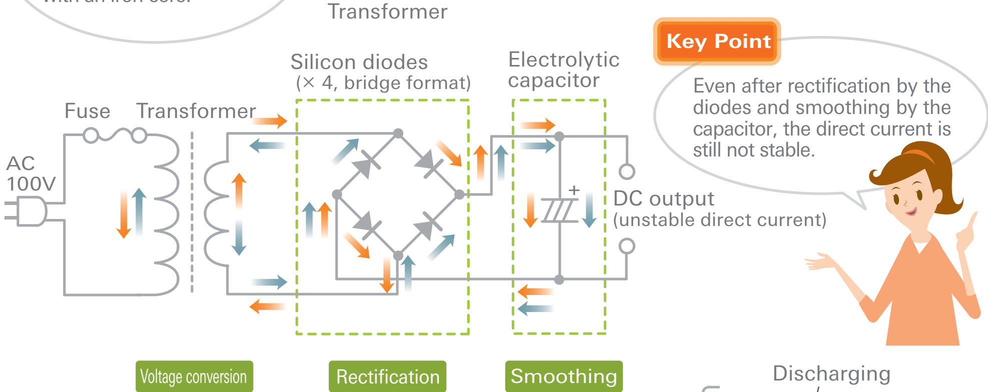
Key Point
The main weakness of switching power supplies is the generation of **switching noise** in conjunction with the high-speed switching of the semiconductor elements. As a result, **EMC countermeasures** (**noise countermeasures**) such as **noise filters** are essential.

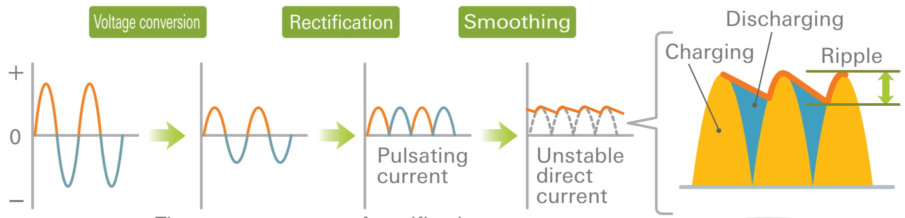
What Is Rectification? What Is Smoothing?

Rectification is the conversion of alternating current to direct current. Rectification is performed by a diode that allows current to flow in one direction but not in the opposite direction. Direct current that has only been rectified, however, has various changes in voltage (**ripples**) lingering from the alternating current. Capacitors are used to **smooth the current** and make it even.

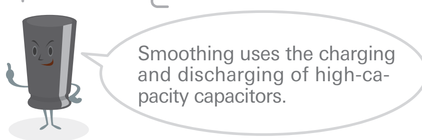
Learn the fundamentals of power supply circuits in the simple AC adapters and battery chargers.







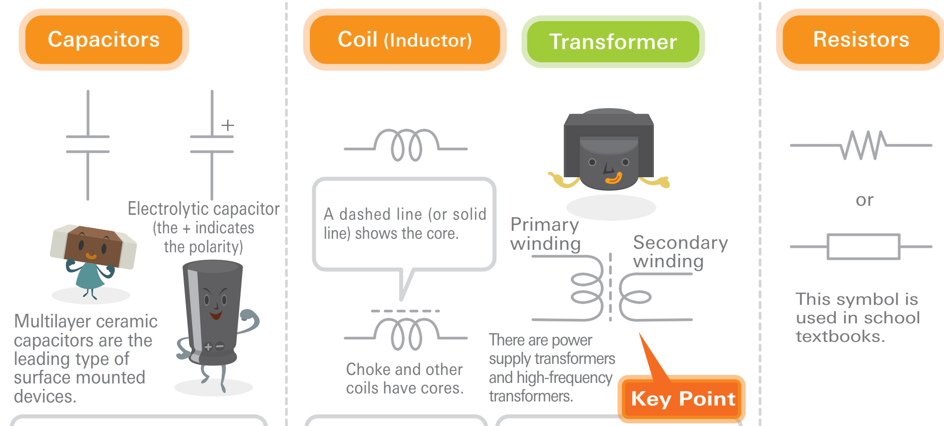
There are two types of rectification: half-wave rectification that rectifies the alternating current flowing in one direction, and full-wave rectification that rectifies the current in both directions. The circuit shown above is full-wave rectification using bridge diodes.



The Functions of Main Components

In order to understand the structure of a power supply, it is necessary to know the functions of its main components. If you become familiar with the symbols used for circuits, you will be able to decipher the basic structure of a power supply circuit.

Capacitors (C), Coils (L), and Resistors (R) Are the Three Main Passive Components.

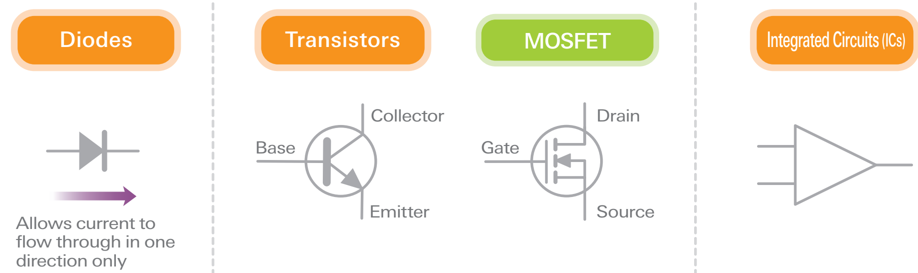


Storing large amounts of electrical charge is the role of a smoothing capacitor in a power supply. The capacitor functions like a battery that can be charged and discharged instantaneously. They also have the property of allowing alternating current to pass through.

Coils allow direct currents to pass through smoothly, but they act as resistors to alternating current and store electrical energy.

Electrical power on a primary side passes through a core and is sent to the secondary side. At this time, losses known as core losses (mainly thermal losses) occur, and as a result, the properties of the core material have a large impact on the efficiency of the power supply.

Semiconductor elements used in power supply circuits are referred to as power semiconductors.



Diodes are elements that have the property of allowing the electric current to flow through in one direction only. They are used in rectification and other circuits.

Transistors are semiconductor elements that have amplification functions. They are used in power supply circuits as switching elements that turned the current ON and OFF. A MOSFET is a field effect transistor that uses metal oxide semiconductors.

An integrated circuit is made up of multiple transistors, the diodes, resistors, and other components mounted on a semiconductor board (made of silicon or other material).

Diodes play an important role in rectification circuits, and capacitors are important for smoothing circuits.

Capacitors allow alternating current to pass through, while coils prevent alternating current from passing.

Creating Optimal Power Supply Systems

Switching power supplies (AC-DC power supplies) and DC-DC converters are available in numerous different formats with various sizes, capacities, shapes, and so on. DC-DC converters are broadly divided into **insulation types** and **non-insulation types**. Insulation types use transformers (to prevent electric shocks), while non-insulation types are more compact and do not use transformers. **Power modules** that integrate numerous components onto a single compact board are also frequently used.

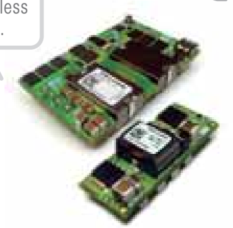
DC-DC converter

- **Non-insulation type**: Used after insulated converters to convert voltage to the voltage necessary to operate circuits. These converters are compact and low cost.
- **Insulation type**: Uses a transformer and is electrically insulated. It is difficult to make these converters compact or at low cost.

