A Filter Solution for the BCM

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Introduction

The BCM Bus Converter is a member of Vicor's family of V•I Chips. It provides an isolated intermediate bus voltage to power non-isolated point-of-load (POL) converters from a narrow input range DC source. It may also be used as an independent DC source.

V•I Chips achieve unprecedented low levels of noise for electrical power processing. Owing to a novel, proprietary class of soft-switching (ZCS/ZVS) topologies, V•I Chips — compared to hard switching sub-MHz bricks — present extremely low conducted and radiated emissions that could plague sensitive circuitry.

Without any external filtering capacitors, output noise at the BCM is less than 1% of its output voltage. Soft switching at 3.5 MHz leverages nominal distribution inductance, associated with board interconnects, in concert with small ceramic bypass capacitors at the point of load to attenuate ripple to less than 0.1% at the load. By overcoming frequency barriers with unique soft-switching technology, system-level EMI filtering becomes less complex, less bulky, and less costly.

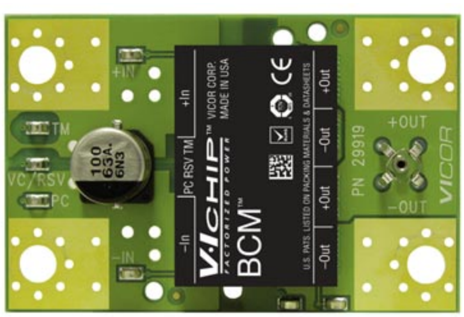
V•I Chips capitalize on the noise-attenuation benefits of soft switching at high frequency. The objective of this Application Note is to present optimized filter solutions, in terms of topology and component values, and practical guidelines to allow the end user to develop a complete BCM solution.

For applications where PCB area is limited, or where a packaged solution is desired, a complete solution is also introduced at the conclusion of this Application Note.

Filter Evaluation Board

The Vicor BCM evaluation board, shown in Fig. 1, provides a simple platform to operate a BCM and to perform basic tests and measurements. The board is designed to hold a V•I Chip and the few other components needed for operation. Large copper pads are provided with holes for input and output electrical connections, for either cable rings or lug bolts.

Figure 1
BCM evaluation board

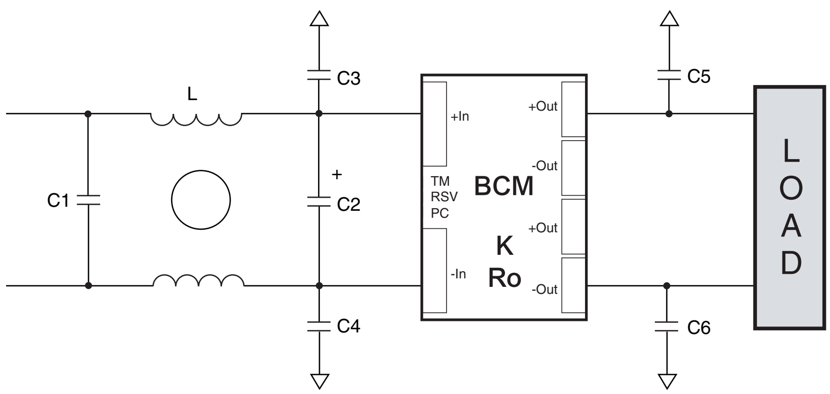


To connect an EMI filter and evaluate the attenuation characteristics, an additional board, shown in Fig. 2, onto which a BCM evaluation board can be mounted is provided. This board supports a single- or dual-cell EMI filter and provides mechanical and electrical connections for the BCM evaluation board.

