

# EMI Suppression for Firewire & USB 2.0 Applications

## Overview

A primary problem for the Firewire IEEE1394 and USB2.0 as with the USB1.1 port designer is common mode noise conducted through the power and signal lines from various sources. EMI susceptibility on data/power lines is also a major concern. The use of a common mode choke in this application will provide a complete low cost, effective, modular, filter solution.

Steward's CM2722 (for single and dual ports), CM3822 (for tri ports), and CM5022 (for quad ports) series of components have the lowest normal mode impedance in the industry and suppress a wide range of digital common mode noise. Normal mode impedance is net circuit impedance i.e. the impedance seen by the differential signal.

## Discussion

Firewire and USB2.0 is a serial data / power port providing a broad range of data and current loads. The initial USB industry specification called for a serial port which operates in a hybrid full duplex mode and a power port that operates up to 1 amp of current. This design has created several layers of EMI problems that must be corrected. Also, USB component performance requirements have been stretched beyond initial specifications which has caused field failures of 1 amp and even 3 amp rated ferrite chip beads. Firewire and USB2.0 have increased the expected design loading to a minimum of 4.0 amps to insure failure free operation.

The source of most USB EMI problems is the two outside conductors in the connector for the power port. The primary problem is conducted common mode noise on the power line and the best EMI solution is a common mode choke.

Common mode chokes have not traditionally been considered complete power and data line solutions because:

### 1. **PROBLEM:**

Traditional common mode choke geometry generates excessive normal mode impedance which causes failure in the transmission signal integrity due to excessive net differential impedance in line. This is exacerbated with Firewire and USB2.0 both of which are clocking at greater than 480 Mb/s, compared to USB1.1 which was operating @ 12Mb/s max.

### **STEWARD SOLUTION:**

Steward's unique product geometry minimizes net circuit Impedance at 500 MHz. The low normal mode impedance will allow for video signals to pass through Steward's common mode chokes without any perturbation to the picture quality. Steward's high performance common mode chokes have the lowest normal mode impedance in the industry today.

### 2. **PROBLEM:**

Traditional common mode chokes exhibit excessive amounts of crosstalk between data lines.

### **STEWARD SOLUTION:**

Steward's unique ferrite material used in all Steward multi-line common mode chokes has high volume resistivity (ohms per cm) which eliminates electrical crosstalk. Also, Steward's unique part geometry minimizes inter-winding capacitance which is the primary source of crosstalk in most traditional wire wound common mode chokes. This is reflected in the higher normal mode performance seen in other products.

### 3. **PROBLEM:**

The USB protocol is normally a fully differential serial data set in that D+ and D- are usually 180° out of phase with each other. However, in low-Speed 1.5Mb/s and full-Speed 12Mb/s signaling as specified in USB 1.1 there is a time period at the end of every packet of data called EOP. During this time period both D+ and D- are held at approx. 0.8V for a specified period of time and this EOP signals an end of packet. This state where both D+ and D- are held at the same potential is commonly known as the signal going "single ended". The "single ended" state can also be used as a reset to a downstream port and can wake a USB device from the suspend state. The time period where D+ and D- are both at the same potential is effectively a common mode signal and could be rejected by a high impedance common mode choke.

**STEWARD SOLUTION:**

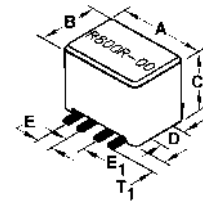
The industry has grown to understand that low normal mode impedance (as defined *Problem 1.*) and common mode impedance below approximately 150 ohms of pure common mode impedance provides an effective filter solution for the data lines. The non-differential signals i.e. end of packet signals will continue to function and will not be rejected by the common mode choke. This has allowed for the use of 80-120 ohm common mode chokes without any functional issues. Using an impedance greater than 150 ohms of common mode impedance will affect the data stream in that an end of packet may not be recognized, leading to data corruption issues.

In virtually all applications the noise coupled to the data lines is common mode energy. For example, most printers / fax / scanner / PDA have primarily common mode noise on the data lines. Therefore a CM choke solution is recommended.