Non-insulation type DC-DC converters are often compact SMD (surface mounted device) types. Output of such converters ranges from less than 1 watt to hundreds of watts.

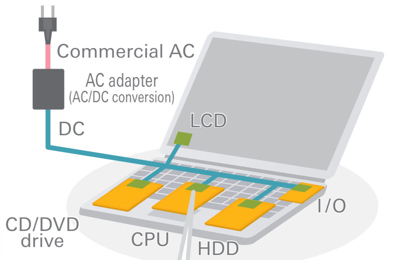
Non-insulation type DC-DC converters

DC input DC output



Insulation type DC-DC converter

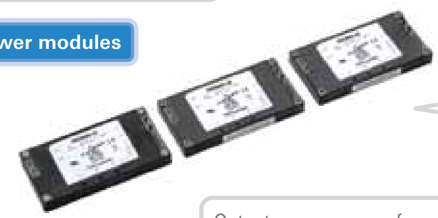
Output ranges from about 1 watt to hundreds of watts



Notebook PCs use multiple compact DC-DC converters to convert voltage to the necessary voltage and supply it to components.

AC-DC power modules

AC input DC output



These power modules integrate an AC-DC converter and a DC-DC converter. They use conduction cooling and do not need a cooling fan. Output power is in the 50 W to 1000 W range.

AC-DC power supplies

Output power ranges from under 10 W to 3000 W and higher. There are various types including wide input and multi-output.

Unit type

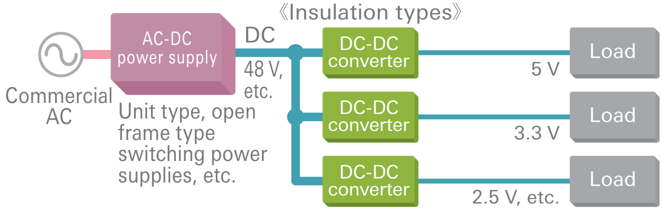
Open frame type

Unit type (rack-mount type)

Distributed Power Supply Systems and Power Modules

In recent years, **ICs have moved to operating at lower voltages and higher currents**, resulting in a shift to distributed power supply systems with compact, high-efficiency **DC-DC converters** installed in the vicinity of the ICs.

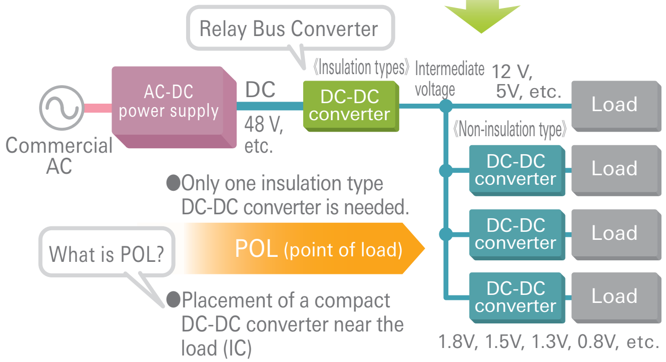
<Earlier Power Supply Systems>



Problems with Earlier Systems

- Using multiple insulation type DC-DC converters is a problem in terms of cost and space.
- ICs are operating on lower voltages, but it is not efficient to suddenly reduce the voltage.
- At higher frequencies, the wire resistance to the load and effects of inductance increase.

<Distributed Power Supply System>



Advantages of Distributed Power Supply Systems

Key Point

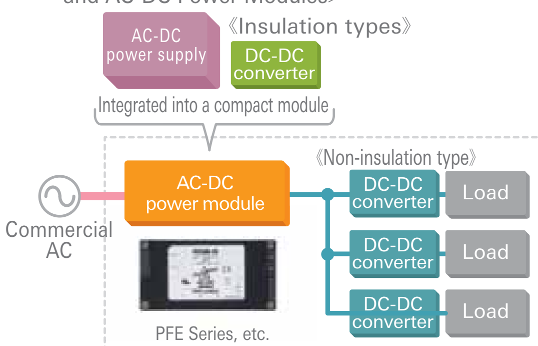
High-efficiency non-insulation type DC-DC converters generate little heat and do not require heat sinks, and as a result, can be mounted near ICs on printed circuit boards.

Power modules can be used to create simple and compact distributed power supply systems.

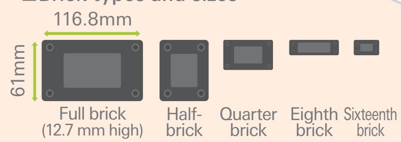
AC-DC power modules integrate AC-DC converters, DC-DC converters, PFHC (power factor and harmonic correction) functions (see page 17), and various other power supply circuits. Such power modules make possible a variety of flexible distributed power supply systems.

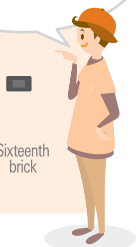
Power modules are standardized using units called **bricks**.

<Distributed Power Supply Systems and AC-DC Power Modules>



■Brick types and sizes





Key Point

Power modules are high efficiency and use **conduction cooling and as a result do not need a cooling fan**. This means that all power supply devices can be mounted on the same printed circuit board.

Non-insulation type DC-DC converters are compact onboard power supplies.

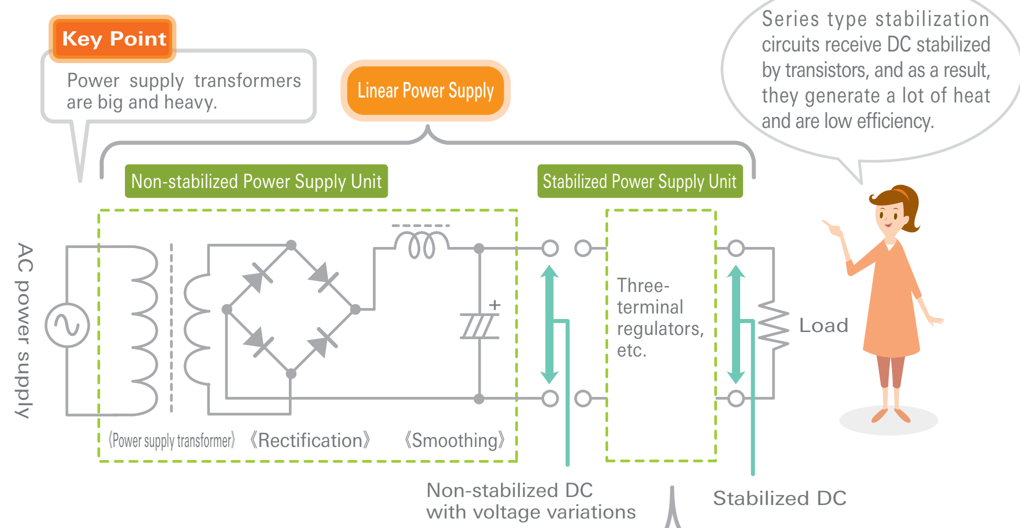
Point of Load means in the immediate vicinity of the load (ICs, etc.)