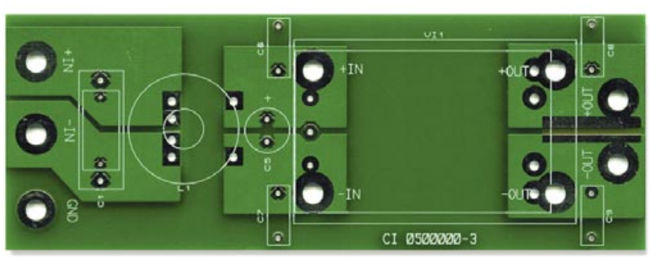
Figure 2
Filter evaluation board

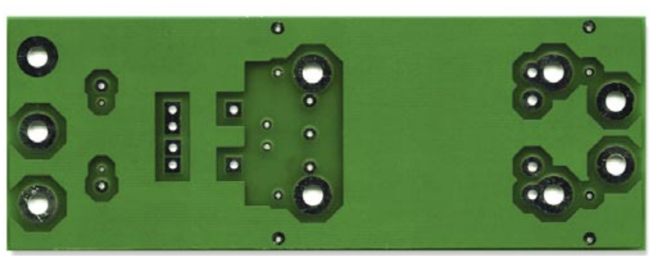
A schematic of the filter evaluation board is illustrated in Fig. 3.

Figure 3
Filter evaluation board schematic



Underneath the BCM, the filter board provides a ground plane where the 'Y' capacitors are connected, with minimal lead length.





Filter Evaluation and Optimization

In designing the EMI filter for the BCM, the goal was to keep the 'Y' and 'X' capacitor values constant, changing only the common-mode choke to find the best solution in terms of attenuation and size. The capacitor values shown in Fig. 3 are as follows:

C1:	2.2 µF, 'X2' Type
C2:	10 µF, 100 V Electrolytic (on the BCM eval board)
C3, C4, C5, C6:	4.7 nF, 'Y2' Type

Three different K factor BCMs were tested to characterize the effects of operating parameters, such as output voltage and output current, on the EMI characteristics:

B048F030T21-EB: K = 1/16 Low voltage / high current BCM

B048F120T30-EB: K = 1/4 Mid voltage / mid current BCM

B048F480T30-EB: K = 1 High voltage / low current BCM

Unless otherwise specified, all the tests, were performed at 48 V nominal input voltage and maximum rated load for each BCM. All the plots were done against the limit mask of EN55022 Level B, Quasi Peak. This is the most common EMI standard.

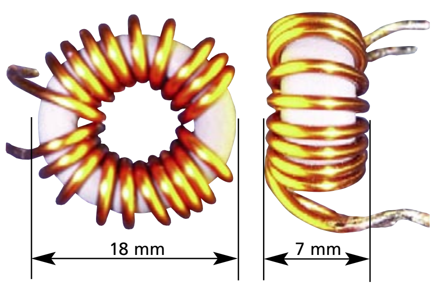
K = 1/16 and K = 1/4 BCM

For K = 1/16 and K = 1/4, 3 V and 12 V output respectively, the inductor that offers the best attenuation and the smallest size has the following characteristics:

Core magnetics: ZW-41450-TC

10 + 10 turns AWG18 wire

Inductance: 432 µH (measured 440 µH)



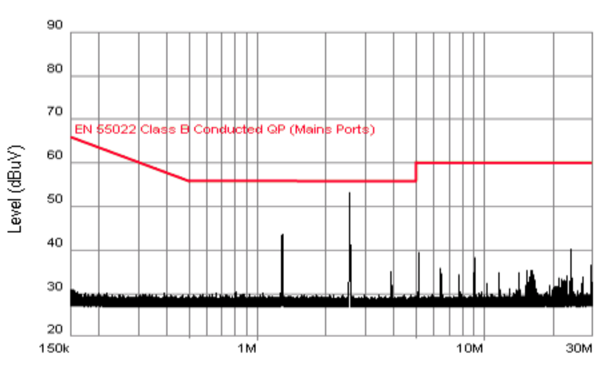


Figure 4
Plot of attenuated harmonic emissions: B048K030T21-EB: low voltage / high current BCM

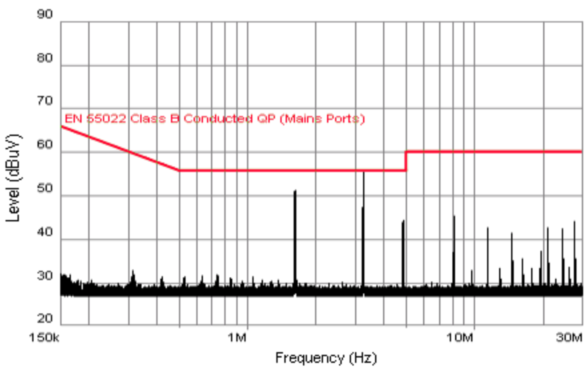
K = 1 BCM

For the 48 V output BCM, due to its higher voltage, the inductor used in the previous case doesn't offer enough attenuation, and the fundamental, as well as the second and third harmonics would increase above the limit. In this case, the inductor must be a larger size in order to have higher inductance.

