History of TDK Inductors and Noise Suppression Components

1937 World’s first ferrite coil cores launched
1962 TDK’s first noise suppression device, “Synchron S Socket,” launched
1964 Linearity coils for color TV’s launched
1965 Line filters for color TV’s launched
1972 Feed-through noise filter FN for communication instruments and measuring equipment launched
1973 Dust-cored SF coils for noise filters launched
1977 Voltage step-up coil WT to drive sound-making devices in wristwatches launched
1978 Automatic manufacturing lines for small fixed coils (SP type) introduced
1980 The world’s first multilayer chip coil MLF launched
1982 Leadless coil NL launched
1983 Multilayer LC filter M0F launched
1985 Three-terminal signal noise filter ZS5I launched
1986 Power chip coil SLF launched
1988 Multilayer integrated device NHID launched
1989 Clamp-type noise filter ZC241 launched
1990 Awarded the Okoshi Memorial Technology Prize for developing technologies and commercial production of multilayer integrated circuits
1991 Received the Science and Technology Merit Award under the Director-General of Science and Technology Agency’s Award for developing multilayer integrated circuits
1993 Thin-film chip coil NLU launched
1995 Multilayer LC filter array MEA (SF type) launched
1996 High-frequency multilayer coil MLG launched
1998 High-frequency multilayer coil MLK launched
1999 Multilayer power bead MBZ launched
2000 Small common mode filter ACM0612 launched
2002 Wire-wound magnetic shield coil SLF1608 launched
2003 Multilayer chip bead MMZ2005S launched
2003 Thin-film common mode filter TCM launched
2003 Transponder coil TPI for automobiles launched
2003 Power coil RL7705RL1516S for automobiles launched
2003 Power coil UZL launched
2004 Multilayer chip bead MNA0402 commercialized
2005 Power coil TFC commercialized (thinnest in the industry and manufactured using our own plating method)
2006 High-frequency multilayer coil MLG0402 commercialized (smallest multilayer ceramic coil in the industry)
Welcome to the world of inductors!

Nice to meet you! I’m an inductor, one of electronic components.
You may wonder what exactly electronic components are. Actually they are indispensable items because electronic devices commonly used in cell phones, PC’s, TV sets, game machines, and so on are made up of electronic components. Among them, inductors are a group of hard workers, performing a variety of tasks—and we’re getting busier and busier with the advent of the ubiquitous society in which people can easily access a mass of information at any time and any place. Now let me introduce the members of our inductor world and describe the excellent jobs they are doing!

We serve to eliminate noise!

Noise suppression components

We are controlling signals!

High-frequency inductors

We serve to stabilize voltage!

Signal inductors

We pull out only the desired signals!

Power inductors

We are controlling high-frequency signals!

DC-DC converter
An inductor is actually just another name for a coil. Inductors are known as such because, to use a technical term, they have inductive properties. That is, it can be observed that when an electric current flows through a coil, it produces a magnetic field; or when a magnetic field passes through a coil, it produces an electric current.

**What really is an inductor?**

- **A coil can transform itself into a magnet.**
  - Electric current produces a magnetic field.
  - A coil is a long wire that is wound around and around, many many turns.
  - An electric current flowing through the coil can produce magnetic field lines just like a magnet.

- **A coil can generate electricity.**
  - Magnetic field produces an electric current.
  - When a magnet is moved back and forth through a coil, an electric current flows through the coil.
  - This is because the coil makes an electric current so that it can produce an opposing magnetic field to counteract the magnetic field produced by the magnet.

Various important electronic devices have been produced using this property, including motors and generators.

- **An inductor is made more powerful when a core is placed inside.**
  - More magnetic field lines are produced when a core is placed inside a coil. This is because the core has the power to concentrate the magnetic field lines. The capability of producing magnetic field lines is referred to as inductance ($L$). TDK’s specialty is to develop core materials having larger magnetic permeability ($\mu$), that is, materials that can concentrate more magnetic field lines.

