Usage of External Input and Output Filter Capacitors on PMB and PMC series Power Modules

Introduction

The Ericsson PMB and PMC series of non-isolated power modules provide a high performance solution for many applications requiring reliable and cost-effective power conversion. A buck topology with synchronous output rectification is utilized to achieve very high efficiencies. These modules are constructed with an open frame packaging design and feature output voltage programmability over a range from 0.75 V to either 3.63 V or 5.5 V depending upon the input voltage range of the model. One series supports input voltages between 3.0 V and 5.5 V and a second series supports input voltages between 8.3 V and 16 V. Maximum output current ratings are 10 A and 16 A. Two packaging structures are offered, a horizontal mount version with SMT compatibility and a vertically mounted version connecting to the user's circuit board with solderable pins. The part numbers available in the PMB and PMC series are summarized in Figure 1.

Package	Horizontal SMT		Vertical PIH	
Input Voltage	3.0 - 5.5	8.3 - 16.0	3.0 - 5.5	8.3 - 16.0
Iout = 10 A	PMC4318	PMC8518	PMB4418	PMB8518
Iout = 16 A	PMC4518	PMC8818	PMB4518	PMB8818

Figure 1 - PMB and PMC Power Modules.

Each of these power modules contains input capacitance internal to the converter to supply dynamic input ripple current as required for the converter's operation. However, operation at high output currents with only the internal capacitance could result in instability (oscillation) under some conditions, especially in situations with an inductive component in the converter's power source. This oscillation can create excessive input and output ripple voltages and can also result in damage to the converter. This exposure can be eliminated by using additional input capacitance external to the power module, and some external capacitance should be used in all circumstances. Since it is recommended to use external input capacitance, the datasheets for these Ericsson products are formulated assuming a specified value of external input capacitance. Performance in accordance with datasheet parameters is only guaranteed if at least this amount of capacitance is provided by the user. The external capacitance has additional benefits. It lowers the ripple current in each of the input capacitors, reduces the input ripple voltage, improves the transient response of the converter and enhances the reliability of the converter by increasing the lifetime of the internal input capacitors.

This application note will define the minimum requirements for input capacitors for each of the PMB and PMC power modules. The capacitor configuration used to obtain the datasheet performance parameters will also be identified. The input ripple voltage will vary with the converter's output voltage setting. Data is provided that shows this relationship when using the external input capacitance as defined in the datasheet. An example is also provided that shows how adding additional external input capacitance can further reduce the input ripple voltage. Recommended values of external output capacitance are also provided.

Capacitor Requirements

The impedance of the input voltage distribution system that is providing power to a converter (the source impedance) and the converter's input circuitry combine to form one overall circuit. There are inductive components inherent to any distribution system such as filters and the distributed inductance of the distribution traces or wires. This inductance can interact with the input impedance of the converter which is capacitive and create instability in some situations. This instability, which most often occurs at high converter output loads, can create oscillations which will prevent the converter from meeting its defined performance parameters and can even damage the converter. This risk can be eliminated by presenting a capacitive distribution impedance to the converter. This can easily be done by using one or more external input capacitors as close as possible to the converter's input pins. In a similar manner, it is important that the converter see a capacitive load on its output rather than a load that is inductive in nature.

For PMB and PMC power modules with a low input voltage range (3.0 V to 5.5 V), a minimum of two paralleled 22 µF ceramic capacitors should be used on the input. Each of these capacitors should have an equivalent series resistance (ESR) of 10 milliohm or less. The PMB and PMC datasheets were developed using this amount of external capacitance.

For PMB and PMC power modules with a high input voltage range (8.3 V to 16.0 V), a minimum of one 4.7 µF ceramic capacitor should be used on 10 A output modules and two paralleled 4.7 µF capacitors should be used on 16 A output modules. Each of these capacitors should have an ESR of 10 milliohm or less. Additional capacitance will provide further benefit as described later. Since it is felt that most high input voltage applications will use some additional capacitance, the PMB and PMC 8000 series datasheets were developed using 4 paralleled 4.7 µF capacitors on the input.

A minimum amount of external output capacitance is also required to insure stability and to guarantee the datasheet parameters at high output loads. As with the input capacitors, these capacitors should also be placed as closely as possible to the converter pins. This capacitance will improve the output ripple performance as well as the converter's transient response to dynamic loads.

