PULSE AUTOMOTIVE CM CHIP CHOKES
INNOVATIVE CONSTRUCTION TO IMPROVE NOISE IMMUNITY

Abstract

In recent years, Ethernet has become very popular in digital data communications due to its rather simple data structure and wide range of data speeds offered. With ever increasing data rates required for on-board cameras, entertainment, and controls for safety and automatic driving, single-pair Ethernet is the most logical choice for Automotive data transmission. To meet such needs, IEEE802.3 has created standards for Ethernet over one twisted pair, with speeds from 10, 100, and 1000 Mbps, and higher speeds to come. Automotive applications typically require much higher noise immunity due to the open environment that the systems are working within. Common-mode chokes (figure 1) are typically placed between the transceiver (PHY) and cable interface (connector) to help filter common-mode noise, in both directions by presenting a large common-mode impedance to help suppress noise coming out of the transmitter, and that coming into the receiver.

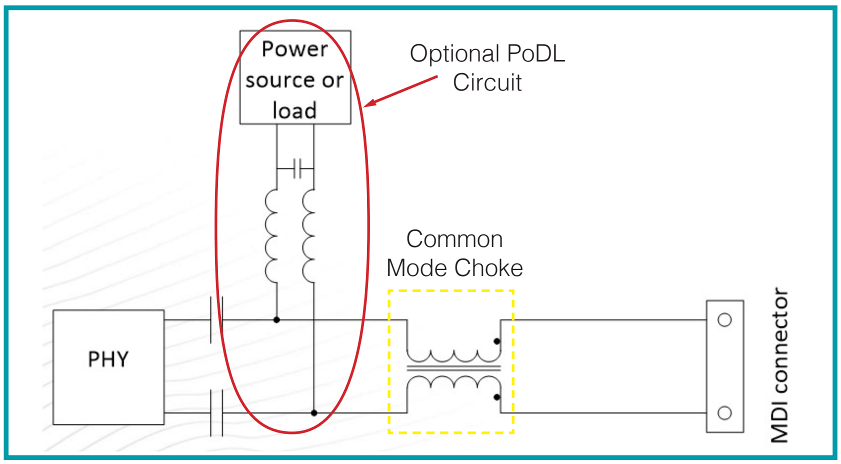


figure 1

Traditionally, common-mode chokes are built using toroidal ferrite cores (figure 2), with small diameter wires wound around the core and terminated and soldered onto pins of a plastic header. Since wires are wound around the toroidal core, common-mode performance at high frequencies typically has a large variation band due to inherent variance of winding angle.