The part developed for this case has the following data:

Core magnetics: ZJ-41809-TC
10 + 10 turns AWG18
Inductance: 611 µH (measured 627 µH)

Figure 5
Plot of attenuated harmonic emissions: B048F120T30-EB: mid voltage / mid current BCM



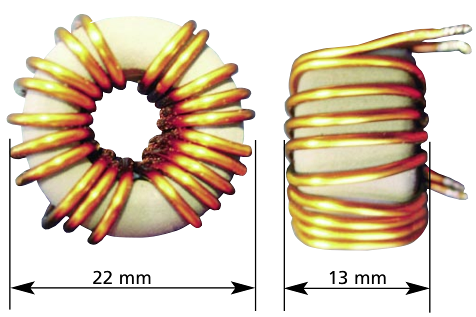
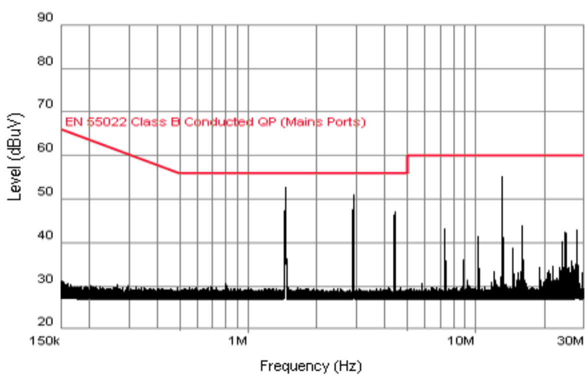


Figure 6
Plot of attenuated harmonic emissions: B048F480T30-EB: high voltage / low current BCM



Filtering Multiple BCMs

The same filter evaluation board described previously also allows the connection of multiple BCM boards sharing a common input filter.

In this implementation, the BCM boards are connected in parallel by means of stand-offs. On the input side, stand-offs make the parallel electrical connections, while the outputs are isolated by using insulated stand-offs.

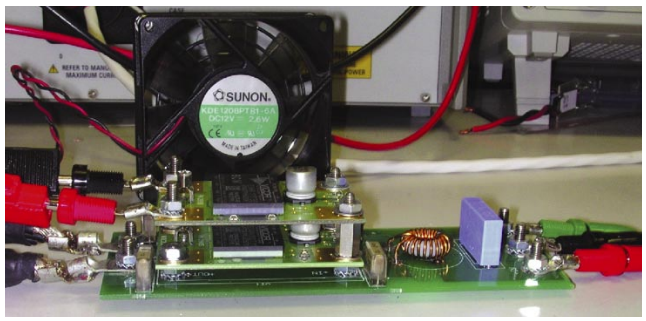


Figure 7
Stacked BCM boards

As the two BCMs are not synchronized, their emissions are not additive, but rather spread over the spectrum; therefore, there is no need for a higher value inductor. The same inductor used for the single K = 1/16 BCM has been used.

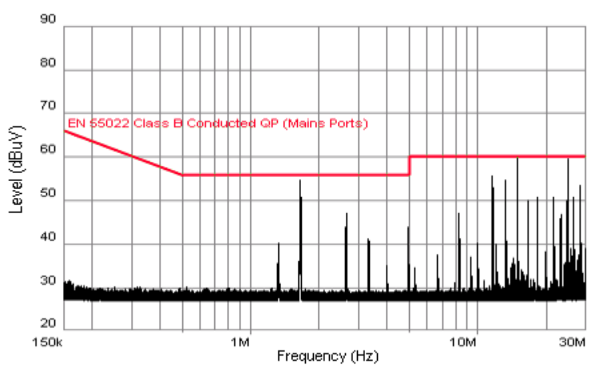


Figure 8
Plot of attenuated harmonic emissions: B048F120T30-EB @ 120 W + B048F030T30-EB @ 150 W

An important remark regarding the plot above is that the upper BCM board, shown in Fig. 7, was not de-coupled by 'Y' capacitors, due to the difficulty of bringing them down to the ground plane on the evaluation board. However, adding the capacitors made a significant improvement, as it can be seen from the plot below.

