SCR-XV and SCT-XV Series, Common Mode Chokes

INTRODUCTION

While carbon-neutral efforts are accelerating worldwide, the growth rate of BEVs and PHEVs in the automotive market is also accelerating rapidly. In 2020, EVs made up 3% of global sales. Some official publications estimate that it will grow to be 15% by 2025, 39% by 2030, and 66% by 2035.

As a result, the use of electrical components in automotive applications is increasing, which has caused the scope of applications in ECE R10 (the UN regulation on EMC first issued in 2011) to expand. Therefore, EMC measures for automotive products have become a must.

KEMET SCR-XV and SCT-XV series offer a standard line-up of 144-part numbers of common mode choke coils (CMC) fully qualified to the automotive AEC-Q200 standard, effective for EMC countermeasures for automotive products. In this article, we will introduce the primary performance and selection criteria for common mode choke coils.

BASIC PRINCIPLE OF COMMON MODE CHOKE COILS

Magnetic flux:

Through a coil, magnetic flux is generated when current flows through a magnetic core.

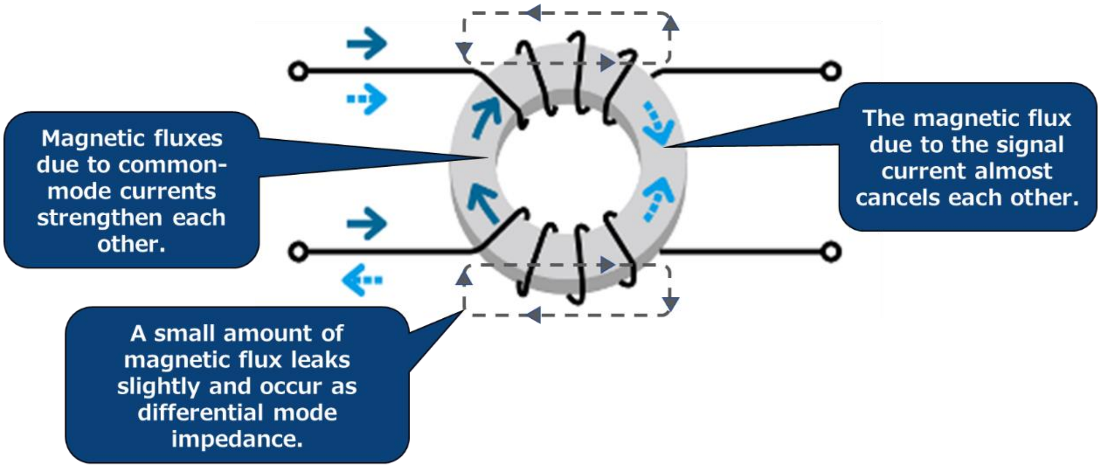


Figure 1

The common-mode choke coil has two wires wound so that the fluxes of the signal currents cancel each other, and the common-mode currents strengthen each other's fluxes. The advantage of common-mode coils is that they eliminate common-mode noise without affecting the power and signal lines. In addition, the leakage flux generated by the component also serves to eliminate differential mode noise. The performance of a common mode choke coil depends mainly on the magnetic material. The higher the impedance at the required frequency point, the more effective the noise suppression. The Curie temperature (Tc) should also be checked along with the operating environment.

Theoretical formula for inductance and performance of magnetic materials:
The theoretical formula for the inductance of a toroidal core can be seen below (Figure 2). Based on this formula, the larger the permeability, the higher the inductance (Figure 3). However, the higher the magnetic permeability, the quicker the material saturates, so selecting the core material according to the frequency band for noise suppression is desired is critical.