The use of common mode chokes in the power circuit is the preferred solution. In some applications, a dual two channel common mode choke can provide filtration for both power and signal lines. Steward's line of common mode chokes provides a simple, reliable and cost effective USB port filter solution.

**Steward PART NUMBERING SYSTEM EXAMPLE**

CM	2722	R	800	R	-	00
PRODUCT SERIES CODE	PART SIZE CODE	RATED CURRENT CODE	IMPEDANCE VALUE CODE	PACKAGING CODE		ADDITIONAL PART DESCRIPTION



PART NUMBER	Fig #	# of Lines	A mm (inches)	B mm (inches)	C mm (inches)	D mm (inches)	E mm (inches)	E1 mm (inches)	T1 mm (inches)	DCR MAX OHMS	Typical Impedance @ 100 MHz
CM2722R450R-00	1	4	6.99 ± 0.10 (0.275 ± 0.004)	5.72 ± 0.10 (0.225 ± 0.004)	2.34 ± 0.08 (0.092 ± 0.003)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	45
CM2722R800R-00	1	4	6.99 ± 0.10 (0.275 ± 0.004)	5.72 ± 0.10 (0.225 ± 0.004)	4.32 ± 0.08 (0.170 ± 0.003)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	80
CM2722R151R-00	1	4	6.99 ± 0.10 (0.275 ± 0.004)	5.72 ± 0.10 (0.225 ± 0.004)	7.62 ± 0.13 (0.300 ± 0.005)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	150
CM2722R201R-00	1	4	6.99 ± 0.10 (0.275 ± 0.004)	5.72 ± 0.10 (0.225 ± 0.004)	9.53 ± 0.15 (0.375 ± 0.006)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	200
CM3822R800R-00	3	6	9.78 ± 0.15 (0.385 ± 0.006)	5.72 ± 0.10 (0.225 ± 0.004)	4.32 ± 0.08 (0.170 ± 0.003)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	80
CM3822R151R-00	3	6	9.78 ± 0.15 (0.385 ± 0.006)	5.72 ± 0.10 (0.225 ± 0.004)	7.62 ± 0.13 (0.300 ± 0.005)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	150
CM3822R201R-00	3	6	9.78 ± 0.15 (0.385 ± 0.006)	5.72 ± 0.10 (0.225 ± 0.004)	9.53 ± 0.15 (0.375 ± 0.006)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	200
CM5022R800R-00	2	8	12.57 ± 0.20 (0.495 ± 0.008)	5.72 ± 0.10 (0.225 ± 0.004)	4.32 ± 0.08 (0.170 ± 0.003)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	80
CM5022R151R-00	2	8	12.57 ± 0.20 (0.495 ± 0.008)	5.72 ± 0.10 (0.225 ± 0.004)	7.62 ± 0.13 (0.300 ± 0.005)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	150
CM5022R201R-00	2	8	12.57 ± 0.20 (0.495 ± 0.008)	5.72 ± 0.10 (0.225 ± 0.004)	9.53 ± 0.15 (0.375 ± 0.006)	2.41 ± 0.008 (0.095 ± 0.003)	0.89 ± 0.13 (0.035 ± 0.005)	1.91 ± 0.13 (0.075 ± 0.005)	1.91 ± 0.25 (0.075 ± 0.010)	.020	200