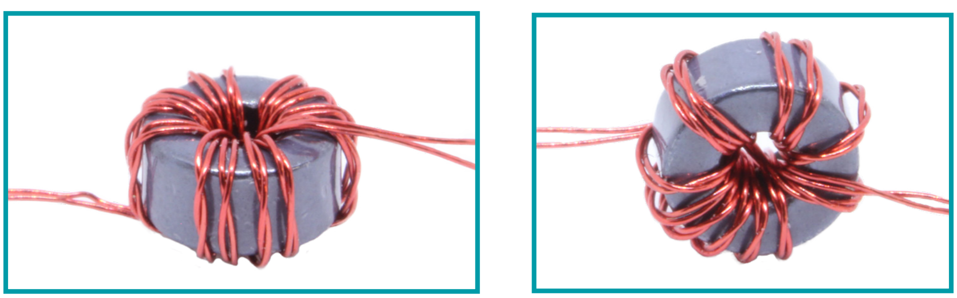


figure 2

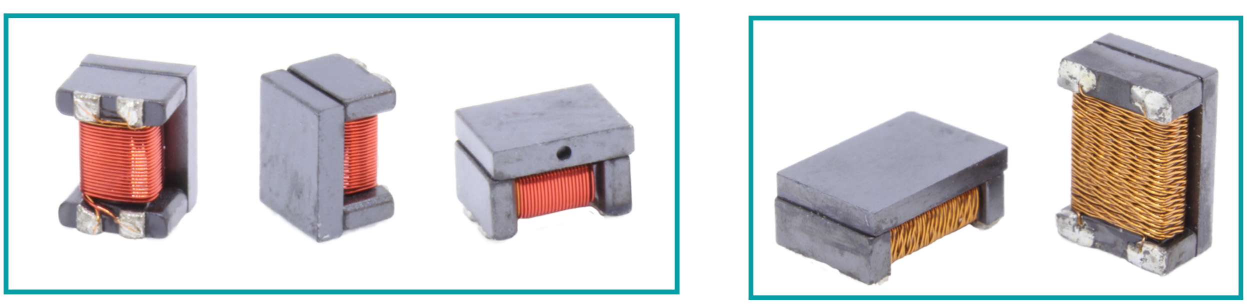


figure 3

New common-mode chokes, or chip-chokes as called henceforth, are designed with 2 wires wound on a rod with flange (figure 4) at the both ends, provide consistent common-mode rejection performance at all frequencies, and do not quickly degrade at high frequencies since the start and finish ends of the windings are always kept apart, and with fixed distance. For common-mode chokes wound on toroidal core, the distance between start and finish ends of the winding may vary (see figure 4) and as these ends get closer, stray capacitance between them increases, which decreases impedance of the chokes by adding a parallel impedance across the winding. In addition, differential signal integrity is also consistent due to fully automatic winding and termination process. Consistency in differential signal integrity helps reduce design margin, which is otherwise needed in toroidal choke design, to ensure that even the worst performing choke will not degrade system performance. In addition to Ethernet, these new chip chokes are also used in other Automotive data transmission applications, such as CAN, CAN-FD, etc., where high level of noise suppression is needed.