$$L = N^2 \times \mu_0 \times \mu_r \times \frac{s}{\ell}$$

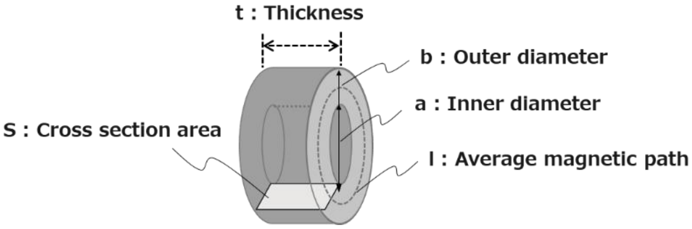


Figure 2

L: Inductance
N: Number of turns
μ_r: Permeability
μ_0: 4π × 10−7 H/m
s: Cross-section area of core

$$S = t \times (b - a)$$

ℓ: Average magnetic path of core

$$\ell = 2\pi \times (a + b) \,/\, 2$$

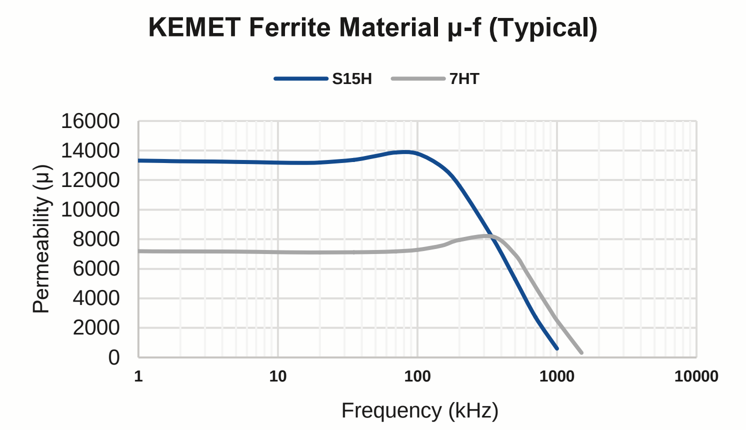


Figure 3 - Permeability vs. Frequency

Temperature characteristics of magnetic materials:
Temperature characteristics are also important in the selection of common mode choke coils. Figure 4 shows the relationship between magnetic permeability and temperature.

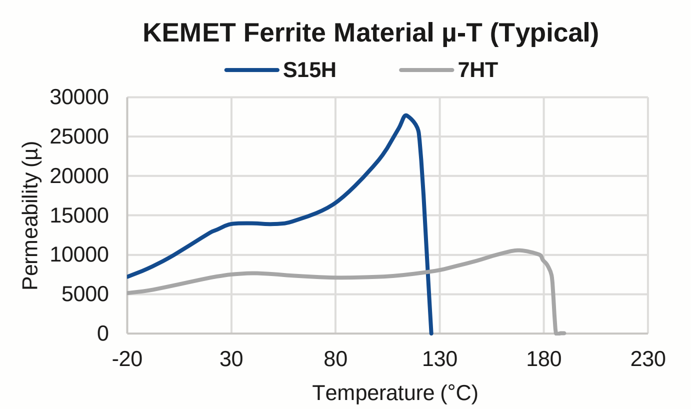


Figure 4 – Permeability vs. Temperature

Around the point where the magnetic permeability drops are the heat resistance temperature of the core, called the Tc. The KEMET SCR-XV series uses high permeability S15H material (Tc >120°C) for high inductance, and the SCT-XV series uses 7HT material (Tc >180°C) for high heat resistance, allowing selection according to the application.

INSULATION STRUCTURE

These SCR-XV and SCT-XV series uses high CTI performance plastics for the insulation case to ensure a 5 mm insulation distance. As a result, it achieves the industry’s highest-rated voltage of 1,000 V and can be used for higher voltage applications in BEV and PHEV systems.

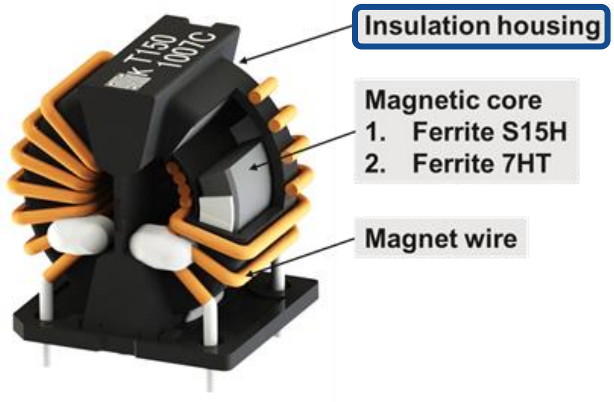


Figure 5

Creepage distance to avoid failure due to tracking based on IEC60664-1:

V rms	**Minimum Creepage Distance (mm)**								
	Pollution Degree								
	1			**2**			**3**		
	Material Group			**Material Group**			**Material Group**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
200	**0.42**			**1.00**	**1.40**	**2.00**	**2.50**	**2.80**	**3.20**
250	**0.56**			**1.25**	**1.80**	**2.50**	**3.20**	**3.60**	**4.00**
320	**0.75**			**1.60**	**2.20**	**3.20**	**4.00**	**4.50**	**5.00**
400	**1.00**			**2.00**	**2.80**	**4.00**	**5.00**	**5.60**	**6.30**
500	**1.30**			**2.50**	**3.60**	**5.00**	**6.30**	**7.10**	**8.00**
630	**1.80**			**3.20**	**4.50**	**6.30**	**8.00**	**9.00**	**10.00**
800	**2.40**			**4.00**	**5.60**	**8.00**	**10.00**	**11.00**	**12.50**
1,000	**3.20**			**5.00**	**7.10**	**10.00**	**12.50**	**14.00**	**16.00**
1,250	**4.20**			**6.30**	**9.00**	**12.50**	**16.00**	**18.00**	**20.00**

Table 1

Pollution degree: 2
Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

Material group: I
600 ≤ CTI (Comparative Tracking Index)

Creepage distance:
5.00 mm at 1,000 V

EMI FILTER CONFIGURATION AND ATTENUATION PERFORMANCE

EMI filters consist of a choke coil and a capacitor. In many cases, multiple combinations of common mode choke coils and capacitors are used. It is important to combine them in an appropriate configuration according to the EMI countermeasure frequency point. This section will introduce how attenuation performance varies based on how the common choke coil and capacitor are combined.

EMI filter basic structure and role of elements:
The EMI filter configuration in Figure 6 is a second-order configuration for both common mode and differential mode attenuation using a common mode choke and X, and Y rated safety capacitors. KEMET products were used to simulate this configuration, and the resulting attenuation characteristics can be seen in Figures 7 and 8.

Element Values:
CMC: SCR25XV-150-1R6A010JV (15 A, 1 mH)
Cx: R475N3330CK01M (0.33 µF)
Cy: P295BE471M500C (470 pF)

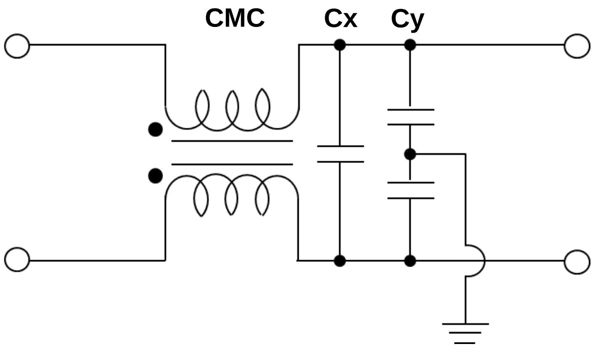


Figure 6

- Common mode attenuation: CMC(Lc)-Cy
- Differential mode attenuation: CMC(Ln)-Cx*
** Ln = Leakage inductance*

