### Switching Power Supply Development History

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>About 1960</td>
<td>Stabilized power supplies using vacuum tubes were common at this time. America’s NASA began developing switching power supplies for use in spacecraft.</td>
</tr>
<tr>
<td>About 1965</td>
<td>Development of semiconductor elements for switching power supplies begins.</td>
</tr>
<tr>
<td>About 1970</td>
<td>TDK and Nippon Electronic Memory Industry Co. Ltd. (predecessor to Nemic-Lambda) enter the switching power supply business.</td>
</tr>
<tr>
<td>1972</td>
<td>Nippon Electronic Memory Industry Co. Ltd. manufactures and markets Japan’s first standard switching power supply.</td>
</tr>
<tr>
<td>1974</td>
<td>TDK manufactures and markets switching power supplies.</td>
</tr>
<tr>
<td>1976</td>
<td>TDK manufactures and markets switching power supply transformers.</td>
</tr>
<tr>
<td>1978</td>
<td>Nemic-Lambda (predecessor to Densei-Lambda) founded, to take over operations of Nippon Electronic Memory Industry Co. Ltd.</td>
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<td>1995</td>
<td>TDK begins production of DC-DC converters for use in HEVs.</td>
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<td>Sales of UPS with lithium-ion batteries (lead-free) begin.</td>
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</table>

### Advances in Switching Power Supplies

<table>
<thead>
<tr>
<th>Generation</th>
<th>Power Supply Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>4600 cm³</td>
</tr>
<tr>
<td>Second</td>
<td>3600 cm³</td>
</tr>
<tr>
<td>Third</td>
<td>1200 cm³</td>
</tr>
<tr>
<td>Fourth</td>
<td>550 cm³</td>
</tr>
<tr>
<td>Fifth</td>
<td>450 cm³</td>
</tr>
</tbody>
</table>

- Compliance with environmental regulations such as the RoHS Directive
- Compliance with EMC regulations, CE marks, etc.
- Further miniaturization and higher efficiency
- Next generation

### Compliance with environmental regulations

<table>
<thead>
<tr>
<th>Year</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>RoHS Directive</td>
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</table>
Welcome to Power Electronics World

Contents

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- What Is Direct Current (DC)? What Is Alternating Current (AC)?
- There Is No Such Thing as Perfect DC or AC
- Why Are Stabilization Circuits Needed?
- Power Supply Devices Play a Variety of Different Roles
- What Is Rectification? What Is Smoothing?
- The Functions of Main Components
- Creating Optimal Power Supply Systems
- Distributed Power Supply Systems and Power Modules

Technology Section

- Structure of Linear Power Supplies
- Structure of Switching Power Supplies
- Basic Circuits of Non-Insulation type DC-DC Converters
  - Chopper Type (Back Converter, Boost Converter), Charge Pump Type
- Basic Circuits of Insulation type DC-DC Converters
  - Flyback Converter, Forward Converter, RCC Type, Push-Pull Type, Full-Bridge Type
- Technologies for Improving Efficiency
  - Areas of Loss in Switching Power Supplies, Soft Switching, Power Factor and Harmonic Correction (PFHC) Circuits, Synchronous Rectification Method, Digital Control
- Key Parts That Support Power Supply Performance
  - Capacitors, Coils and Transformers
- Noise Countermeasures in Switching Power Supplies
- Uninterruptible Power Supplies
- New Power Supply Systems and Batteries
- Switching Power Supply Development History
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 has uniform direction of flow and amount (voltage) of electricity.

**AC is an abbreviation for alternating current.**

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

**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. In general, high frequency means AC with a frequency in the kilo-Hertz, mega-Hertz, or higher range.

**The voltage of a battery falls steadily. The discharge curves vary depending on the type of battery.**

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.

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

---

**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>**

- **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.

**<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).
Why Are Stabilization Circuits Needed?

The DC from a battery or converted from commercial AC using an adapter 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.

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.

Unstable DC can cause electronic devices to malfunction. Devices that convert direct currents to alternating currents are called inverters.
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.

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.

1. **Capacitors (C), Coils (L), and Resistors (R) Are the Three Main Passive Components.**
   - Capacitors: store and release energy, smoothing the current.
   - Coils (Inductors): prevent alternating current from passing and allow direct current to pass smoothly. They store electrical energy.
   - Resistors: limit current flow and convert energy into heat.

2. **Diodes**
   - Allow current to flow in one direction only.
   - Rectify the alternating current into direct current.

3. **Transistors**
   - Switch the current ON and OFF.
   - Used as amplifiers in power supply circuits.

4. **MOSFET**
   - A field effect transistor that uses metal oxide semiconductors.

5. **Integrated Circuits (ICs)**
   - Made up of multiple transistors, diodes, resistors, and other components mounted on a single chip of silicon or other material.

6. **Transformers**
   - Change the alternating current and voltage level.
   - Power supply transformers and high-frequency transformers.

---

**Key Point**
- Rectification is half-wave rectification using bridge diodes.
- 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.

Earlier Power Supply Systems

Today, 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.

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.

Advantages of Distributed Power Supply Systems

- 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.

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 >

Insulation types

- Only one insulation type DC-DC converter is needed.
- Placement of a compact DC-DC converter near the load (IC) is possible.

Non-insulation type

- DC-DC converters are compact onboard power supplies.