Structure of Linear Power Supplies

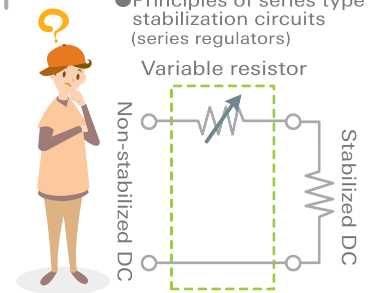
Even after commercial AC is rectified and smoothed, the DC that is produced is not stable (see page 7). A stabilization circuit converts this to DC with little variation in voltage. Let' s first examine a linear type **stabilization circuit**, which was once the most common type of stabilization circuit.

Linear power supplies require large and heavy power supply transformers.

<Linear Power Supplies Use Three-Terminal ICs>

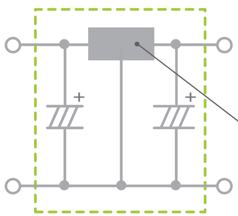


●Principles of series type stabilization circuits (series regulators)



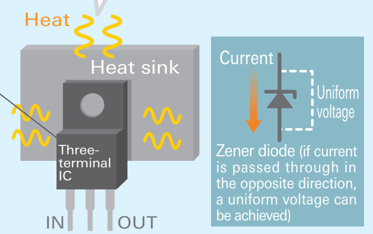
Variations in the input voltage are adjusted by a variable resistor to produce stabilized output voltage.

●Stabilization circuit using three-terminal ICs (three-terminal regulator)



The three-terminal ICs play the same role as the variable resistor.

Key Point Heat is generated, so a **heat sink** is needed.



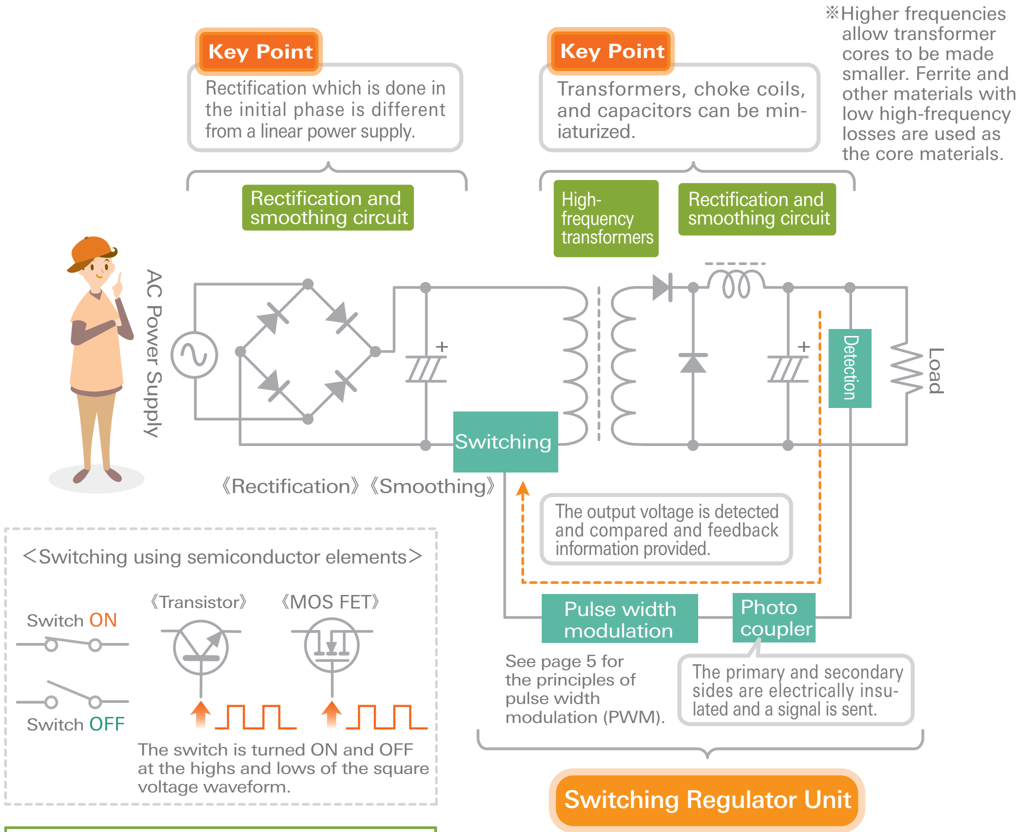
Three-terminal ICs are integrated circuits made from transistors, Zener diodes, and other components. They generate heat, so a heat sink is attached.

Key Point Linear power supplies place resistors in series to control the current, so they are also called **series power supplies**. They use resistance to reduce the voltage, so they are also called **dropper** and **series dropper** power supplies.

Structure of Switching Power Supplies

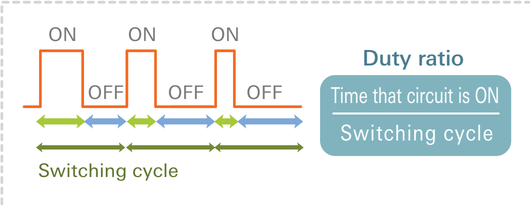
Non-stabilized DC power that has been rectified is converted to high-frequency pulses by a switching element (a transistor or MOSFET) using high-speed switching and sent to a transformer. The output voltage is detected and compared and feedback data provided to control the pulse widths to produce stable DC. Switching power supplies are **compact, lighter, and higher efficiency than linear power supplies**, but the **circuits are more complex** and the high-speed switching generates noise, so noise countermeasures are essential.

Feedback control of the pulse width makes possible the generation of DC power with a uniform voltage.



Principles of Switching Regulators

The current is turned ON and OFF by switching elements at set intervals, converted to a pulse wave, and sent to a transformer. A comparison of the timing of the ON status and OFF status (duty ratio, duty cycle) is used to control the output voltage. By controlling the duty ratio (pulse width) in relation to variations in the input voltage, the output voltage is stabilized (PWM method).



Linear power supplies are fundamentally low efficiency and have high thermal losses.

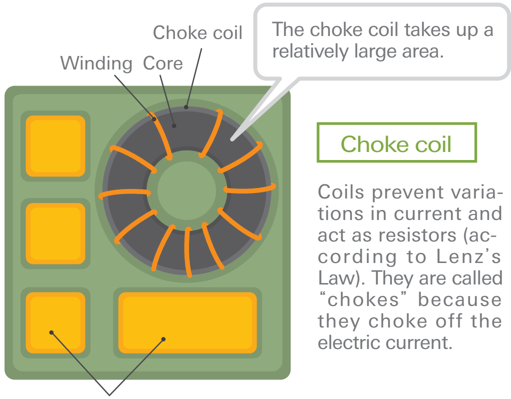
The key features of switching power supplies are compact size, light weight, and high efficiency.

Basic Circuits of Non-Insulation Type DC-DC Converters

There are various forms of non-insulation type DC-DC converters also. A form known as the **chopper format** is a compact onboard type with output power in the range of less than 1 watt to several watts. Types of chopper converters include the **step down** back converter and the **step up** boost converter. Each type is suitable for configuring a compact, low-cost local power supply with a low parts count. An even more simple approach is the charge pump type which uses only capacitors but no coils or transformers.

Chopper type — Compact, onboard types with low output

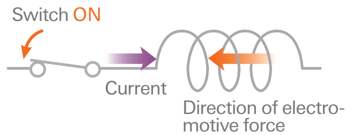
<Example of component mounting for compact onboard DC-DC converters (chopper type)>



Choke coil

Coils prevent variations in current and act as resistors (according to Lenz's Law). They are called "chokes" because they choke off the electric current.