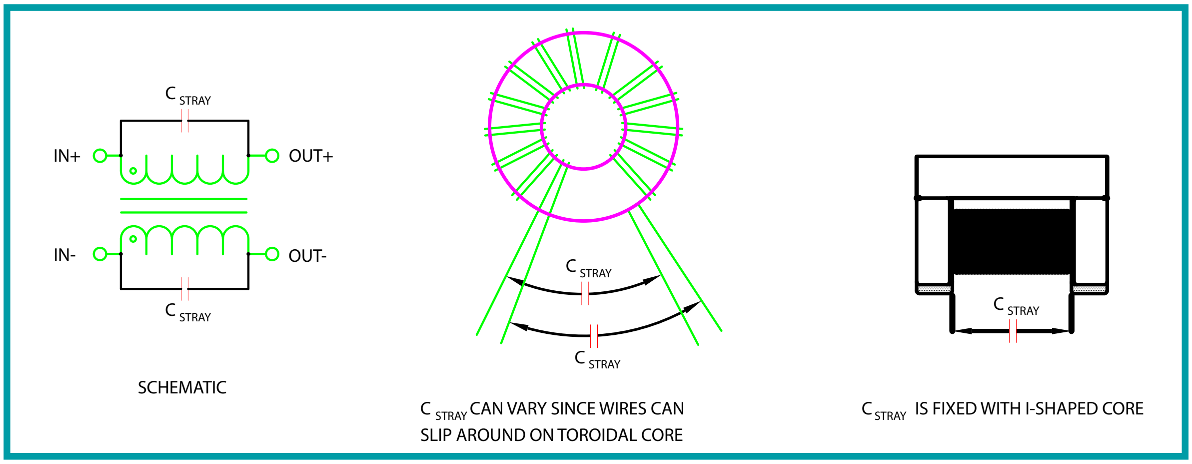


figure 4

Performance

Common-mode chokes are designed to help suppress common-mode noise, and mode conversion, but should be as transparent to differential signals as possible. Affected differential parameters are insertion loss and return loss (figures 5, 6). For common-mode parameters, they are common- to common-mode and common- to differential-mode conversion (figures 7, 8, 9).

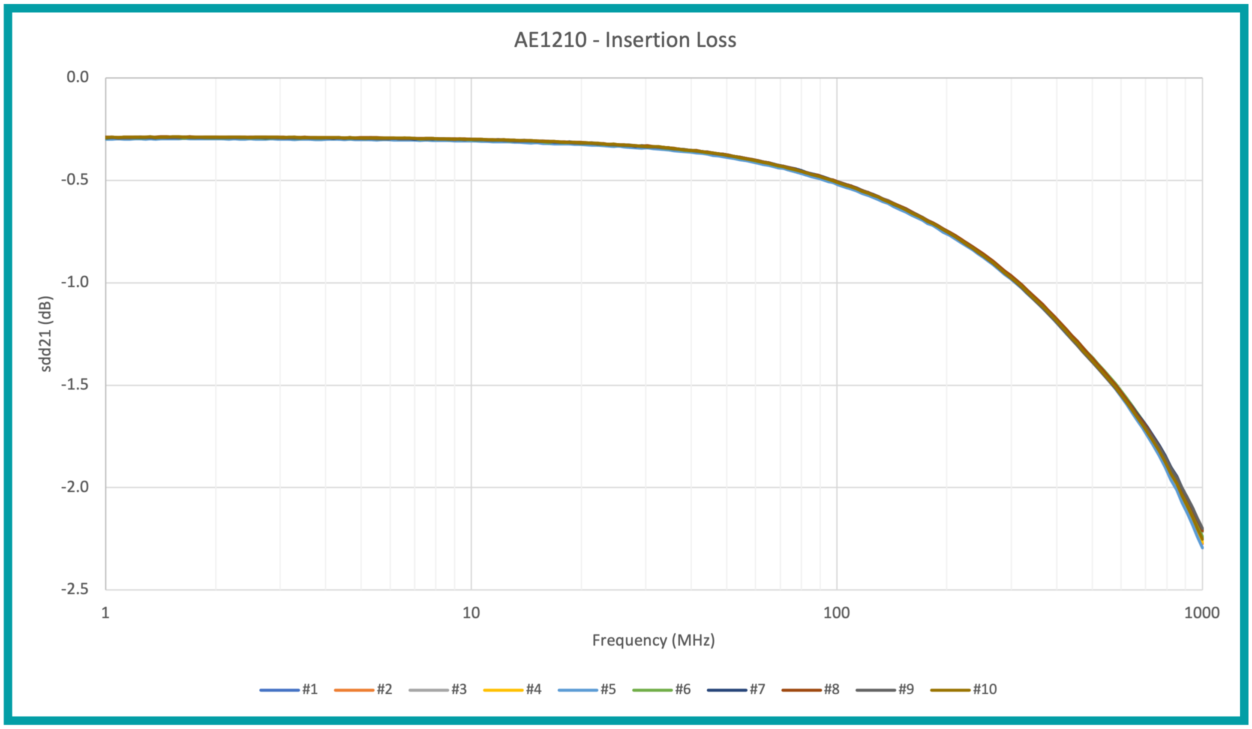
With the start and finish ends of these chip chokes well separated, self-resonance frequency (SRF) of the common-mode choke is also increased, depending on wire gauge and insulation coating thickness. These wire parameters are carefully chosen to allow the choke to be wound with enough turns to provide sufficient common-mode impedance, and at the same time, yield decent signal integrity by matching nominal differential line impedance, which is typically 100Ω, to minimize signal loss and echo over intended transmission frequency spectrum. Core material is chosen to retain relatively good permeability and impedance at high frequencies, to maintain enough common-mode impedance to help pass the more stringent noise immunity in Automotive applications.

