Application Notes – EMI/RFI Filters 601 Series

BOURNS®

General Description

Continual advances in digital IC technology are creating stringent demands on EMI/RFI levels in equipment.

EMI/RFI low pass filters are required in personal computers, data terminals, test equipment and process controllers for high frequency suppression into or out of electronic equipment.

Filter Selection and Design Considerations

The "roll-off" frequency fc, defined as the frequency at which the filter passes one-half the power it receives at its input terminal, can be specified from the low megahertz range up to about 100MHz. This frequency, also known as the "-3 dB" frequency, will be determined by the R and C values chosen. Custom resistor and capacitor values are available to optimize system performance.

The specification of these values will depend on constraints relating to noise frequencies, system performance and driver loading. The following procedure is suggested to choose appropriate values of R and C.

The first step is to determine the desired roll-off frequency of the filter, which will lie between the signal frequency and the dominant frequencies of the EMI/RFI noise. By determining the pole of the filter (setting the denominator of the transfer function equal to zero), the roll-off frequency can be expressed in terms of R and C:

$$f_c = \frac{R_S + R_L + 2R}{2\pi C(R + R_S)(R + R_L)}$$

Furthermore, the RC combination must be chosen so that the additional RC time delay will not result in exceeding the sampling window of the receiving IC, due to excessive lengthening of signal rise and fall times.

Rise time from 10% to 90% of the waveform amplitude can be calculated in terms of the circuit's RC time constant using the $1 - \exp(-t/RC)$ relationship for a charging capacitor. At 10%, $t_L = 0.1$ time constants, and at 90%, $t_H = 2.3$ time constants. "Time constant" equals $R_{th}C$, where R_{th} is the Thevenin-equivalent resistance as seen by the capacitor.

Therefore, equating the difference in the two times to the maximum tolerable rise (or fall) time:

$$t_{max} = t_H - t_L = 2.2R_{th}C$$

$$t_{max} = 2.2\frac{(R + R_S)(R + R_L)C}{R_S + R_L + 2R}$$

A final consideration is the insertion loss. As mentioned previously, the voltage drop across the two resistors will attenuate the voltage reaching the load. Normally, logic high and low levels will still be within valid limits. The signal attenuation can be minimized by choosing small R values relative to the load impedance. Typical values for R range from 10 to 50 ohms.

Bourns Low-pass Filters for EMI/RFI Suppression
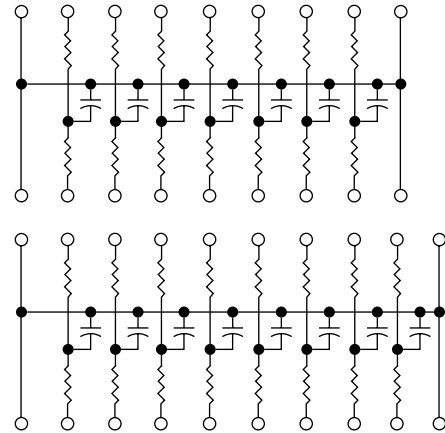
NO. OF LINES	BOURNS P/N	PACKAGE
7	4118R-601-RC/CC	DIP
8	4120R-601-RC/CC	
8	4420P-601-RC/CC	Wide Body SMD

Standard Resistance/Capacitance Values And Codes

RC	R	CC	C
250	25Ω	500	50pF
270	27Ω	101	100pF
470	47Ω	181	180pF
820	82Ω	201	200pF
101	100Ω		

Reducing EMI/RFI

The radiation of electromagnetic interference and radio frequency interference (EMI/RFI) to the environment is a pressing concern for many manufacturers of electronic equipment. According to FCC regulations (Parts 15 and18), emissions must not exceed certain maximum levels depending on whether the equipment is for strictly industrial use or also for residential use. A graphical representation of these limits is shown in Figure 1. Similar restrictions apply to equipment sold in Europe (VDE 0871, a West German standard), Japan (VCCI), and to the military (MIL-STD-461/462.)
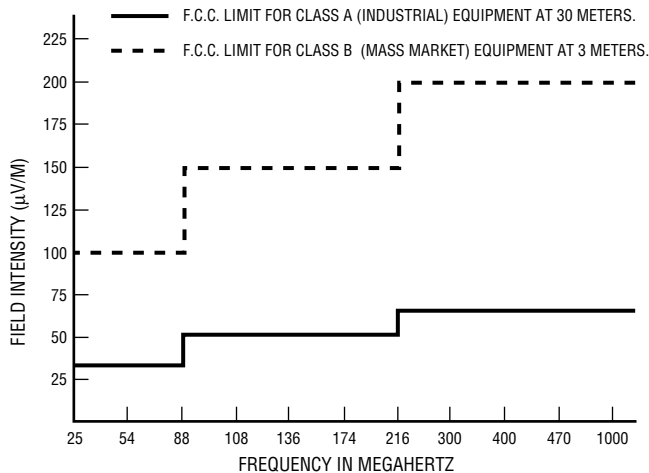

Figure 1.
F.C.C. radiation limits for class A
and class B computing devices

Several approaches are available today to control EMI/RFI emissions, including grounded metal enclosures, shielded cables, judicious component placement and interconnect designs, power-supply decoupling, and low-pass filtering of signal lines.

Low-pass filtering can be effective for EMI/RFI filtering when the noise components to be rejected occur at frequencies higher than the signal frequency (to be passed). For these situations, Bourns has developed low-pass resistor-capacitor filter networks which are ideal for board-level EMI/RFI filtering.

A typical application would be to filter signal lines between RS-232 drivers and their corresponding connectors. In such low to medium frequency applications, these networks represent a more useful (and economical) solution than inductive type filters such as ferrite beads. In fact, ferrite beads become mostly ineffective below 10MHz.

The basic "T" configuration (Figure 2) is a standard R-C network available in versions for 7 or 8 input lines. The 8 input-line version is available in both through-hole DIP and surface-mount models.
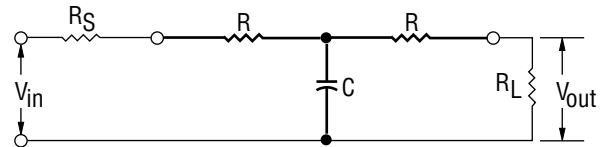

Figure 2.
basic T-Filter configuration

Under steady state conditions, the capacitor C offers an infinite impedance to the DC component of the input waveform (which will be assumed for the moment to be entering from the left side). Thus, the DC component of the signal voltage is passed to the load, but reduced in value by the voltage drop across the two resistors.

The impedance of C becomes lower at higher (noise) frequencies. Thus, the noise component of the signal faces a voltage divider consisting of the first resistor (R) and C. At the high frequencies of the noise component, R will be much greater than the impedance of C, therefore, most of the noise voltage will be dropped across the resistor. Almost no noise current flows through the load and, therefore, will hardly affect the DC voltages (i.e., the signal) across the load.

Since the filter is symmetric, its principle of operation is the same for waveforms traveling in the opposite direction, in which case the voltage divider is formed by the second resistor and the capacitor. Such a symmetrical design is useful for filtering signals on a bidirectional bus.

Assuming purely resistive source and load impedances, the transfer function is given by:

$$\frac{V_{out}}{V_{in}} = \frac{R_L}{j\omega C(R + R_S)(R + R_L) + (R_S + R_L + 2R)}$$