**How can inductance ($L$) be increased?**

- By increasing the number of turns ($n$)
- By using a magnetic core ($\mu$)
- By increasing coil diameter ($S$)

Where $L = k \times \mu \times n^2 \times S \times \frac{1}{L}$

Inductance is calculated by Dr. Nagaoka, a physicist, to concentrate magnetic field lines (magnetic permeability).
Coils can store electrical energy in a form of magnetic energy using the property that an electric current flowing through a coil produces a magnetic field, which in turn produces an electric current. In other words, coils offer a means of storing energy on the basis of inductivity (reactive magnetic flux).

Voltage regulating converters are stabilized when used in combination with inductors that can store magnetic energy, capacitors that can store electric energy, and a switch. Inductors can be used in combination with capacitors, which complement the function of inductors, to form LC filters that can separate the required signals from unwanted ones.

Function of inductors

Coils can control signals

Function of coils depends on signal frequencies. This is because the higher the frequency, the less easily the signal flows.

“Pass”
Zero frequency, that is, direct current is allowed to pass.

“Braking”
The voltage of the passing signals decreases with increasing frequencies.

“Signal stopped”
The voltage approaches zero at further higher frequencies, finally stopping the signals.

Noise is eliminated, or only the desired signals are allowed to pass.

Coils can store energy

Coils can store electrical energy in a form of magnetic energy using the property that an electric current flowing through a coil produces a magnetic field, which in turn produces an electric current. In other words, coils offer a means of storing energy on the basis of inductivity (reactive magnetic flux).

Vincent regulating converters are stabilized when used in combination with inductors that can store magnetic energy, capacitors that can store electric energy, and a switch.

DC-DC converter (voltage step-down type)

Switching controls cause the output voltage to change (basic principle of DC-DC converters).

Input

Output

Inductor (choke-coil)

Capacitor

Diode

Low-pass filter

High-pass filter

Noise is eliminated, or only the desired signals are allowed to pass.
Signal inductors, wire-wound type

Signal inductors are the basic TDK inductors. They have small transmission loss (low resistance), featuring a large current-handling capacity and high accuracy (narrow tolerance), thus providing a rich lineup that can satisfy the specifications of our customers.

Signal inductors, multilayer type

It was TDK who developed the world’s first inductors without winding. TDK has also developed high-frequency glass ceramic inductors and the low-transmission loss “Gigaspiral Multilayer Structure.”

Power inductors, wire-wound type

TDK have developed special power inductors based on a newly designed unique structure, where a drum core is sandwiched by two V-shaped cores, thus successfully achieving a large current capacity and reduction in calorific loss.

Noise suppression components, thin-film type

TDK has commercialized thin-film common mode filters to meet the demand for smaller and thinner electronic devices, forming thin-film of high flux density ferrite material and high-resolution pattern thin film coils on the basis of state-of-the-art nanotechnology.
Inductors are used for various equipment and applications!