Figure 1

Typical Application Example 1 - Single Port

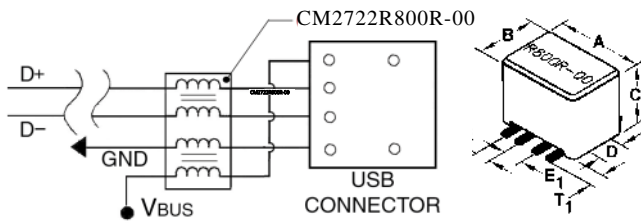


Figure 2

Typical Application Example 2 - Dual Port or x2 for a Quad Port

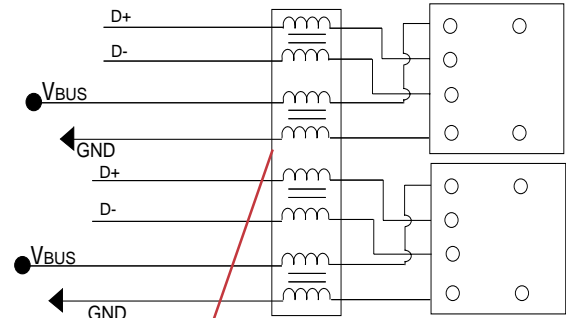
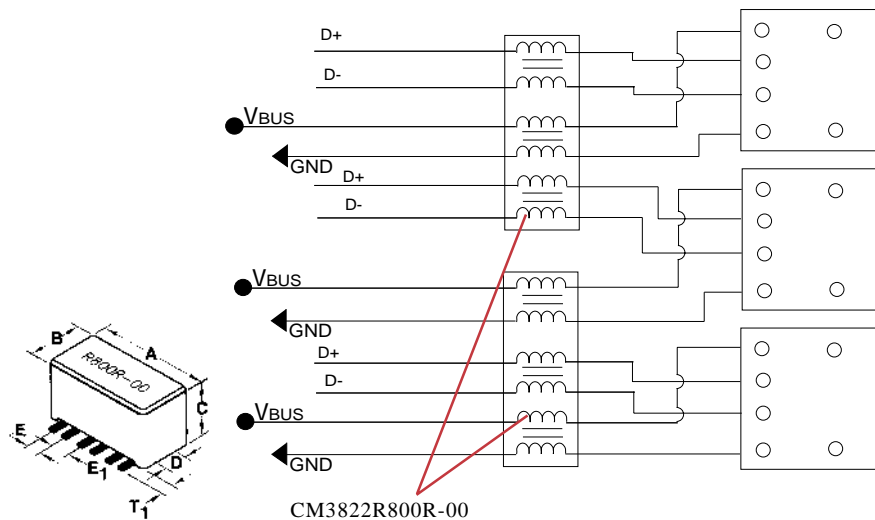
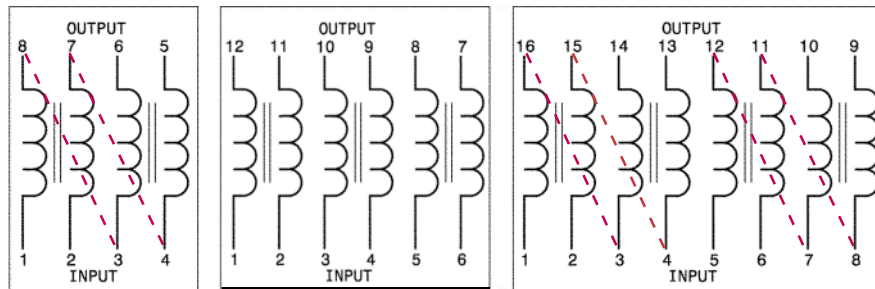