Advantages of Distributed Power Supply Systems

- 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.

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.
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.

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).

Key Point

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)**
- **Switching and Operation of the Coil**
  - Switch ON: When energy flows from the input to the output, the choke coil accumulates energy.
  - Switch OFF: The choke coil releases the stored energy in an attempt to maintain the current.

**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.

**Diodes, capacitors, control ICs, etc.**

---

### 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.

**Input voltage > Output voltage**

- **Switch ON**: The charged capacitors are connected in series and switching is performed to raise the voltage.

**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.**

---

### Key Points

- The choke coil plays an important role in chopper type converters.
- Coils and capacitors have the ability to store energy.
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). 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 grey circle.

Flyback Converter

Low and Medium Output Power Types

When the switch is ON, current flows in the primary winding and the core is magnetized. When the switch is OFF, the energy accumulated in the core and current flows through the diode. The transformer coil plays a role similar to that of the choke coil.

Key Point

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

Forward Converter (Single-switching type)

Medium Output Power Type

When the switch is ON, electro-motive force is generated in the primary and secondary windings as a result of the transformer principle. When the switch is OFF, the choke coil generates electromagnetic force, preventing changes in the current, and the stored energy is released, and current flows through the reverse flow diode (D2).

Key Point

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

RCC Type (self-exciting flyback converter)

Low Output Power Types

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.

Key Point

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

Push-Pull Type

Medium to High Output Power Types

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.

Key Point

When Q1 is ON, collector current flows through 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). When the switch is OFF, the current flows in the opposite direction.

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 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.

B-H Curves of Magnetic Cores

Saturation magnetization

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.

### Soft Switching

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.

### 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).

### Synchronous Rectification Method

The low resistance power MOSFET is used in place of a diode. The linkage between Q1 and Q2 (synchronous rectification) increases efficiency.

### 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 voltages, 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 initial current is possible.
- PLL power management for the distributed placement of multiple DC-DC converters is beneficial.
- The number of components can be reduced.

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

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 frontlines of power supply technology.

*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.*
### Technology Section

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

**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.

- A gap is placed in the core to prevent magnetic saturation.
- The characteristics can be controlled by adjusting the gap. Magnetic shielding is needed to prevent magnetic flux leakage from the gap.

**Examples of choke coil cores (toroidal cores)**

- The magnetic flux leaking from the gap can cause noise, so shielding must be used.
- The effects from magnetic flux leakage can be minimized by creating a gap in the center pole.

**Examples of choke coil cores (toroidal cores)**

- The operation of capacitors and resistors can control the switching noise and spike noise of transistors and diodes.
- Wire loops become antennas and radiate noise, so the area of such loops must be minimized.

**Ferrite absorbs noise to control radiated noise.**

- A flexible electromagnetic shield material that absorbs radiated noises, converts it to heat, and eliminates it.

**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 wires leads can also have an impact, so wiring and leads are made as short as possible.

**Key Point**

Switching power supplies use numerous transformers and coils.

**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.

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

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

- The operation of capacitors and resistors can control the switching noise and spike noise of transistors and diodes.
- Wire loops become antennas and radiate noise, so the area of such loops must be minimized.
- Ferrite absorbs noise to control radiated noise.
- A flexible electromagnetic shield material that absorbs radiated noises, converts it to heat, and eliminates it.
- A common mode filter on the output line prevents noise from flowing in and out.
- Advanced circuit design and simulation technologies are needed.
Uninterruptible power supplies (UPS) are used to prevent unforeseen 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 (sinewave output)
- Standard inverter type (sinewave output; connection is instantaneous, so there is no interruption of the wave form)

**Power Supply Structure Using the Standard Inverter Method**
- Rectifier
- Battery
- Inverter

**Method of Calculating UPS Capacity**

1. Total capacity of input AC (VA)
2. Total capacity of output AC (VA)
3. Total capacity of input DC (Wh / hour)
4. Total capacity of output DC (Wh / hour)

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**

- **Level 9**
  - Standard commercial power supply type
  - Highest capacity
  - Battery: Several hundred watts to about 1000 watts
- **Level 5**
  - Line interactive type
  - Capacity: Several dozen watts to several hundred watts
- **Level 5**
  - Standard inverter type
  - Capacity: Several dozen watts to several hundred watts

UPS operates during normal operation of AC input and during power outages. Output of a high-quality sine wave with no distortion or noise.

**Uninterruptible Power Supplies**

**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**

- Lithium-ion battery
- Nickel–hydrogen battery
- Lead storage battery

**Key Point**

- Saving on batteries requires high-efficiency onboard DC-DC converters.
- 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.

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

Power electronics will play a major role in saving energy and protecting the global environment.
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.

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Nippon Electronic Memory Industry Co. Ltd. manufactures and markets Japan’s first standard switching power supply.

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
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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.

2006
Sales of UPS with lithium-ion batteries (lead-free) begin.

2008
Sales of TDK-Lambda brand products begin.

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

- Compliance with environmental regulations such as the RoHS Directive
- Compliance with EMC regulations, CE marks, etc.
- Global standards


Power supplies have undergone amazing miniaturization.

First generation
4600cm³

Second generation
3800cm³

Third generation
1300cm³

Fourth generation
1200cm³

Fifth generation
550cm³

Next generation
Further regulations and higher efficiency