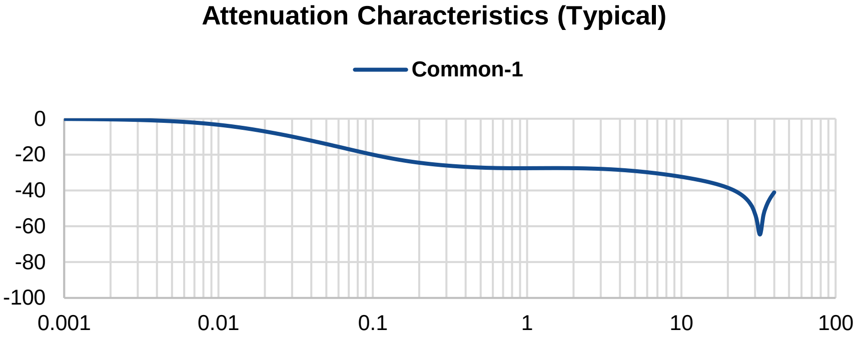


Figure 7

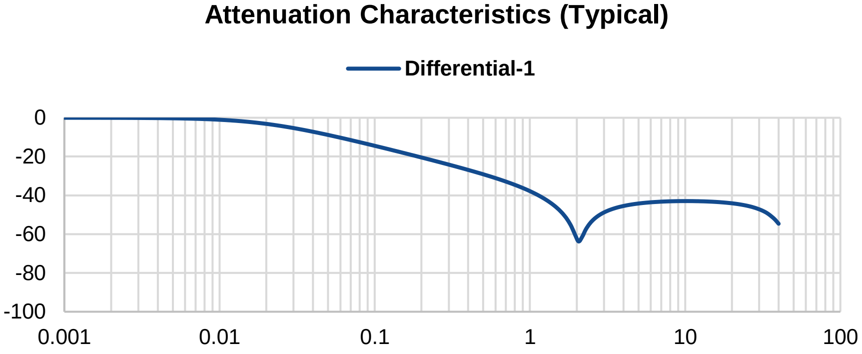


Figure 8

Next, let's look at the difference in attenuation performance based on the position of the capacitors when two common mode choke coils are used. An additional common mode choke is introduced to the circuit, and the configuration seen in Figure 9 is simulated. Attenuation characteristics can be seen in Figures 10 and 11.

Configuration with two common mode chokes - 1: CMC1-CMC2-Cx & Cy:

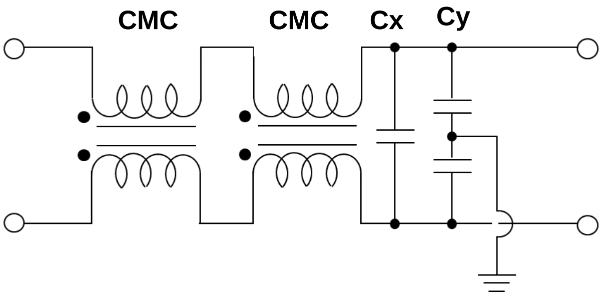


Figure 9

Common mode attenuation: CMC1(Lc)-CMC2(Lc)-Cy

Differential mode attenuation: CMC1(Ln)-CMC2(Ln)-Cx

Element Values:
CMC1: SCR25XV-150-1R6A010JV (15 A, 1 mH)
CMC2: SCR25XV-150-1R6A010JV (15 A, 1 mH)
Cx: R475N3330CK01M (0.33 µF)
Cy: P295BE471M500C (470 pF)

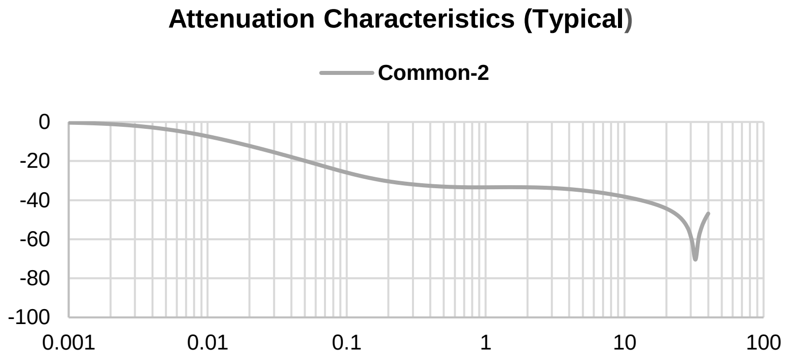


Figure 10

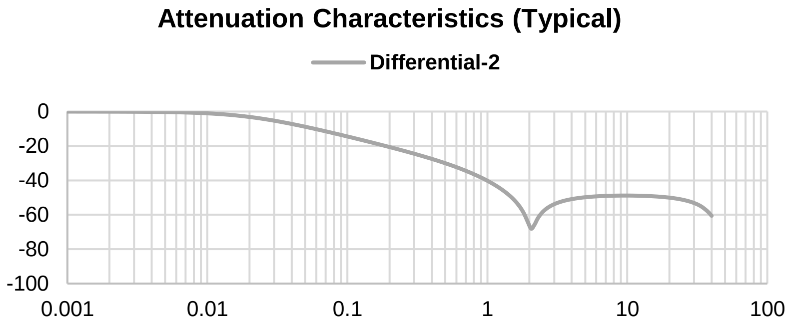


Figure 11

The attenuation performance improves due to the increase in CMC components, which is slightly effective. However, this is still a second-order noise filter configuration.