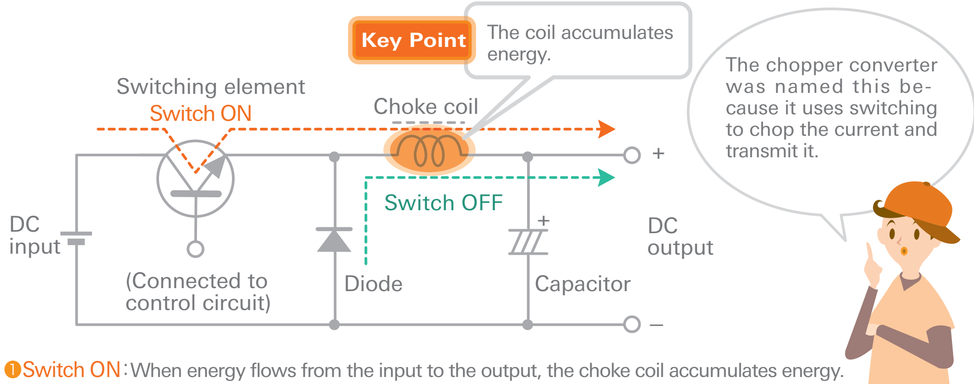
<Switching and Operation of the Coil>



When the switch is ON, the coil generates electromotive force in a direction that prevents current from flowing in.

When the switch is turned off, the coil generates electromotive force in the direction as if to maintain the current.

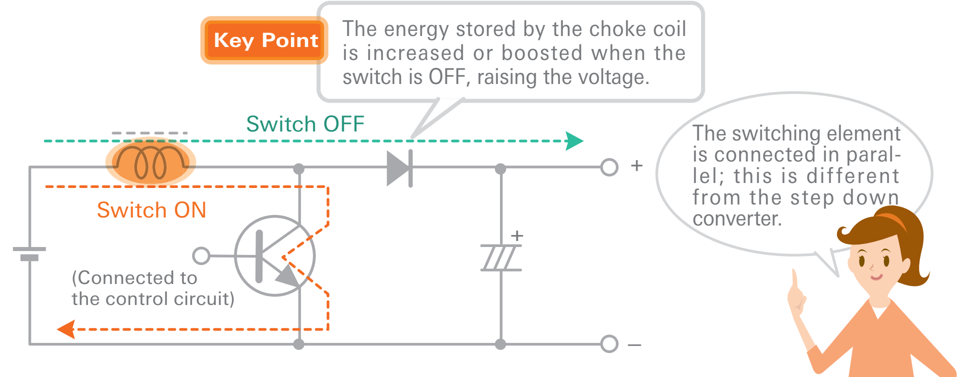
Back Converter (Step Down) — Input voltage > Output voltage



❶Switch ON: When energy flows from the input to the output, the choke coil accumulates energy.

❷Switch OFF: The choke coil generates electromotive force in an attempt to maintain the current and current flows through the diode to the output (the switching element is connected in series with the circuit; the needed voltage can be reduced by setting the duty cycle).

Booster Converter (Step Up) — Input voltage < Output voltage



❶Switch ON: When energy flows from the input to the output, the choke coil accumulates energy.

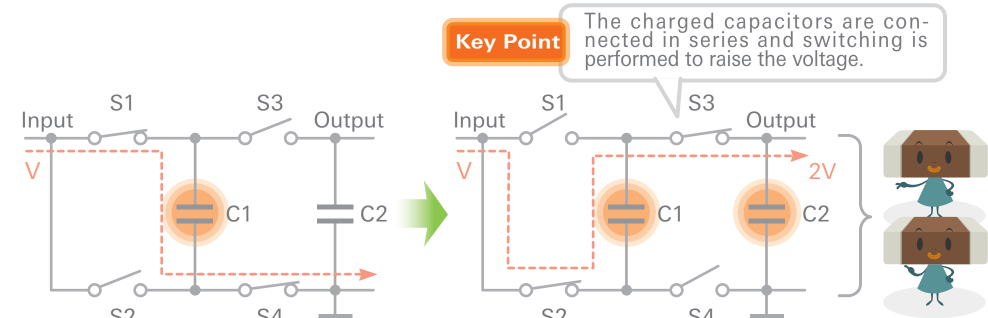
❷Switch OFF: The choke coil releases the stored energy in an attempt to maintain the current.

* There is also a back boost format that combines the functions of the back converter and the boost converter. This converter is characterized by the ability to reverse the polarity.

Charge Pump Type — Low-output type that uses capacitors

Capacitors are also known as condensers because their basic function is to store electric charge. The charge pump type converter makes use of this function. They are compact, simple DC-DC converters that do not use any transformers or coils and use only capacitors to convert voltage. The electric charge stored in the capacitor is carried by switching as if in a bucket relay to increase the voltage.

<Basic Principles of Charge Pump Type DC-DC Converters (step up type)>



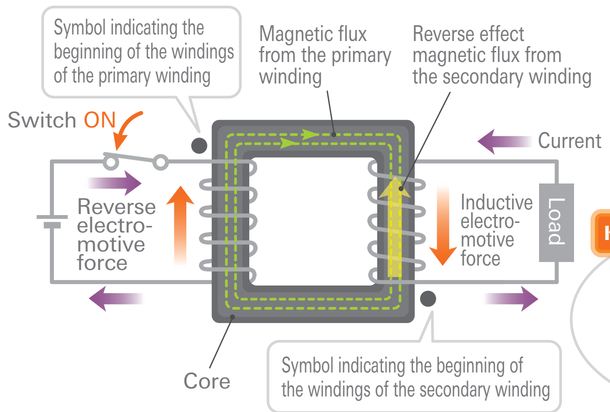
S1 and S4 are turned ON and C1 is charged (actual switching is performed through IC operation).

When S1 and S4 are OFF and S2 and S3 are ON, the charge in C1 is carried to C2 and the output has twice the voltage.

Basic Circuits of Insulation Type DC-DC Converters

Insulation type DC-DC converters actively use transformers and support high output power. Understanding the basic principles and core circuits will deepen your understanding.

<Principles of Transformers and Direction of Electromotive Force>

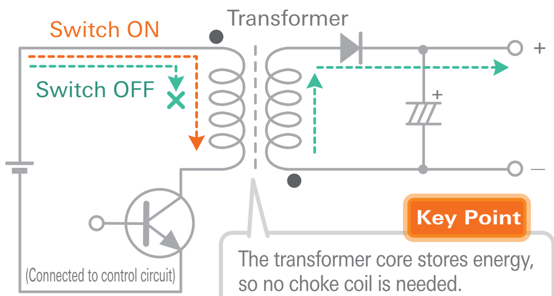


When the switch is ON, magnetic flux is generated by the primary winding, but electromotive force (reverse electromotive force) is generated to prevent the magnetic flux from doubling. The magnetic flux from the primary winding passes through the core and reverse effect magnetic flux from the secondary winding is generated, creating electromotive force (inductive electromotive force) and current (inductive current) flows. When the switch is OFF, the current flows in the opposite direction.

Key Point

The direction of the electromotive force from the primary and secondary windings (reverse electromotive force and inductive electromotive force) is towards the gray circle (●).