Figure 3

Typical Application Example 3 - Tri Port

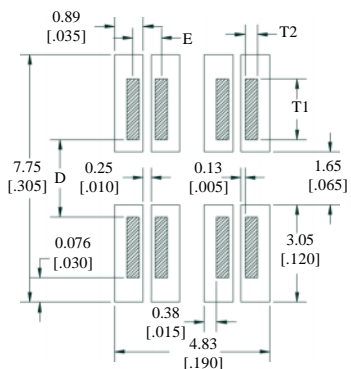


One Turn / 2X Series Equivalent Circuits



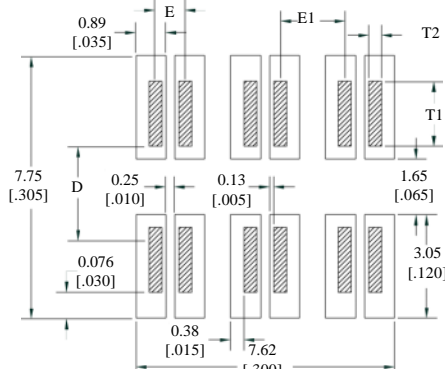
CM2722

LAND PATTERN FOR REFLOW SOLDERING



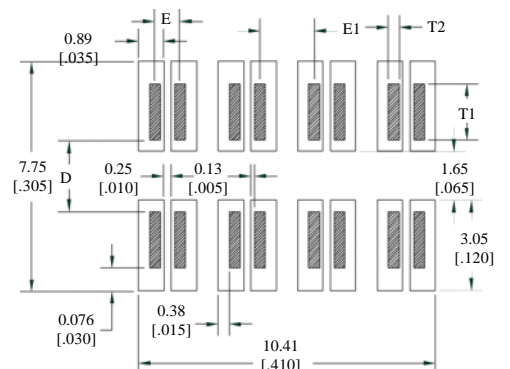
CM3822

LAND PATTERN FOR REFLOW SOLDERING



CM5022

LAND PATTERN FOR REFLOW SOLDERING



\* WIRE LENGTH [ T1 = 1.91 (.075) ]

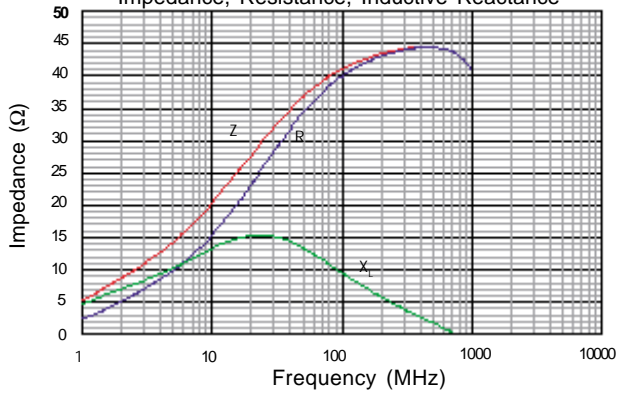
\* WIRE WIDTH [ T2 = 0.38 (.015) ]

\* WIRE THICKNESS [ T3 = 0.38 (.015) ]

**CM2722R450R-00**

Z, R,  $X_L$  vs. Frequency

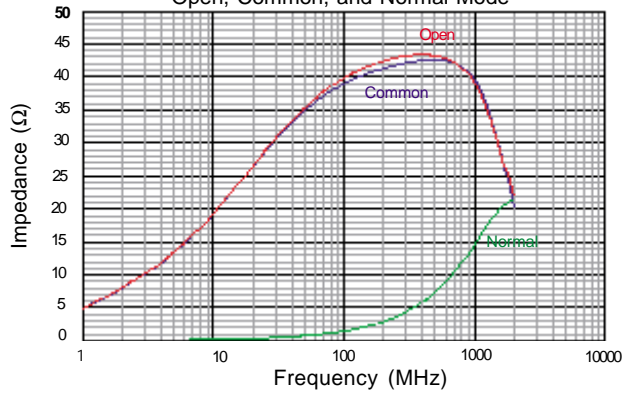
Impedance, Resistance, Inductive Reactance