In short, chip chokes offer higher, more consistent performance, and improved reliability over traditional chokes wound on toroidal shape core.

Test data for a typical common-mode choke wound on toroidal core and those for a Pulse Chip part below show the difference between the 2 design constructions. Pulse Chip CMC shows much more consistent in all parameters as compared to CMC wound on toroidal core.

Even though Pulse Chip has more differential insertion loss, it is still less than 1dB up to 300MHz, with much better differential return loss and mode conversion than toroidal counterpart.

figure 5


AE1210 - Insertion Loss
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
sdd21 (dB)
1
10
100
1000
Frequency (MHz)
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10

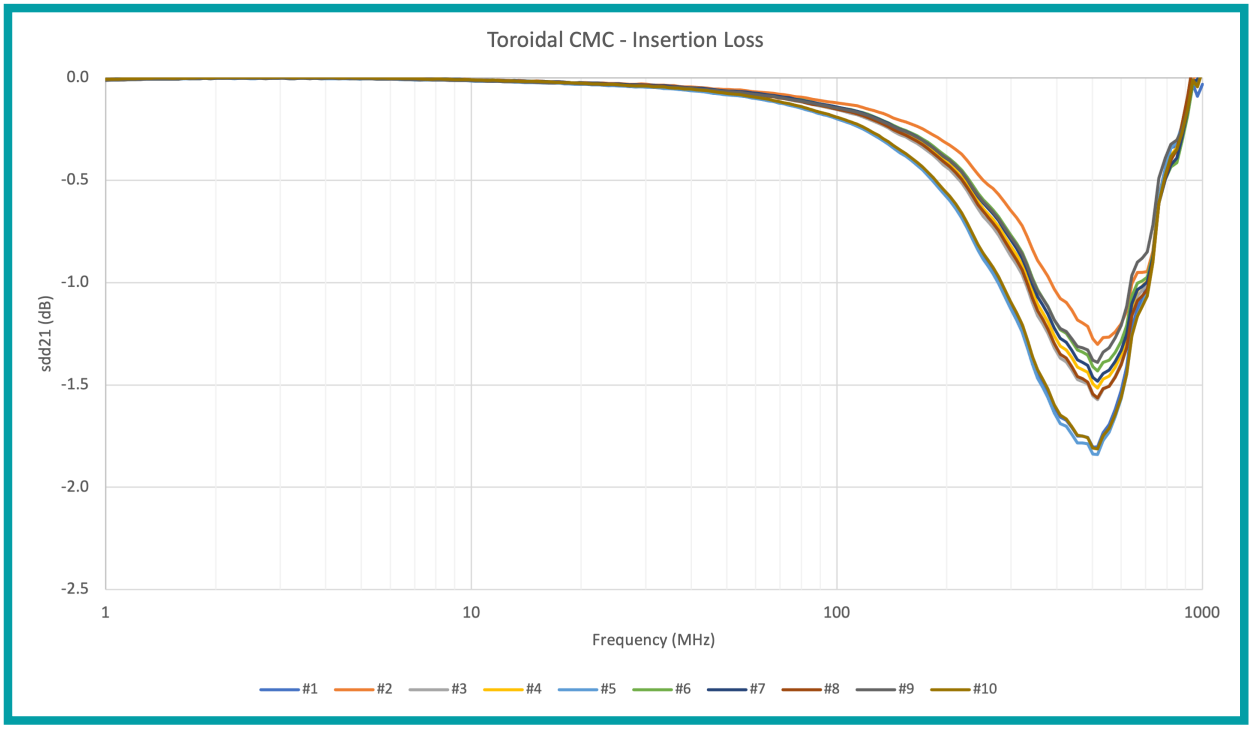
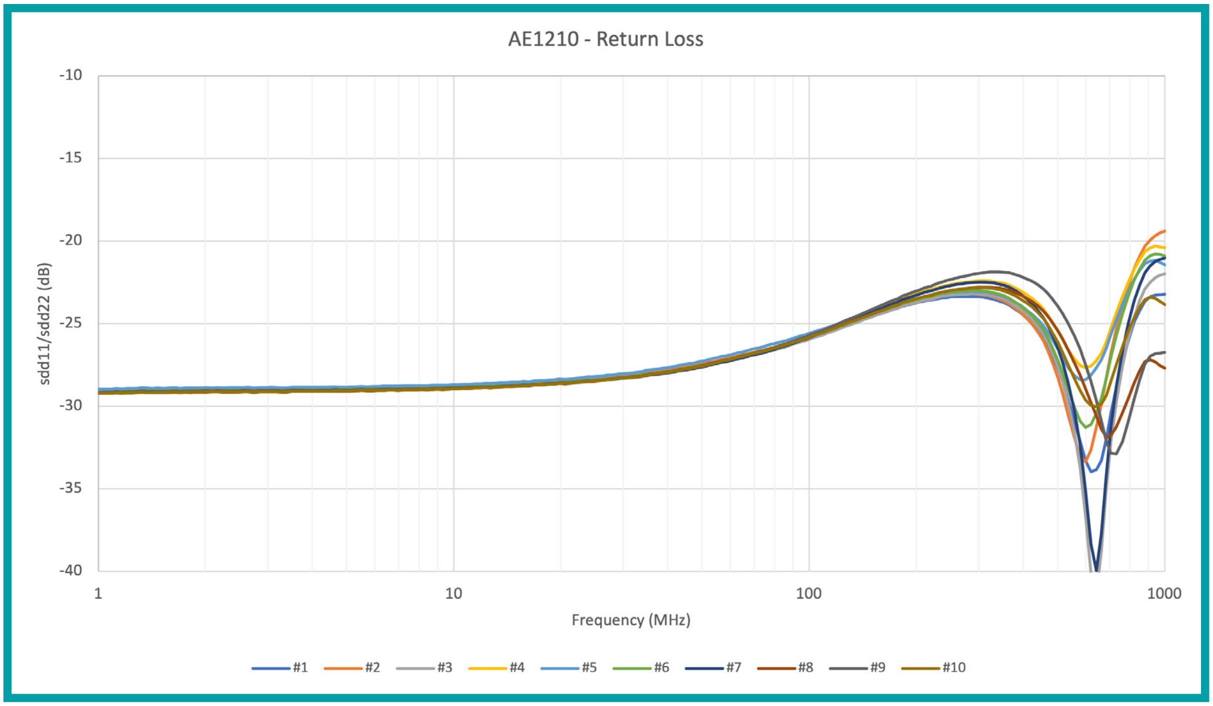

Toroidal CMC - Insertion Loss
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
sdd21 (dB)
1
10
100
1000
Frequency (MHz)
#1 #2 #3 #4 #5 #6 #7 #8 #9 #10

figure 6


AE1210 - Return Loss
-10
-15
-20
-25
-30
-35
-40
sdd11/sdd22 (dB)
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