Flyback Converter — Low and Medium Output Power Types



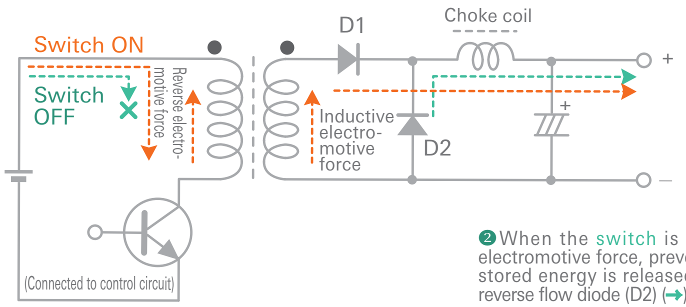
Key Point

The transformer core stores energy, so no choke coil is needed.

❶When the switch is ON, current flows in the primary winding (→) and the core is magnetized from the generated magnetic flux (energy storage). The direction of the diode is reversed, so no inductive current flows through the secondary winding.

❷When the switch is OFF, the energy accumulated in the core is released and current flows through the diode (→). The transformer coil plays a role similar to that of the choke coil.

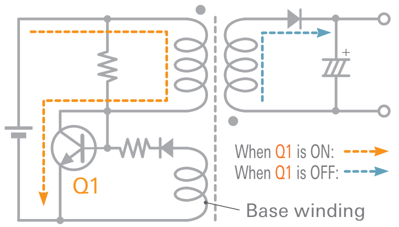
Forward Converter (Single-switching type) — Medium Output Power Type



❶When the switch is ON, electromotive force (reverse electromotive force and inductive electromotive force) is generated in the primary and secondary windings as a result of the transformer principle and current flows through the diode (D1) (→). At this time, energy is stored in the choke coil.

❷When the switch is OFF, the choke coil generates electromotive force, preventing changes in the current, the stored energy is released, and current flows through the reverse flow diode (D2) (→).

RCC Type (self-exciting flyback converter) — Low Output Power Types

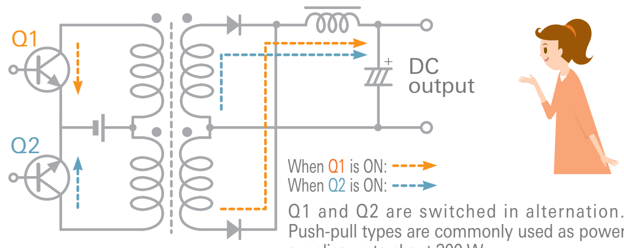


*A gap is placed in the transformer core to prevent magnetic saturation (See page 19).
*RCC : Ringing Choke Converter

When Q1 is ON as a result of the base current from the base winding, collector current flows. When the base current is insufficient and Q1 is OFF, current flows on the secondary side. The converter is a self-exciting type that performs this operation repeatedly. It requires only a small number of components and can be used as a simple, low output power power supply.

Medium to high output power types use multiple switching devices which makes the circuit configuration more complex but enables higher efficiency, lower noise, and advanced functionality.

Push-Pull Type — Medium to High Output Power Types

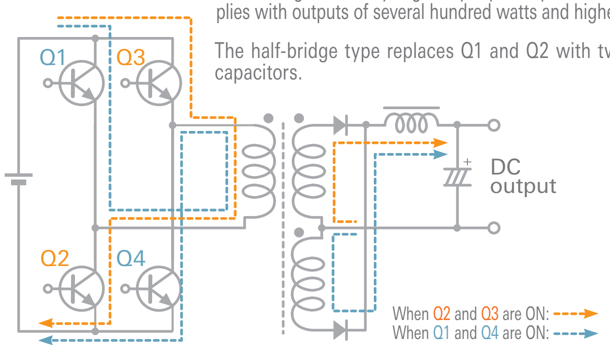


Q1 and Q2 are switched in alternation. Push-pull types are commonly used as power supplies up to about 300 W.

Full-Bridge Type — Medium to High Output Power Types

Used as high-efficiency, high output power power supplies with outputs of several hundred watts and higher.

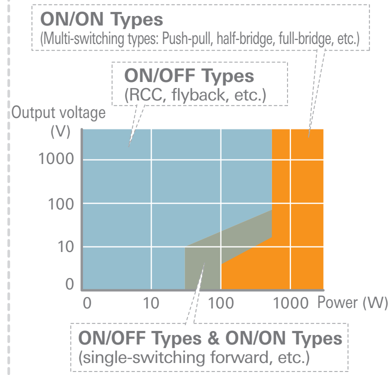
The half-bridge type replaces Q1 and Q2 with two capacitors.



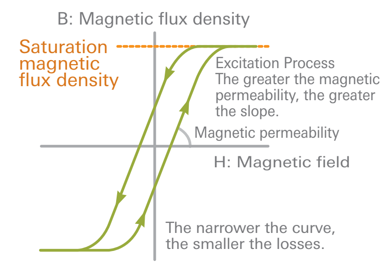
ON/ON Types and ON/OFF Types

DC-DC converters are available in ON/ON types that output energy when the switching elements are on and ON/OFF types that output energy when the switching elements are off.

Types by Output Voltage and Power



B-H Curves of Magnetic Cores



Comparison of Performance of Core Types

	Silicon	Ferrite	Amorphous
Magnetic permeability	Acceptable	Good	Excellent
Saturation magnetization	Excellent	Acceptable	Acceptable
Iron losses	Poor	Excellent	Excellent
Manufacturing cost	Acceptable	Excellent	Poor

The transformer is the key component of insulation type DC-DC converters.

Iron cores generate high losses (thermal losses) at high frequencies, so they are not used.

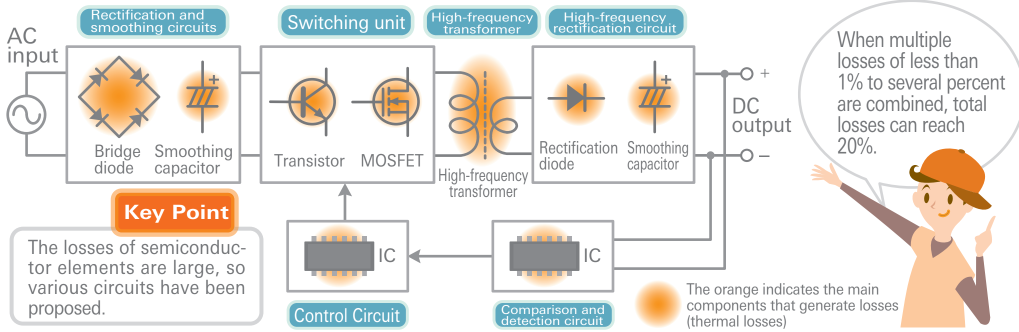
Technologies for Improving Efficiency

If the efficiency of power supplies could be increased by just one percent, this would have a tremendous energy-saving impact on society as a whole. Some new technologies for improving energy efficiency are discussed below.

Areas of Loss in Switching Power Supplies

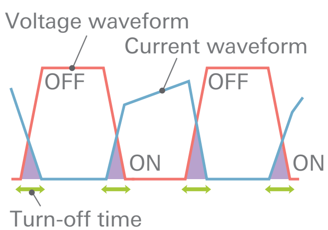
The properties of the transformer core material have a major impact on efficiency. Using accumulated ferrite technologies is one of TDK's strengths.