For the 4000 series PMB and PMC modules (low input voltage range), a minimum of one 150 µF low ESR polymer capacitor should be used. Two such capacitors should be paralleled for the 8000 (high input voltage range) modules (300 µF minimum capacitance). The PMB and PMC datasheet performance parameters are predicated upon these values of capacitance.

Module Type	Input Caps		Output Caps	
	Minimum	Used in Datasheet	Minimum	Used in Datasheet
PMB4418 PMB4518 PMC4318 PMC4518	2 x 22 µF	2 x 22 µF	1 x 150 µF	1 x 150 µF
PMB8518 PMC8518	1 x 4.7 µF	4 x 4.7 µF	2 x 150 µF	2 x 150 µF
PMB8818 PMC8818	2 x 4.7 µF	4 x 4.7 µF	2 x 150 µF	2 x 150 µF

Figure 2 - Summary of Capacitor Requirements.

Figure 2 summarizes both the minimum and datasheet values for the input and output capacitors to be used with the PMB and PMC series power modules.

Effect of Output Voltage and Load Current on Ripple Voltage

The PMB and PMC datasheets contain a single typical value for the input ripple voltage. This value assumes the added external input capacitors as defined in the preceding section, and represents the highest ripple voltage that should be seen over the range of programmable output voltages. In actuality, the input ripple voltage will vary as a function of the converter's output voltage setting and output power, and will quite often be less than the specified value.

To provide an appreciation for this effect, the variation in input ripple voltage with output voltage is shown in Figures 3–10 for each of the 8 models in the PMB and PMC series of power modules. The data in these figures have been taken with the maximum output current for each module type and with the most commonly used nominal input voltages (3.3 V and 5.0 V for low input voltage models and 12.0 V for high input voltage models). External input and output capacitors for these curves are the same as used for the datasheets as defined in Figure 2. For example, with an input voltage of 3.3 V and an output voltage setting of 2.5 V, the typical full load input ripple voltage of the PMC4518 would be 170 mV compared to a datasheet specification of 300 mV.

The input ripple voltage will generally scale with the output power of the power module. If the converter is derated so that it is operating at less than its maximum output current, the input ripple voltage will be less than the datasheet value. It is also important to understand that the input ripple voltage can be further reduced by using additional external input capacitance. The reduction in ripple voltage will enhance the reliability of the application by reducing the stress levels on all the capacitors, both external and internal to the converter.

An example of these two effects is shown in Figure 11 for the PMC8818 converter. In this example, the converter is programmed for an output voltage of 5.0 V. The maximum input ripple as defined in the datasheet is about 500 mV. This assumes the 4 paralleled 4.7 µF external input capacitors. The full load input ripple voltage can be reduced to about 250 mV by using 7 input capacitors and to about 150 mV with 11 such capacitors. This can be a good design trade-off for applications demanding high levels of reliability and performance. Figure 11 also shows the effects of output power derating. If the maximum output power is 30 W, using only the minimum 2 paralleled 4.7 µF capacitors will give a typical input ripple of 250 mV. These two capacitors would support the 500 mV datasheet rating up to an output power of about 60 W.

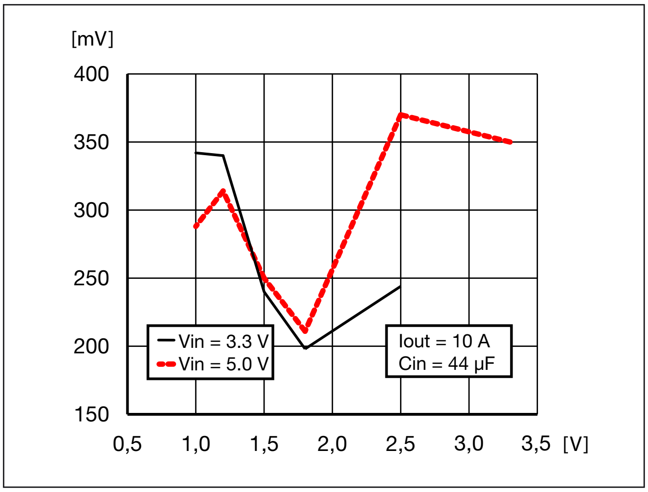

Figure 3 - Input Ripple Voltage vs. Vout - PMB4418.