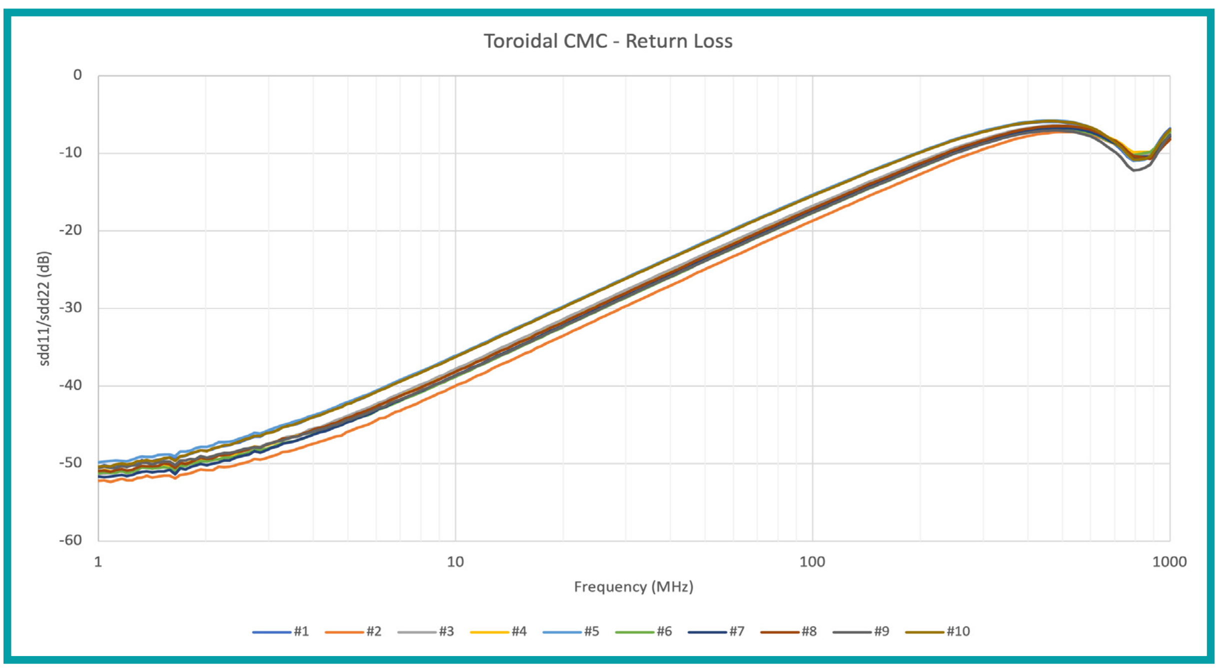
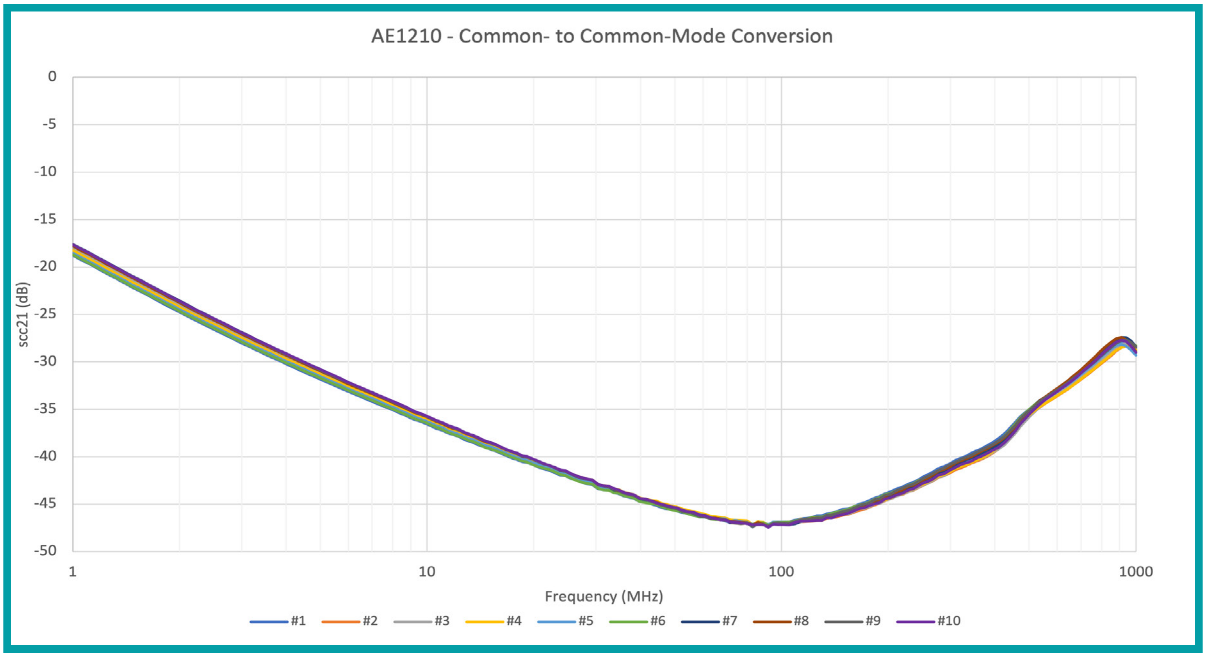

Toroidal CMC - Return Loss
0
-10
-20
-30
-40
-50
-60
sdd11/sdd22 (dB)
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

figure 7


AE1210 - Common- to Common-Mode Conversion
scc21 (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