<Main areas of loss (thermal losses) in AC-DC switching power supplies>



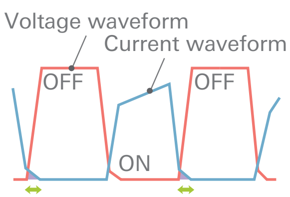
Soft Switching

Normal switching (hard switching)



The areas of overlap are switching losses (voltage × current).

Soft Switching



The areas of overlap are reduced and dead times created to reduce switching losses.

Soft switching is an advanced technology that precisely controls the timing of the ON and OFF switching to reduce switching losses. There is the **zero voltage switching (ZVS) method**, which performs switching with the voltage at zero, and the **zero current switching (ZCS) method**, which performs switching with the current at zero.

In response to the use of higher frequencies, a technology known as **resonant power supply** that uses the resonance of a coil and a capacitor to perform switching is also starting to be applied in practical applications.

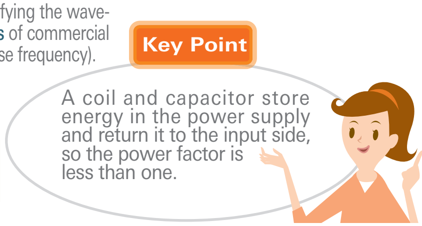
Power Factor and Harmonic Correction (PFHC) Circuits

This technology improves the **power factor** by rectifying the waveform through control of the **high-frequency portions** of commercial AC (the portions that are integral multiples of the base frequency).

Efficiency and Power Factor of a Power Supply

Efficiency = Output power (W) / Input power (W)

Power factor = Effective power (W) / Apparent power (VA)



A power module that integrates an AC-DC converter with PFHC and a DC-DC converter

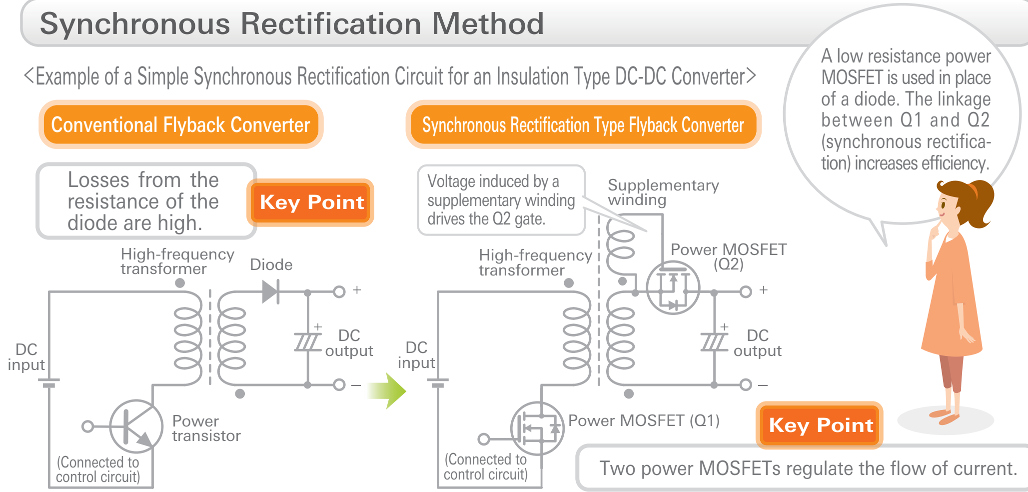
PFE Series

(The apparent power is the product of the values obtained from a voltmeter and an ammeter. It is the power that appears to be present.)

In the switching power supplies, the semiconductor elements in particular generate high losses. Also, the power supplies are compact, and as a result if the frequency of the switching operation is increased, losses also increase. Research to solve these problems is being conducted on the front-lines of power supply technology.

Synchronous Rectification Method

<Example of a Simple Synchronous Rectification Circuit for an Insulation Type DC-DC Converter>



Digital Control

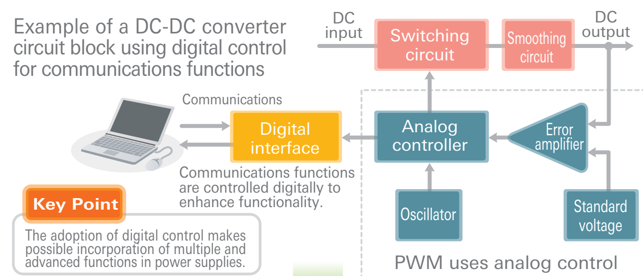
Digital control of power supplies began in communications fields and is progressing towards **full digital control** including control circuits.

Benefits of full digital control

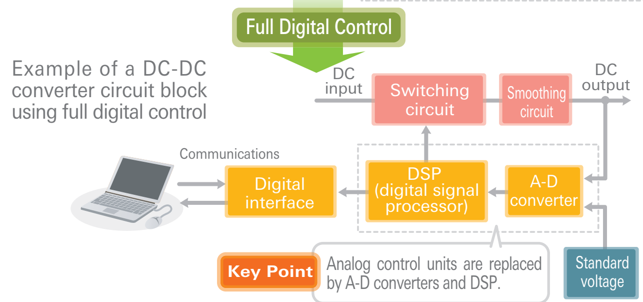
- Power supply information such as the input and output voltage, output current, and temperature can be displayed on a PC in real time.
- Energy savings are possible through precise control of the output.
- A soft start function to prevent damage to semiconductor elements from inrush current is possible.
- POL power management for the distributed placement of multiple DC-DC converters is beneficial.
- The number of components can be reduced.

* In 2005, we launched full digital control DC-DC converters with DSP (Digital Signal Processing). Currently, AC-DC power supplies using digital control are being developed for market introduction in the near future.

Example of a DC-DC converter circuit block using digital control for communications functions



Example of a DC-DC converter circuit block using full digital control



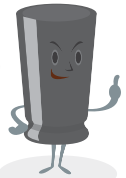
Key Parts That Support Power Supply Performance

Switching power supplies contain semiconductor elements such as diodes, transistors, MOSFETs, and ICs, while passive components such as capacitors, coils, and transformers also play important roles.

Capacitors (electrolytic capacitors, film capacitors, multilayer ceramic chip capacitors)

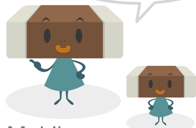
Multilayer ceramic chip capacitors are compact and offer high reliability and long life spans. There are also high capacity types that encroach on the territories of film capacitors and electrolytic capacitors. Multilayer ceramic chip capacitors are important as EMC countermeasure components (noise countermeasure components).

Since the capacity is high, capacitors are used for smoothing.

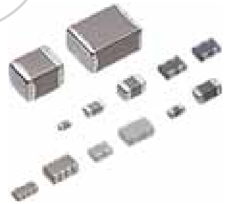


Aluminum electrolytic capacitors

Such capacitors are characterized by their compact size, high reliability, and longer life spans. They also have excellent high-frequency characteristics.



Multilayer ceramic chip capacitor

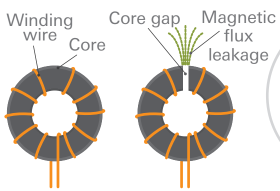


Coils (choke coils, SMD power coils) and Transformers (high-frequency transformers)

Switching power supplies use numerous transformers other than the main transformer as well as coils. Mobile phones and other devices use SMD (surface mounted device) type compact power coils. The characteristics of the core material have a substantial impact on making power supplies more efficient as well as making them smaller, slimmer, and lighter.

