Common Mode Filters that Eradicate the Causes of Emission Noise without Affecting Signals

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1 Differential Mode Current and Common Mode Current

As is shown in Figure 1, currents that flow through two parallel cables that transmit signals are divided into differential mode currents and common mode currents.

▶ Differential mode currents

These are the signal components that are intended for transmission. Since currents with equal amplitudes flow in opposing directions, the radiated electric fields have opposing directions and cancel each other out. Though the two conductors are not described as having no space in between in the actual PCB, most of the generated magnetic fields will be canceled out. As a result, the radiated electric fields will become relatively small.

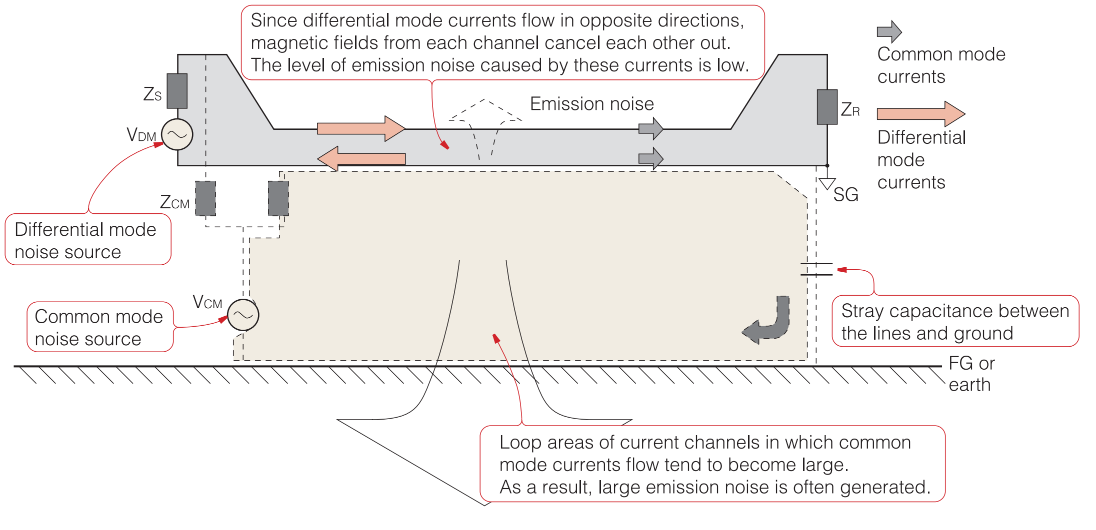
▶ Common mode currents

These are currents with the same amplitude flowing in the same direction. They are unnecessary currents that are caused by coupling between the cables and the ground due to parasitic capacitance or electromagnetic induction. Although they are very small, when compared to differential mode currents, they cause large radiated electric fields since they flow in a large loop. It is no exaggeration to say that the main cause of emission noise is common mode currents.

2 Eliminating only Common Mode Noise

Chip beads are often used as components for emission noise countermeasures; however, as they attenuate both common mode currents and differential mode currents, they might attenuate signal components that are necessary for operations. Common mode filters (hereinafter referred to as CMFs) can solve this problem. CMFs reduce only common mode noise, without affecting differential mode currents at all.

Figure 1 Channel in Which Common Mode Currents and Differential Mode Currents Flow



3 | Split Winding and Bifilar Winding Methods

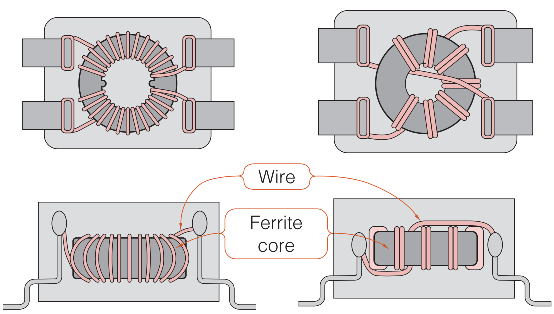
CMF structures can be divided into the following two types, according to the method of winding.

- Split winding
- Bifilar winding

As is shown in Figure 2, CMFs are made by winding conductive wire around a toroidal core or an EI core. The coupling coefficient or frequency characteristics of CMFs vary according to their winding methods or core types. The leakage flux is 0, i.e., all magnetic flux passes through the core, and the coupling coefficient of a CMF in which all the magnetic flux passes through the wire is 1. This is an ideal CMF that does not affect the differential mode current in any way.