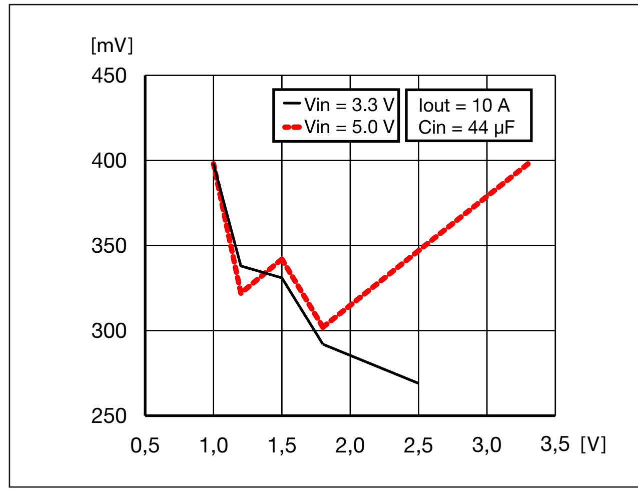

Figure 4 - Input Ripple Voltage vs. Vout - PMB4518.

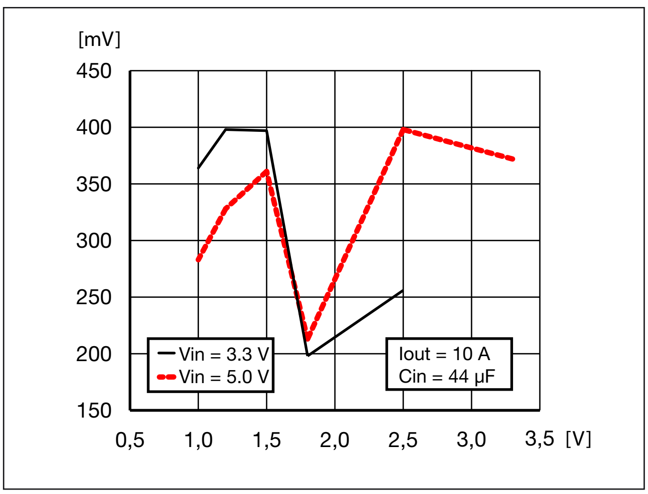

Figure 5 - Input Ripple Voltage vs. Vout - PMC4418.

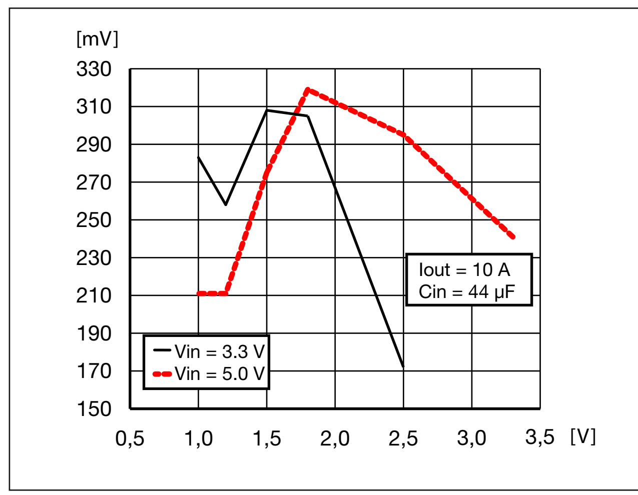

Figure 6 - Input Ripple Voltage vs. Vout - PMC4518.

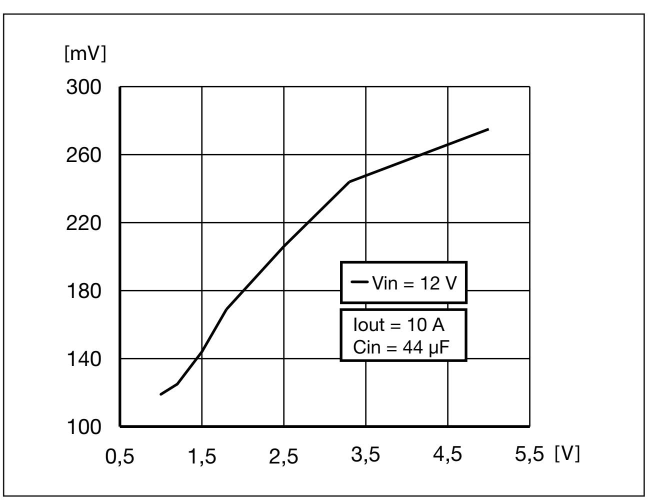

Figure 7 - Input Ripple Voltage vs. Vout - PMB8518.