Choke Coils

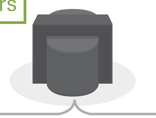
Examples of choke coil cores (toroidal cores)

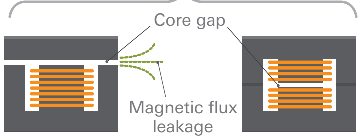


A gap is placed in the core to prevent magnetic saturation.

The magnetic flux leaking from the gap can cause noise, so shielding must be used.

Transformers



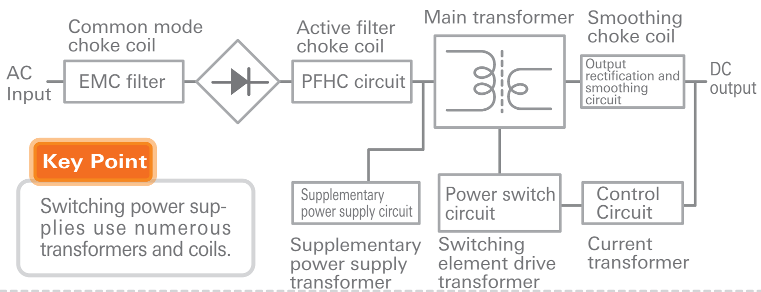


●EI Core

The characteristics can be controlled by adjusting the gap. Magnetic shielding is needed as a countermeasure against the magnetic flux leaking from the gap.

●EE Core

The effects from magnetic flux leakage can be minimized by creating a gap in the center pole.



Key Point

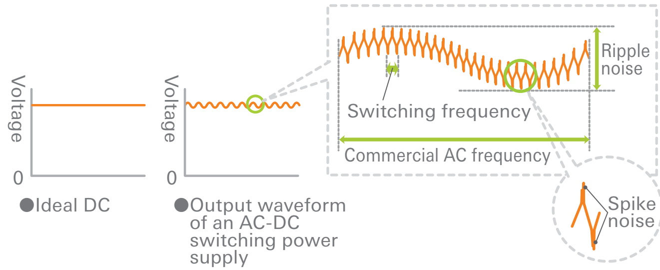
Switching power supplies use numerous transformers and coils.

Winding bobbins, transformer exteriors, and ferrite cores (various types including EE cores and EI cores)

Noise Countermeasures in Switching Power Supplies

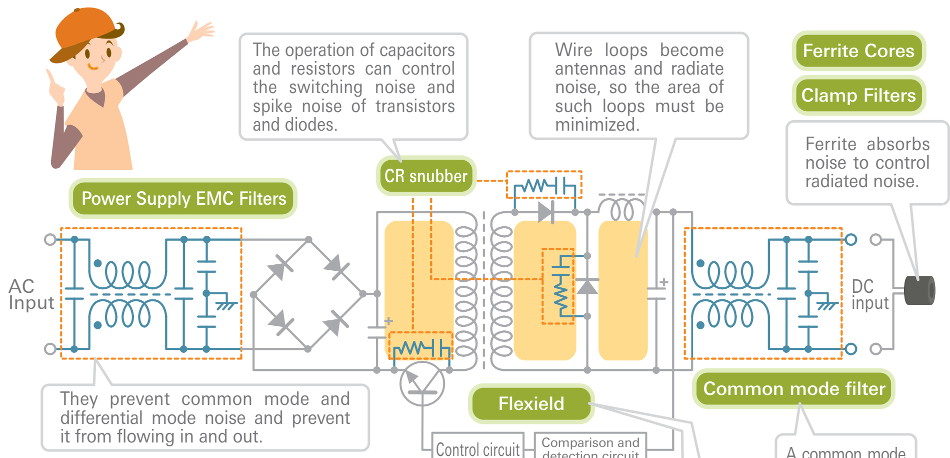
One of the weak points of switching power supplies is the generation of electromagnetic noise. TDK provides total EMC solutions that support all aspects of noise control from input to output and include various EMC countermeasure components (noise countermeasure components) and noise measurement in anechoic chambers.

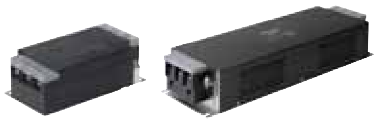
<Noise Unique to Switching Power Supplies (AC input)>



EMC countermeasures implemented from the design and development stages reduce total costs.

<Examples of EMC countermeasures for switching power supplies (AC input)>





《EMC Filters for Power Line》

Other Sources of Noise

- ●Noise generated by transistors and diodes is also radiated from heat sinks designed to release thermal energy.
- ●Magnetic flux leakage from transformers and choke coils can cause eddy current in metal cases, generating noise.
- ●Wires and components where large currents are turned ON and OFF. The inductor portion of wire leads can also have an impact, so wiring and leads are made as short as possible.

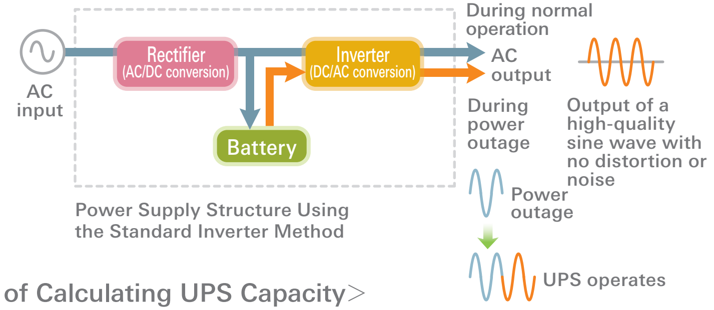
Advanced circuit design and simulation technologies are needed.

Uninterruptible Power Supplies

Uninterruptible power supplies (UPS) are used to prevent unforseen information system downtime caused by various interruptions to power supplies such as power outages, drops in voltages, and distortions to commercial AC waveforms. There are many types of UPS available depending on the application.

Main Power Supply Methods of UPS

- ●Standard commercial type (square wave output)
- ●Line interactive type (sine wave output)
- ●Standard inverter type (sine wave output; connection is instantaneous, so there is no interruption of the wave form)



Power Supply Structure Using the Standard Inverter Method

<Method of Calculating UPS Capacity>

- Total capacity (VA) = (Total capacity of indicated VA of device) + (Total capacity of indicated W of device / 0.6)
- Total capacity (W) = (Total capacity of indicated VA of device × Power factor*) + (Total capacity of indicated W of device)

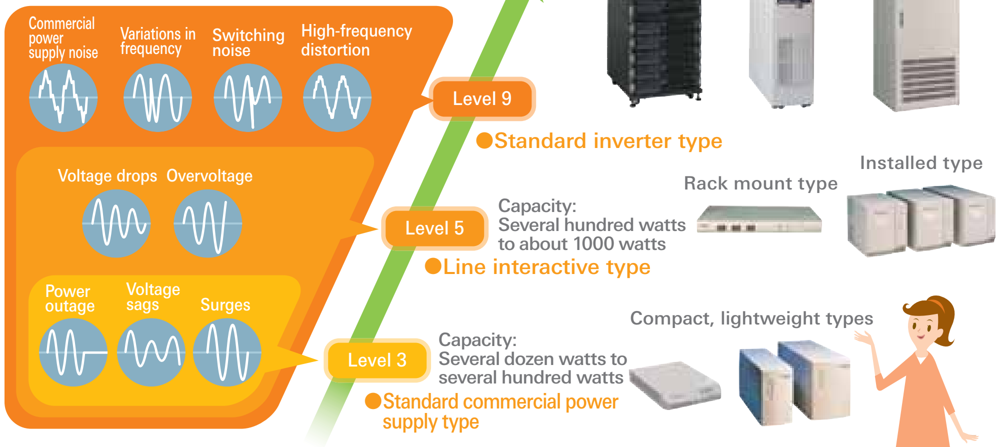
→ 10% to 30% additional capacity is added on top of total capacity (VA) and total capacity (W) → Select a UPS with a capacity larger than both of the calculated figures. It is necessary to have extra margin during a power outage.