Figure 2 Two Types of Winding Structures for Common Mode Filters

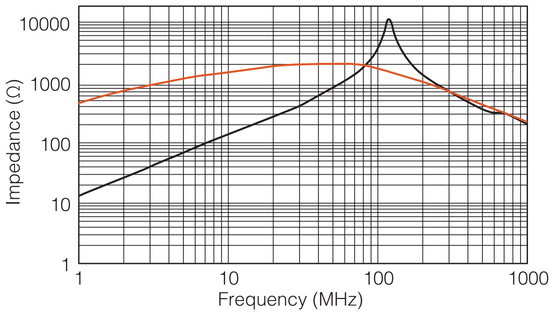
(a) Split winding (b) Bifilar winding



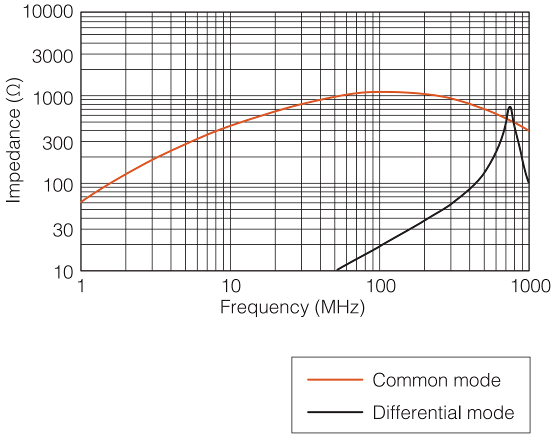
The impedance frequency characteristics of a CMF with a split winding structure and a CMF with a bifilar winding structure are shown in Figure 3.

Figure 3 Impedance Frequency Characteristics of CMFs

(a) Split winding



(b) Bifilar winding



As is clear from Figure 3, a coil with a split winding structure has a relatively large differential mode impedance; therefore, it will attenuate not only noise but signal components as well. Although it is not ideal as a CMF, it is more advantageous than a coil with a bifilar structure in terms of heat resistance or pressure resistance. Therefore, it is suitable for applications in which differential mode impedance is not very important, e.g., application in a DC power line containing no signal components. A split winding structure is employed to improve heat resistance against large currents or to achieve high pressure resistance between lines. There are filters that positively utilize differential mode impedance (two-mode filters).

In a CMF with a bifilar winding structure, coupling between two wires is high and differential mode impedance is small. CMFs with this structure are suitable for high-speed signal transmission lines, since they do not affect the waveforms of transmitted signals.

● Application of each CMF

The types of CMFs for signal lines or DC power lines and their main electrical characteristics are shown in Table 1.

In CMFs for signal lines, large common mode impedance and small differential mode impedance are required. These types of CMFs adopt a bifilar winding structure, and are used for high-speed interfaces, such as USB, IEEE1394, HDMI and DisplayPort.

In CMFs for DC power lines, not only a bifilar winding structure but a split winding structure is employed, as large differential mode impedance does not cause problems as long as the cores do not become saturated.

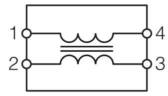
As for onboard applications, “CAN” and “LIN”, which are common standards for communications between ECUs, and the next-generation onboard LAN standard “FlexRay”, are examples in which CMSs (CAN/FlexRay) or LC filters (LIN) are used as EMC countermeasure components. Their aim is to provide radiation noise countermeasures and immunity against external noise to onboard equipment. In order to apply CMFs to components of onboard equipment, it is necessary to meet the demand for reliability under severe environments in vehicles. TDK provides CMFs that satisfy the reliability requirements even under high temperature loads from –40°C to +150°C.

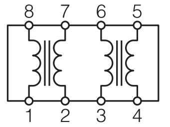
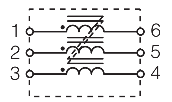
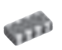
Photo 1 is a CMF for AC power supplies. This type of CMF can reduce conducted noise between 150 kHz and 30 MHz. Even if the differential mode impedance is high, it can be used without problems as long as the core does not saturate; that is to say, it can positively be used as a countermeasure against differential noise.