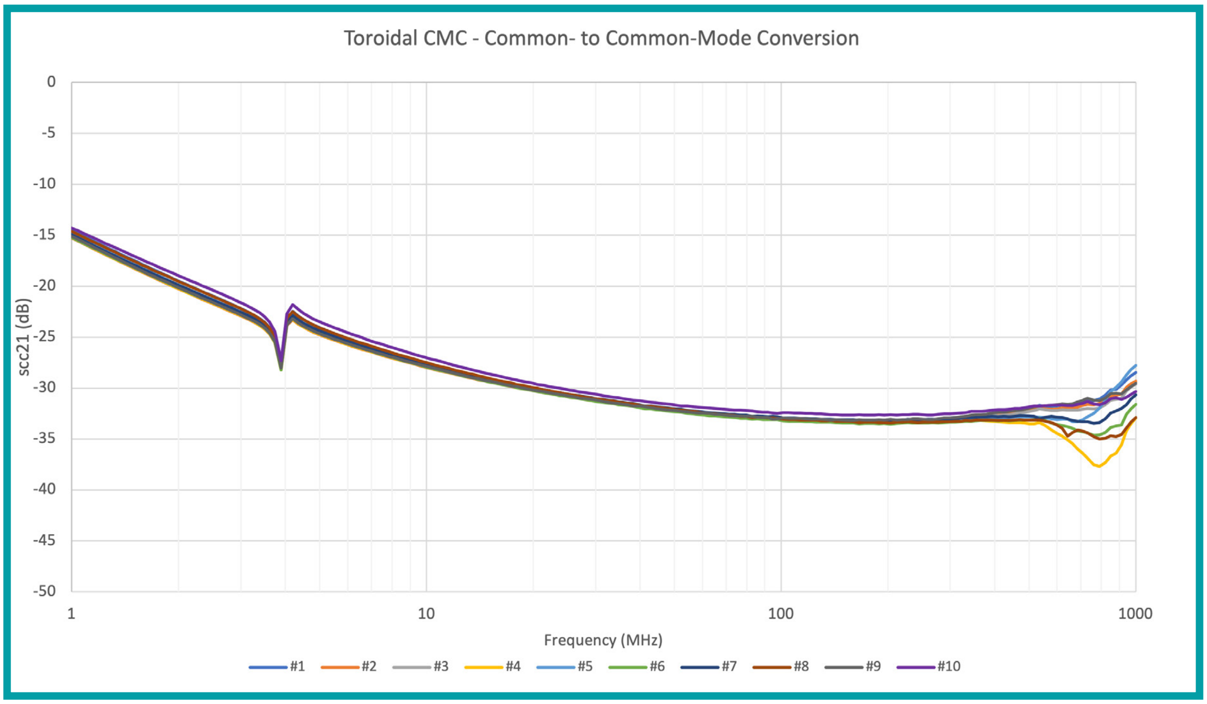
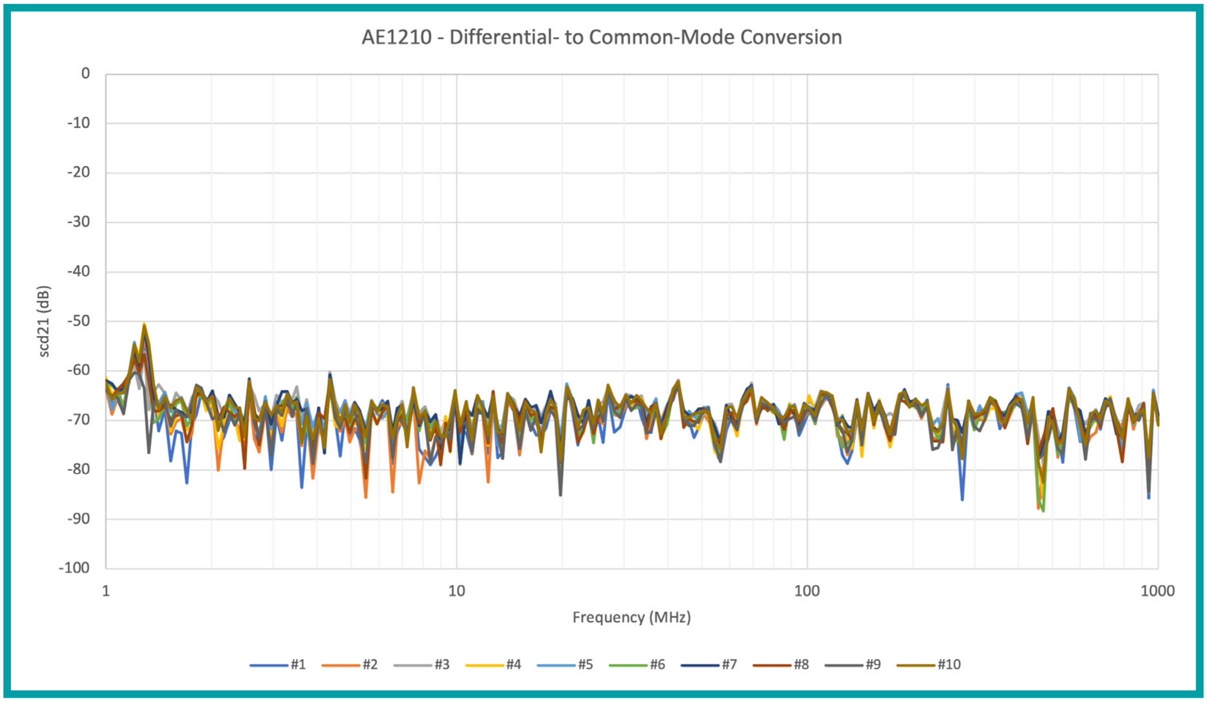