The filter circuit is then rearranged, and the configuration seen in Figure 12 is simulated.
Configuration with two common mode chokes-2: CMC1-Cx & Cy-CMC2:

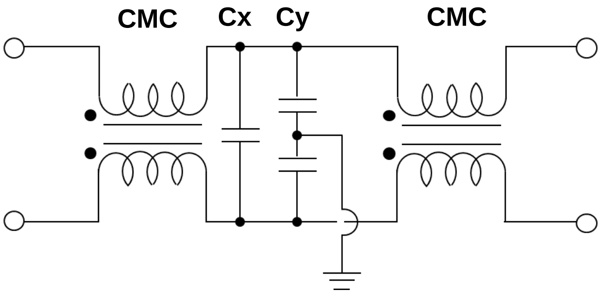


Figure 12

Common mode attenuation: CMC1(Lc)-Cy-CMC2(Lc)
Differential mode attenuation: CMC1(Ln)-Cx-CMC2(Ln)

Element Values:
CMC1: SCR25XV-150-1R6A010JV (15 A, 1 mH)
Cx: R475N3330CK01M (0.33 µF)
Cy: P295BE471M500C (470 pF)
CMC2: SCR25XV-150-1R6A010JV (15 A, 1 mH)

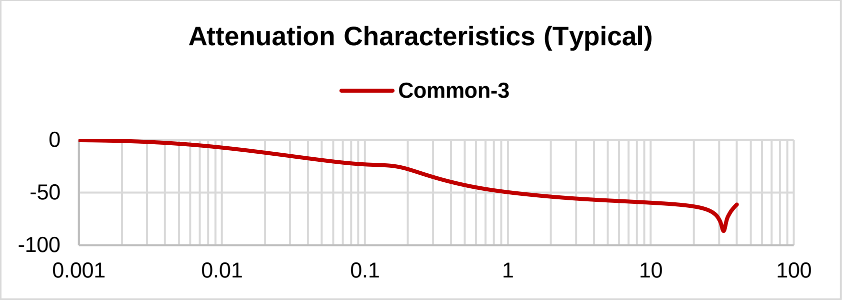


Figure 13

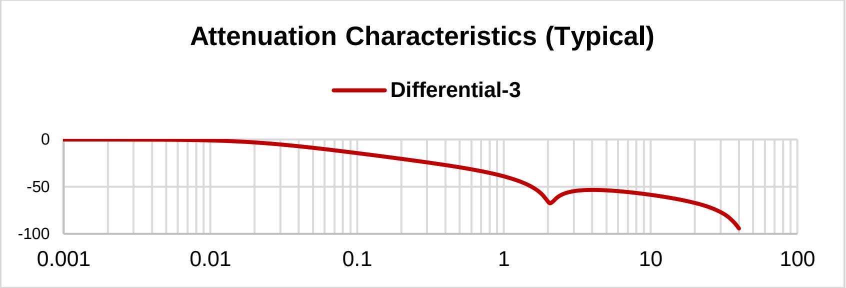


Figure 14

Changing the configuration of components has resulted in a third-order noise filter. Figures 13 and 14 show the resulting attenuation performance using this configuration.

When we compare this performance to the previous filter configurations (Figures 15 and 16), the attenuation performance is improved over a wide frequency range compared to the previous filter configurations.