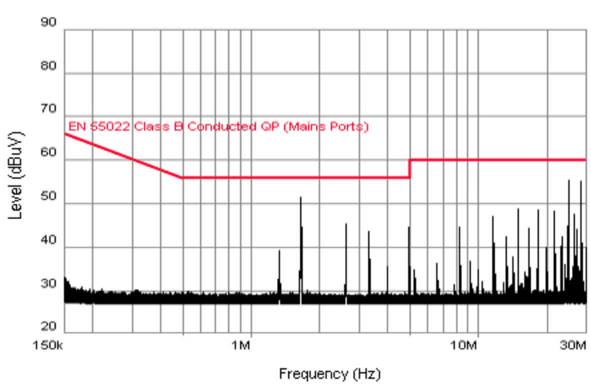
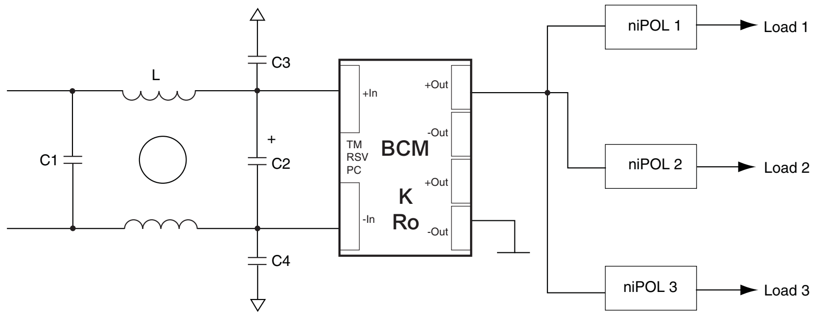


Figure 9
Improvement of Figure 8 achieved by de-coupling both BCM boards with 'Y' caps.

BCM Powering niPOLs

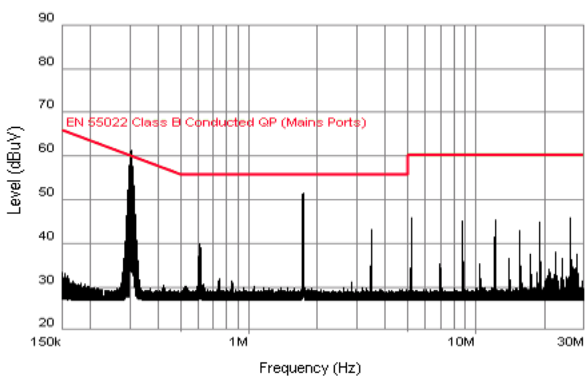
A typical IBC (Intermediate Bus Converter) application consists of a BCM powering one or more niPOL (non-isolated point-of-load) converters as shown in Fig.10.

Figure 10
Typical IBC application



To evaluate this configuration, a K = 1/4 BCM was used with unsynchronized third party niPOLs connected to resistive loads. The inductor was the same as per the K = 1/4 single BCM configuration.

Figure 11
Plot of attenuated harmonic emissions for IBC application. One niPOL connected @ Iout = 10 A



It is very easy to identify the fundamental 300 kHz and second harmonic generated by the niPOLs. Due to the much lower switching frequency, the filter originally designed for the BCM would require a larger inductor to reduce its corner frequency and to provide enough attenuation to the niPOL emissions.

Conclusion

Due to their inherent low noise, the BCMs are quite easy to filter to levels meeting the international standards for conducted emissions. In general, a single common-mode choke is sufficient, and the inductor value can easily be optimized for the BCM used, whether high output voltage / low current, or low output voltage / high current. The BCM should be de-coupled to the ground plane by means of 'Y' capacitors mounted as close to the device as possible.

Multiple BCM systems can also be filtered with the same method because the harmonic emissions of each device don't sum coherently, but instead are spread over the spectrum. Hence their amplitude doesn't increase when compared to a single BCM.

Packaged Solutions, for Space Savings

Filters for V•I Chips are available in packages that occupy only 1/2 in^2 of PCB Area. Slightly larger models are available with an integrated total hot-swap function. For more information please visit picorpower.com.

Actual Size