**Signal inductors** (for controlling signals)
- GLF
- MLG
- MLK

**Power inductors** (for stabilizing voltage)
- VLF
- VLF
- SLF

**Noise suppression components**
- TCM
- MEA

**Mobile devices** (mobile phones or music players)
- Increased functionality
- One-segment broadcasting

**Television sets**
- Digitalization
- Larger and thinner

**Personal computers and game machines**
- Connection to the Internet
- High-speed processing

**Automobiles**
- Installation of electric components
- Automobile LANs

**Installation of electric components**
- Larger and thinner

**Connection to the Internet**
- Automobile LANs

**Automobiles**
- One-segment broadcasting

**Increased functionality**
- One-segment broadcasting

**Digitalization**
- Larger and thinner

**Larger and thinner**
- High-speed processing

**High-speed processing**
- Automobile LANs

**Increasing functionality**
- Digitalization

**Applications and types of inductors**

**Family of inductors for various applications**

**Applications and types of inductors**

**Signal inductors** (for controlling signals)
- GLF
- MLG
- MLK

**Power inductors** (for stabilizing voltage)
- VLF
- VLF
- SLF

**Noise suppression components**
- TCM
- MEA

**Mobile devices** (mobile phones or music players)
- Increased functionality
- One-segment broadcasting

**Television sets**
- Digitalization
- Larger and thinner

**Personal computers and game machines**
- Connection to the Internet
- High-speed processing

**Automobiles**
- Installation of electric components
- Automobile LANs

**Installation of electric components**
- Larger and thinner

**Connection to the Internet**
- Automobile LANs

**Automobiles**
- One-segment broadcasting

**Increasing functionality**
- Digitalization

**Digitalization**
- Larger and thinner

**Larger and thinner**
- High-speed processing

**High-speed processing**
- Automobile LANs

**Increasing functionality**
- Digitalization
Trends in mobile phones and market requirements for inductors

- Increased number of ICs installed resulting from increase in functions
- Increased demand for power inductors
- High-density circuit board resulting from the increased number of components
- Further reduction in size and weight
- High-resolution screen, speech quality assurance

Mobile phones are becoming more and more convenient multimedia terminals as they feature a variety of functions, including cameras, color liquid crystal displays, GPS navigation, digital money, one segment broadcasting, and built-in compact HDDs. Inductors are also expected to contribute to the further enhancement of multifunction mobile phones, improved battery lives, and improved speech quality.

The keys that support multifunction devices are energy saving and noise suppression.

As multifunction mobile phones are becoming popular, energy saving and noise suppression appear to be a problem. Our power inductors “VLF series” are now widely used, because the inductors can reduce heating loss and handle a high level of electric current, thus contributing to energy saving.

To receive one segment broadcasting, we need to pay attention not only to the communication frequency band (860 MHz - 2 GHz), but also the broadcasting frequency band (470 – 770 MHz). TDK has developed industry’s first noise suppression components in its “MEA series” for one segment broadcasting.

Serial transmission is the key to improving the design freedom of mobile phones as the LCD display is often opened, closed, or reversed while in operation. To meet this requirement, we have developed the “TCM series” of thin-film common mode noise suppression filters.

EMC countermeasures at the LCD interface

Parallel transmission
- An FPC with 40 or more parallel signal wires is used as an interface to send signals to the LCD.
- However, parallel transmission cannot match high-resolution LCDs and increased content.
- Mainstream technique for noise suppression measures in parallel transmission systems is to use LC filters (low-pass filters) combined with inductors and capacitors.

High-speed serial transmission
- Faster transfer speed
- Increase in design freedom
- Common mode noise suppression measures
- In serial transmission systems, common mode filters are indispensable elements to reduce the noise caused by the power line between different cards.
Trends in game machines and market needs for inductors

- Demand for reduction in size and weight
- Transition to smaller SMD components
- Increased number of DC-DC converters resulting from increase in functions
- Built in fast digital interface
- Noise suppression measures using common mode filters
- Use of wireless LAN
- Increased number of high-frequency components such as high-frequency inductors

Graphics processing power for recent game machines with high-definition 3D image processing is so high that it is almost comparable to that of supercomputers. TDK inductors and noise suppression components are used in new-generation game machines equipped with blue-ray discs, HDDs, and wireless LAN capability.

A game machine is an integrated body of state-of-the-art technology.

Do not regard game machines as mere toys. Actually, a game machine is an integrated mass of state-of-the-art electronic device technologies. Graphics processing power is superior to that of PCs, and comparable to that of some supercomputers. Some game machines will not only be equipped with HDDs, but can also use next-generation DVDs and blue-ray discs.

As game machines progress, more and more information processing capacity is required, and many inductors are required for noise suppression and signal control. Next, we will learn about impedance, which is indispensable for signal processing.

Impedance matching

Impedance is the resistance to alternating current flow in an electrical circuit. Impedance can be roughly considered from two directions, that is, 1) impedance toward the signal source direction, and 2) impedance toward the load direction. Impedance matching is required between the two impedances. Unless the matching between them is properly performed, the circuit reflects back some of the signals, causing transmission loss, or distorts signals, preventing normal transmission of data. This is why we need signal inductors to do their job. TDK has a rich lineup of inductors, including the “MLF series” and the high-frequency “MLG series” inductors, which satisfy our customers’ needs for signal inductors.
In place of CRT-based television sets, mainstream televisions are now those with large-screen flat displays or plasma displays. After the beginning of terrestrial digital broadcasting, not only screen size, but also image quality and various optional functions are drawing consumers’ attention.