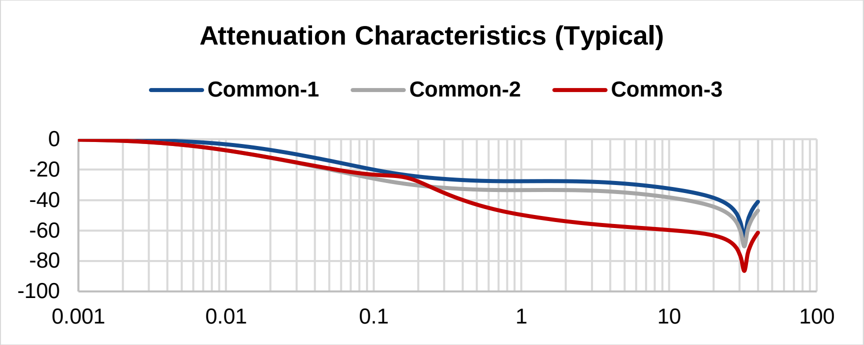


Figure 15

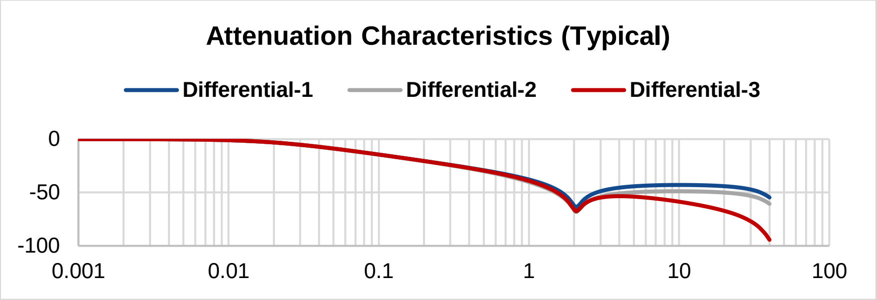
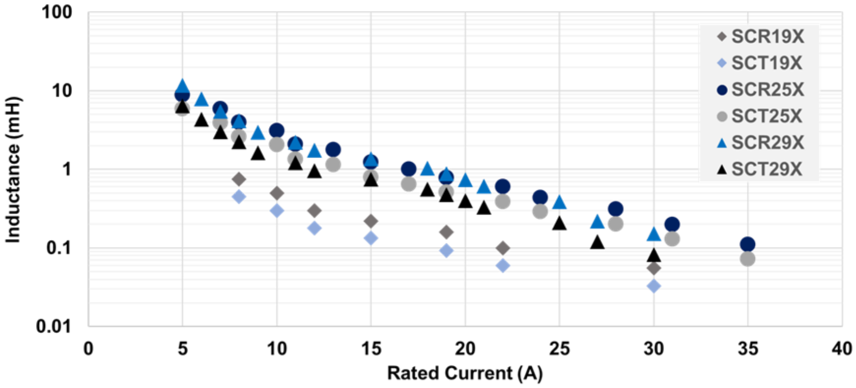


Figure 16

As described, the attenuation performance varies greatly depending on the position of the common mode choke coil and capacitors within the filter. Hence, the configuration of the elements is critical.

SCR-XV AND SCT-XV SERIES SPECIFICATIONS

As seen above, one can choose between core materials S15H (SCR-XV) and 7HT (SCT-XV). Core sizes available are 19, 25, and 29 mm in both horizontal and vertical orientations. The series is rated at 1,000 V, with rated current up to 35 A.



Vertical Type
Smaller Footprint

Horizontal Type
Lower Height

Part Number System

SCR	29	XV-	300-	2R4	A	005	JV
Series	Outer Core Diameter	Approval	Rated Current	Wire Diameter	Windings	Number of Turns	Terminal Base Type
SCR = S15H ferrite core SCT = 7HT ferrite core	19 = 19 mm ø 25 = 25 mm ø 29 = 29 mm ø	XV = AEC-Q200	300 = 30 A	2R4 = 2.4mm ø	A = Single wire	005 = 5 turns	JV = Vertical type JH = Horizontal type

SUMMARY

With an increase in BEVs and PHEVs in the automotive market, there is a need for higher voltage componentry. KEMET’s SCR-XV and SCT-XV series offer solutions to this need.

Significant benefits are:

- High inductance with SCR-XV
- High heat resistance with SCT-XV
- Rated voltage up to 1,000 V
- Rated current from 5 A to 35 A
- Fully AEC Q200 qualified

KEMET’s SCR-XV and SCT-XV series can provide optimal EMI performance for automotive products, where electrification is accelerating.

Customization support is offered, so please contact your KEMET sales representative if you have specific requirements.