Clamp filters, which will be described another chapter, are categorized as CMFs. They are mounted onto cables, which are a major cause of emission noise.

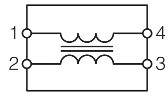
Table 1 Types and Main Electrical Characteristics of CMFs for Signal Lines and DC Power Lines

(a) CMFs for signal lines

Equivalent circuit							
Type	TCM0605	TCM0806	TCM1210 TCM1210U	ACM2012 ACM2012H	ACM2520	ACM3225	ZCYS1512 ZCYS8684 ZCYS9058
Common mode impedance [100 MHz]/ Inductance [100 kHz]	30 to 90 Ω	35 to 90 Ω	12 to 300 Ω	90 to 1000 Ω	300 to 1000 Ω	1000 Ω	0.47 to 20 mH
Rated current (A)	0.05 to 0.1	0.1	0.05 to 0.1	0.1 to 0.3	0.2 to 0.4	0.2	0.2 to 0.4
Rated voltage (V)	5	5	10	50	20	50	80
Number of lines	2	2	2	2	2	2	2
Appearance							
Target set	Portable devices	Portable devices game machines, etc.	AV equipment, PCs, game machines, etc.	AV equipment, PCs, game machines, etc.	AV equipment, PCs, game machines, etc.	AV equipment, PCs, game machines, etc.	Modems
Application	USB2.0 LVDS HDMI (C connectors), etc.	USB2.0 LVDS HDMI (C connectors), etc.	USB2.0 LVDS HDM/DVII SATA/SAS D-Port, etc.	USB2.0 LVDS HDM/DVI SATA/SAS D-Port Ethernet, etc.	Audio lines, Ethernet, etc.	Audio lines	xDSL

Equivalent circuit				
Type	TCM1608	ACM2520-3P	ACM4532-3P	ZCYS51R5
Common mode impedance [100 MHz]/ Inductance [100 kHz]	35 to 200 Ω	800 Ω	1000 Ω	400 Ω
Rated current (A)	0.05	0.15	0.2	0.5
Rated voltage (V)	5	20	50	50
Number of lines	4	3	3	4, 6
Appearance				
Target set	AV equipment PCs	AV equipment PCs	PCs	AV equipment PCs
Application	LVDS USB 2.0 HDMI, etc.	Audio lines, etc.	Audio lines, etc.	RGB lines, etc.

(b) CMFs for power lines

Equivalent circuit							
Type	ACM3225-601	ACM4532-601/801	ACM4520	ACM7060	ACM9070	ACM1211	ACM1513
Common mode impedance [100 MHz]	600 Ω	600 to 800 Ω	100 to 1400 Ω	300 to 700 Ω	700 Ω	700 to 1000 Ω	550 Ω
Rated current (A)	1	1.5 to 2.0	1.5 to 6	4 to 5	5	6 to 8	10
Rated voltage (V)	50	50	50	50	50	50	50
Number of lines	2	2	2	2	2	2	2
Appearance							

(c) CMFs for onboard applications

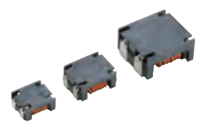
	On-board LAN					Signal lines	Power lines
Type	ACT45S	ACT45B	ACT45R	ZJYS81R5	ZJYS90V	ACM2012	ACM70V/90V/12V
Common mode inductance [100 kHz]/ impedance	22 μH	11 to 100 μH	100 μH	1000 to 2000 Ω [10 MHz]	100 μH	90 to 360 Ω [100 MHz]	700 Ω [100 MHz]
Winding method	Split winding	Bifilar winding	Bifilar winding	Split winding/ Bifilar winding	Bifilar winding	Bifilar winding	Split winding
Rated current (A)	0.2	0.2	0.2	0.5	0.5	0.22 to 0.4	4 to 8
Rated voltage (V)	50	50	50	50	50	20	80
Operating temperature range (°C)	–40 to +150	–40 to +150	–40 to +150	–40 to +125	–40 to +125	–40 to +105	–40 to +125
Appearance							
Application	CANBUS	CANBUS FlexRay	FlexRay	CANBUS	FlexRay	LVDS	Power lines

Photo 1　Examples of CMFs for AC Power Supplies

UF2327L type

HF2018R type

LH series (Gear-wound products)