If V and A are indicated, multiply them (e.g., 100 V & 1.8 A --> 180 VA)
* Power factors will vary depending on the device. They are generally in the range of 0.6 to 0.8.

There are many different types of UPS available with various capacities and power supply interruption levels.

<Power supply interruption types and TDK-Lambda UPS categories>

Key Point Select the UPS that is optimal for the power supply interruption types and the necessary capacity.



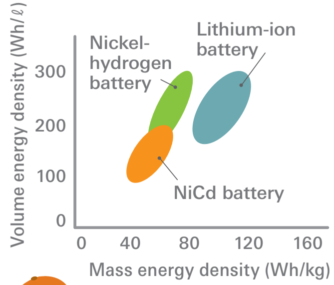
The levels according to the number of power supply interruptions that the UPS can protect against and the corresponding power supply formats.

New Power Supply Systems and Batteries

Recently, UPS batteries have been changing from conventional lead storage cells to **lithium-ion batteries**, and UPS units are rapidly becoming smaller and lighter and have longer life spans. Batteries will also be the key to the proliferation of electric automobiles such as hybrid electric vehicles (HEV).

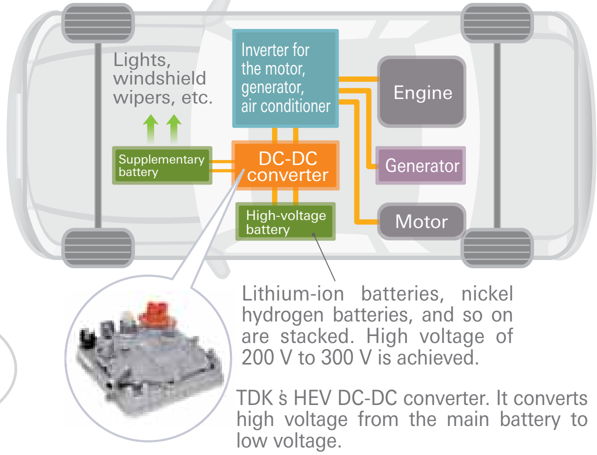
Batteries are a key technology used in electric automobiles (hybrid electric vehicles and electric vehicles).

<Energy Density of Secondary Batteries>



Key Point Saving on batteries requires high-efficiency **onboard DC-DC converters**.

<Basic Mechanism of an HEV (using a parallel format as an example) and DC-DC Converter>



Lithium-ion batteries, nickel hydrogen batteries, and so on are stacked. High voltage of 200 V to 300 V is achieved.

TDK's HEV DC-DC converter. It converts high voltage from the main battery to low voltage.

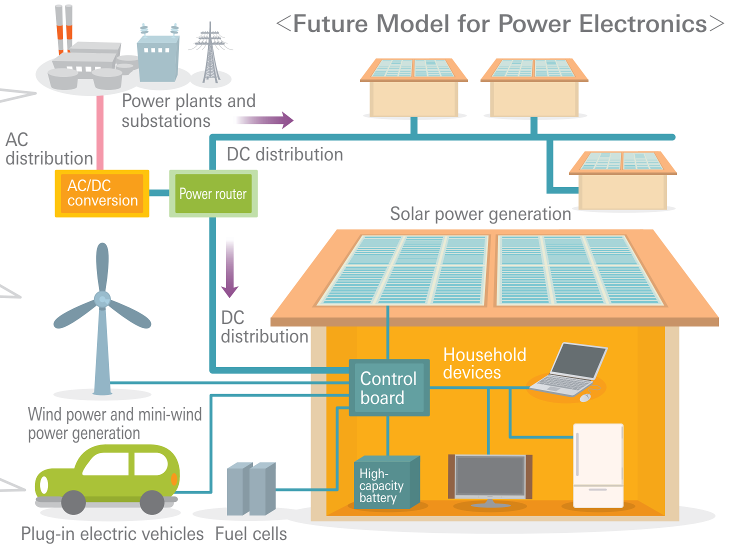
Lithium-ion batteries can be useful for the full-scale utilization of natural energy sources.

<Future Model for Power Electronics>

Electronic devices operate on DC, and there is the idea of supplying offices and homes with DC as well.

Energy from wind and solar power is initially stored in lithium-ion batteries.

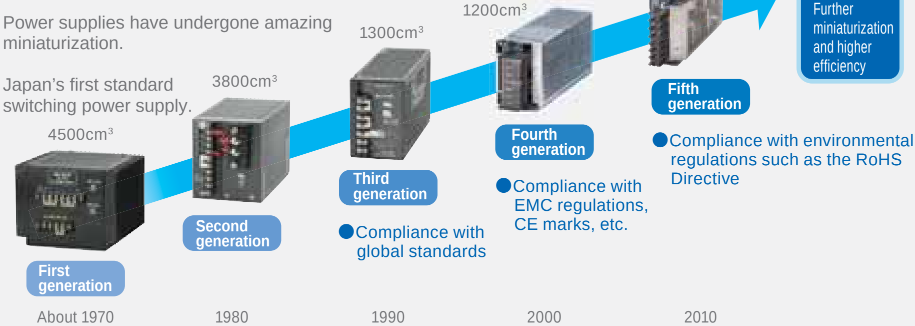
Plug-in hybrids that can be charged from a regular outlet are also appearing on the market.



Switching Power Supply Development History

About 1960	Stabilized power supplies using vacuum tubes were common at this time.
	America's NASA began developing switching power supplies for use in space craft.
About 1965	Development of semiconductor elements for switching power supplies begins.
About 1970	TDK and Nippon Electronic Memory Industry Co. Ltd. (predecessor to Nemic-Lambda) enter the switching power supply business.
1972	Nippon Electronic Memory Industry Co. Ltd. manufactures and markets Japan's first standard switching power supply.
	TDK manufactures and markets switching power supplies.
1974	Switching power supplies are adopted for use in commercial television games and the switching power supply market expands.
1976	TDK manufactures and markets switching power supply transformers.
1978	Nemic -Lambda (predecessor to Densei-Lambda) founded, to take over operations of Nippon Electronic Memory Industry Co. Ltd.
1995	TDK begins production of DC-DC converters for use in HEVs.
2000	TDK launches the RKW and JBW series of switching power supplies.
2004	Densei-Lambda (the predecessor to TDK-Lambda) launches the HWS series of switching power supplies.
2005	Densei-Lambda joins the TDK Group.
	Sales of UPS with lithium-ion batteries (lead-free) begin.
2006	Sales of TDK-Lambda brand products begin.
	TDK and Densei-Lambda market a total of 234 types of EMC filters for power line in 13 series.
	All models available on the market comply with the RoHS Directive.
2008	TDK-Lambda Corporation launched.

Advances in Switching Power Supplies (unit type, 150 W comparison)



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