Audio-visual equipment can be easily connected to television sets using the next-generation interface, HDMI.

In Japan, analog broadcasting will finish at the end of July 2011, and digital broadcasting will follow. The well-known white, red, and yellow cable connectors will disappear, and all the transmission systems for television sets will be unified with a High-Definition Multimedia Interface (HDMI). In other words, you can easily connect your television set to other equipment through a single cable. HDMI uses a differential transmission system to send high quality signals at a high speed without compressing them. However, one problem is common mode noise. TDK took advantage of filter design techniques and various advanced technologies that have been accumulated in the company, and have successfully developed the “ACM-H” and “TCM-H” series common mode filters that have a far wider transmission band than conventional filters.

Noise can be divided into two types: normal mode and common mode noise. Common mode noise is caused by the differential transmission system in which a pair of identical signals but of opposite polarities are sent.

Audio-visual equipment can be easily connected to television sets using the next-generation interface, HDMI.
Trends in automobiles and market needs for inductors

- Pursuit of safety
- High-reliability, impact resistance, water resistance
- ECU installation in engine rooms
- Noise suppression measures applied to in-vehicle LAN

It is said that an automobile is made up of more than 20,000 components, and the percentage of electronic components to the total number of components is constantly increasing. Further, electronic components are not allowed to malfunction because they are used in the vehicles to which our lives are committed. What is needed is a highly reliable product that can be used even in a harsh environment.

Common mode filters are indispensable for vehicles equipped with electrical components.

The Controller Area Network (CAN) BUS is one of the standards for in-vehicle LANs, which was designed to reduce the weight of automobiles. A CAN-BUS is less subject to noise because it uses the differential transmission system, but common mode noise still becomes a problem. The performance of TDK’s "ACT series" common mode filter has been enhanced, and they are now available in a temperature range from -40 to 150 °C. The common mode filters are designed for good performance in harsh environments such as in engine room.

In addition, TDK has also developed the "ACM-V series" common mode filters for automobile ECU power supply lines.

Common mode filters are used at the points marked with open circles.

Transponder coils (transponder coil, air-pressure sensor, etc.)

Tire-Pressure Monitoring System (TPMS) needs transponder coil

Installation of the tire pressure surveillance system in North-American automobiles was made obligatory in 2003. This surveillance system is a wireless communication-based safe-driving system, and uses a pressure sensor to detect information on individual tires, which is wirelessly sent to the main system in the driver’s compartment. TDK’s "TPL series" transponder coils are used as antenna coils to receive the signals from the sensors. In order to develop small, high-sensitivity, and reliable transponder coils, advanced core technology and winding techniques are required.
Magnetic core for inductors is where TDK started. The magnetic material referred to as “ferrite” is widely used for almost all inductor cores. TDK was founded to industrialize the manufacture of ferrite. Since then, TDK has launched products that serve to support our lives, including not only inductors, but capacitors, magnetic heads, and recording media, on the basis of the material technology cultivated through ferrite manufacturing, as well as process technologies that can take advantage of those materials.

Long years of accumulated raw material technology

The first key point to raw material technology is “composition.” The basic characteristic of raw materials is decided by what materials are mixed at what rate and at what timing. The next point is “firing.” Not only temperature and firing time, but also the environment in the firing furnace (oxygen condensation) must be accurately controlled. In addition, very small cores must be very carefully formed to prevent them from becoming cracked or chipped.

Advanced wire-winding technique, accurate to an order of microns

It is virtually impossible to wind wires around very small coil cores, which are less than 1 mm long. TDK has developed machines that can wind wires not only accurately, but also at a high speed around many tiny cores. For example, the high-precision automatic wire-winding machine (lower-left picture) is capable of simultaneously winding wires around a large number of coil cores. In addition, the gap between wires for common mode filters (lower-right picture) is controlled to an order of microns. Two wires are wound at the same time and at the same space interval to produce effective noise suppression components.