Toroidal CMC - Common- to Common-Mode Conversion
scc21 (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

figure 8


AE1210 - Differential- to Common-Mode Conversion
scd21 (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

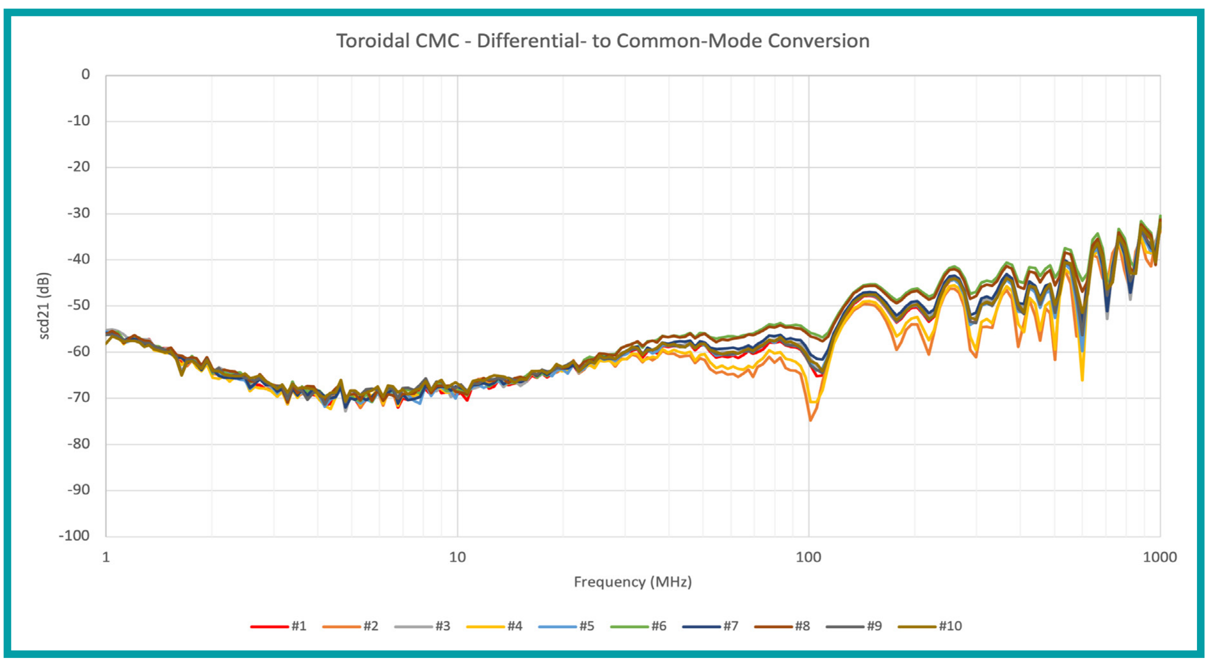
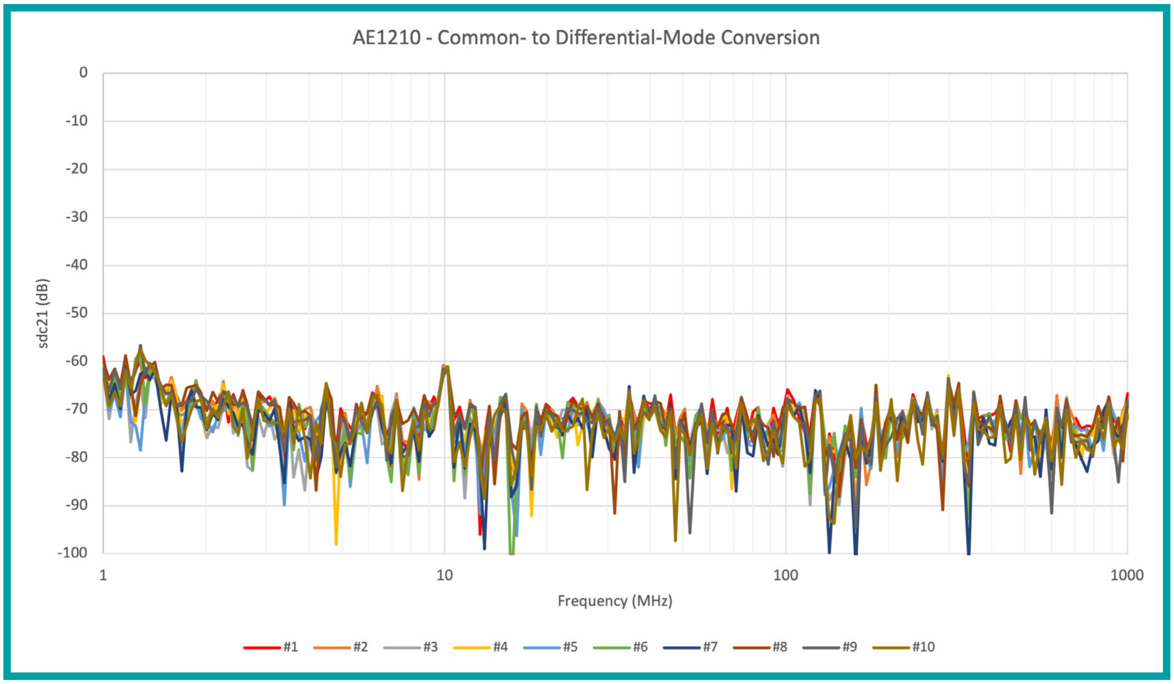
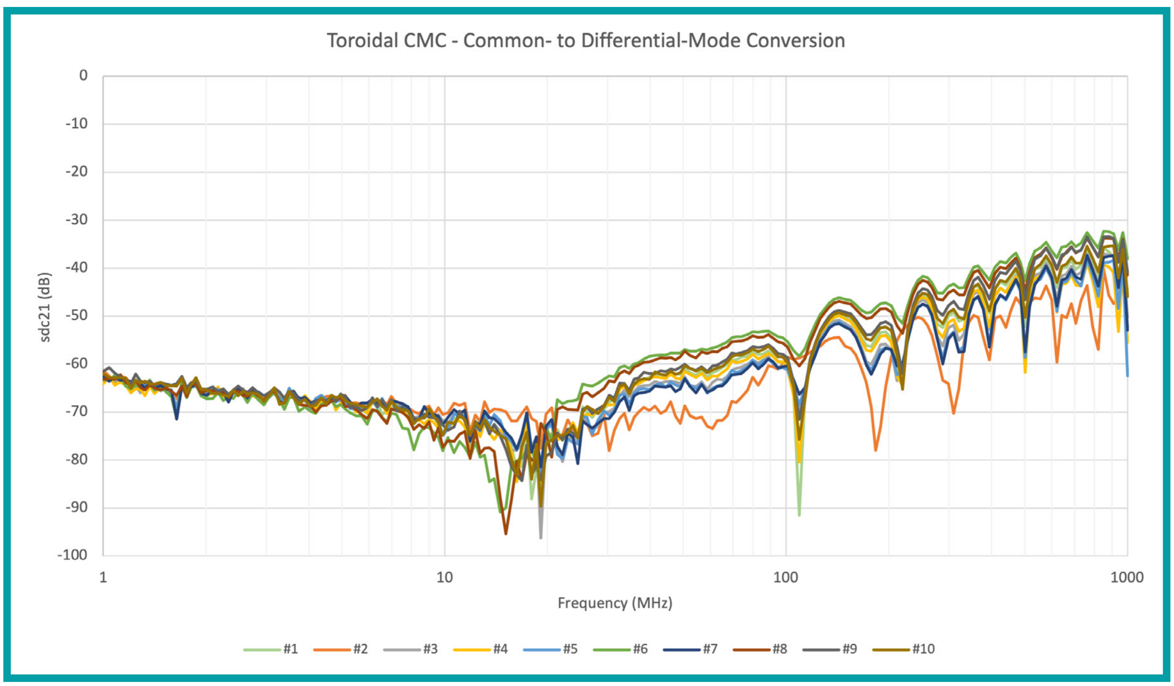

Toroidal CMC - Differential- to Common-Mode Conversion
scd21 (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

figure 9


AE1210 - Common- to Differential-Mode Conversion
sdc21 (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10


Toroidal CMC - Common- to Differential-Mode Conversion
sdc21 (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
10
100
1000
Frequency (MHz)
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

Applications and Pulse Part Numbers

Pulse offers chip-chokes for Ethernet applications with 10Mbps (10BASE-T1S and 10BASE-T1L), 100Mbps (100BASE-T1), 1000Mbps (1000BASE-T1), with and without Power over Data Line (PoDL), and CAN-FD with different classes of common- to differential-mode conversion (CDMR) per IEC 62228-3, Annex D standard, in 1210 (3.2mm X 2.54mm), 1812 (4.5mmX3.2mm), and 2518 (6.5mmX-4.5mm) size. In addition to those in this table, chip chokes for other applications with different data speeds are also under development.

Part number	Size	Ethernet speed (Mbps)	Rated PoE Current (mA)
AE0100	1210	100	-
AE1210	1210	1000	-
AE2002	1812	100	-
AE5002	1812	1000	-
AE3003	2518	100	300
AE3005	2518	100	350
AE3006	2518	100	475

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