**CM2722R450R-00**

Z vs. Frequency

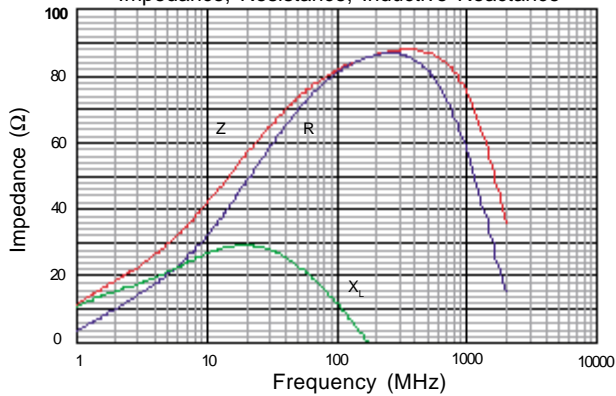
Open, Common, and Normal Mode



**CM2722R800R-00, CM3822R800R-00, CM5022R800R-00**

Z, R,  $X_L$  vs. Frequency

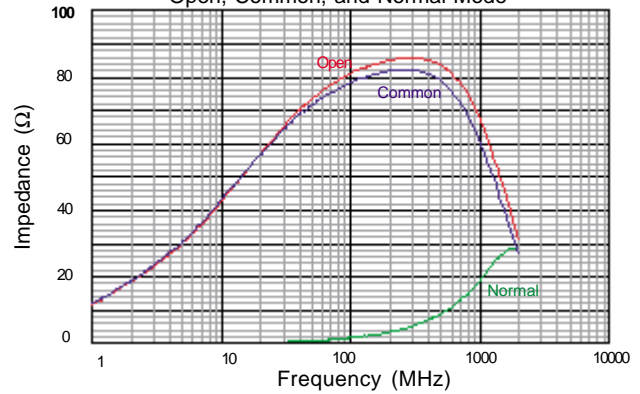
Impedance, Resistance, Inductive Reactance



**CM2722R800R-00, CM3822R800R-00, CM5022R800R-00**

Z, vs. Frequency

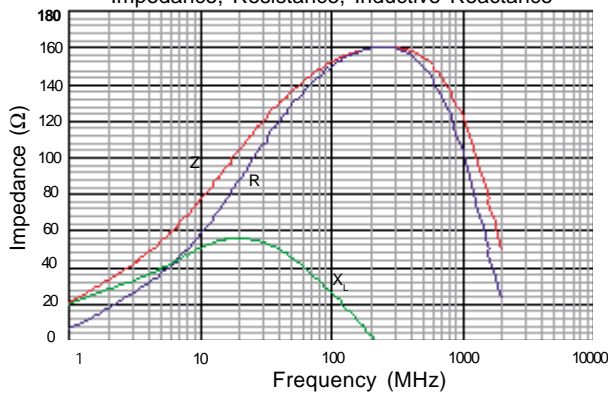
Open, Common, and Normal Mode



**CM2722R151R-00, CM3822R151R-00, CM5022R151R-00**

Z, R,  $X_L$  vs. Frequency

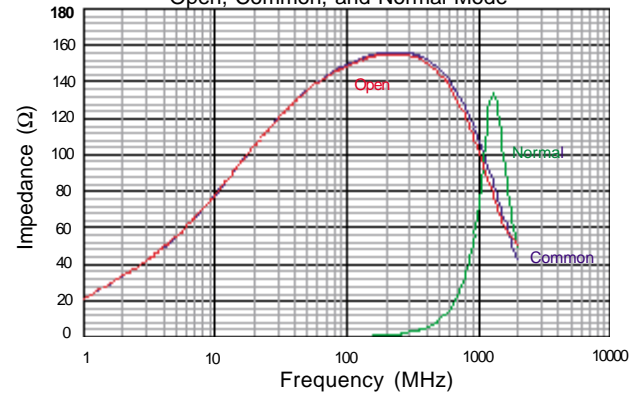
Impedance, Resistance, Inductive Reactance



**CM2722R151R-00, CM3822R151R-00, CM5022R151R-00**

Z, vs. Frequency

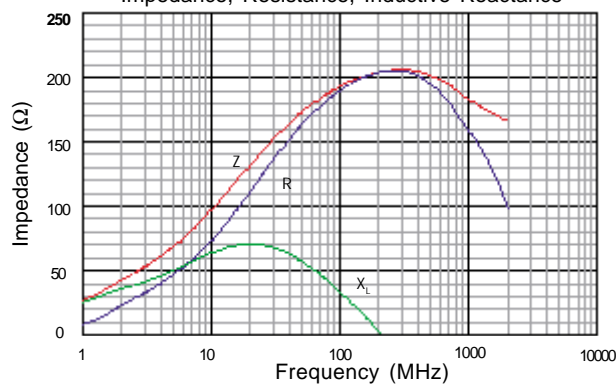
Open, Common, and Normal Mode



**CM2722R201R-00, CM3822R201R-00, CM5022R201R-00**

Z, R,  $X_L$  vs. Frequency

Impedance, Resistance, Inductive Reactance



**CM2722R201R-00, CM3822R201R-00, CM5022R201R-00**

Z, vs. Frequency

Open, Common, and Normal Mode