Layering technique that enabled realization of inductors without wire-wound coils

As we have explained, coils are made by winding wires around cores, but TDK has upset this conventional wisdom. Ferrite material is first processed to a paste, which is then formed as a thin sheet of film. Next, a conductive pattern is printed on the film. Then, some films with conductive patterns are stacked in layers, and finally the laminated body is fired. Using this innovative method, TDK realized the world’s first chip inductor in 1980. TDK inductors were manufactured on the basis of TDK’s original techniques from its accumulated know-how such as paste mixing, pattern printing, laminating, and firing.

TDK’s advantages

Why are TDK inductors so competitive? The answer is because TDK has been consistently tackling various issues from “raw material technology” to “process technology,” and even the development of devices.
Inductors are manufactured through various processes. Furthermore, expert know-how is required for each of those processes. Here, let’s see how typical wire-wound products and multilayer products are manufactured.

### Wire-winding type

- **Core manufacturing**
  After the processes of creating the fine particles, molding, and firing, electrodes are formed on the manufactured core (magnetic core).

- **Wire-winding**
  A wire is wound around the core, and the terminals of the wire are connected to the core.

- **Frame processing**
  The wire-wound core is sandwiched by the frame.

- **Molding**
  Resin is poured over the coil sandwiched by the frame.

- **Terminal treatment**
  The resin-covered coil is separated, and the frame is bent to form electrodes.

### Multilayer type

- **Paste forming**
  Ferrite powder and resin are mixed to form ferrite paste.

- **Sheet forming and printing**
  The ferrite paste is flattened into a sheet form, and electrodes are printed on it.

- **Multilayer process**
  Electrode-printed ferrite sheets are stacked in layers and pressed.

- **Cutting and firing**
  The stacked sheets are cut with a blade into the prescribed size, and perfectly fired in a furnace.

- **Electrode coating and plating**
  Both ends of the fired coil are dipped in electrode paste, and then baked. Next, the entire body of the coil is dipped in plating solution.
History of TDK Inductors and Noise Suppression Components

1937 World's first ferrite coil cores launched
1962 TDK's first noise suppression device, "Synchro V Socket," launched
1964 Linearity coils for color TVs launched
1965 Line filters for color TVs launched
1972 Feed-through noise filter FN for communication instruments and measuring equipment launched
1973 Dust-coated SF coils for noise filters launched
1977 Voltage step-up coil WT to drive sound-making devices in wristwatches launched
1978 Automatic manufacturing lines for small fixed coils (SP type) introduced
1980 The world's first multilayer chip coil MLF launched
1982 Leadless coil NL launched
1983 Multilayer LC filter M0F launched
1985 Three-terminal signal noise filter ZS launched
1988 Power chip coil SLF launched
1988 Multilayer integrated device NHD launched
1989 Clamp-type noise filter ZCA1 launched
1990 Awarded the Okochi Memorial Technology Prize for developing technologies and commercial production of multilayer integrated circuits
1991 Received the Science and Technology Merit Award under the Director-General of Science and Technology Agency's Award for developing multilayer integrated circuits
1993 Thin-film chip coil NLU launched
1995 Multilayer LC filter array MEA (T-type) launched
1996 High-frequency multilayer coil MLG launched
1998 High-frequency multilayer coil MKL launched
1999 Multilayer power bead MPZ launched
2000 Small common mode filter ACM2012 launched
2002 Wire-wound magnetic shield coil SLFY168 launched
2003 Multilayer chip bead MM20505 launched
2003 Thin-film common mode filter TCM launched
2003 Transponder coil TRP for automobiles launched
2003 Power coil RL7045/RL10165 for automobiles launched
2003 Power coil VI/1 launched
2004 Multilayer chip bead NM20402 commercialized
2005 Power coil TFPC commercialized (thinnest in the industry and manufactured using our own plating method)
2006 High-frequency multilayer coil MLG0402 commercialized (smallest multilayer ceramic coil in the industry)