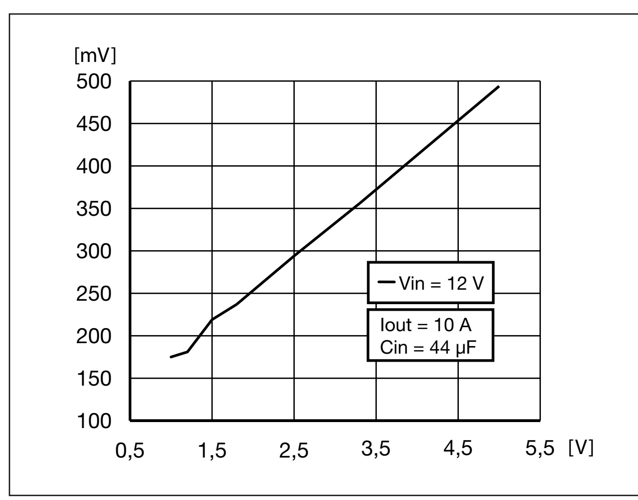

Figure 8 - Input Ripple Voltage vs. Vout - PMB8818.

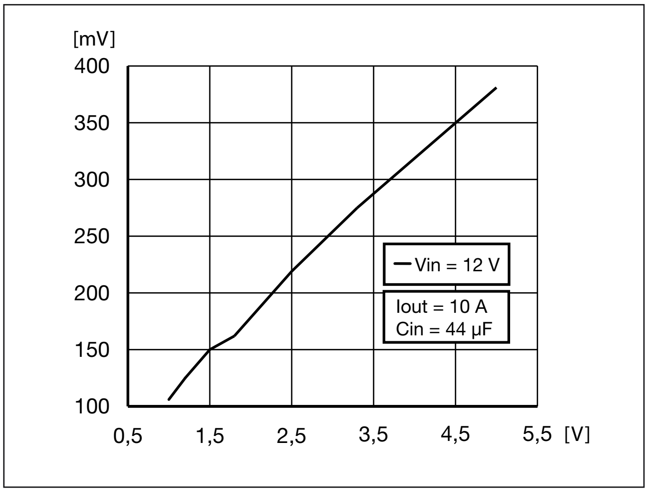

Figure 9 - Input Ripple Voltage vs. Vout - PMC4518.

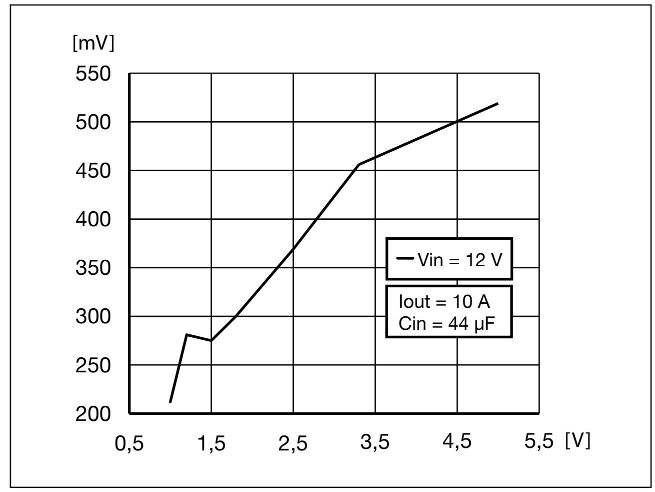

Figure 10 - Input Ripple Voltage vs. Vout - PMC8818.

Output Power (W)	Desired Input Ripple (mV)		
	150	250	500
0 - 20	2 x 4.7 µF	2 x 4.7 µF	2 x 4.7 µF
20 - 40	5 x 4.7 µF	2 x 4.7 µF	2 x 4.7 µF
40 - 60	8 x 4.7 µF	5 x 4.7 µF	2 x 4.7 µF
60 - 80	11 x 4.7 µF	7 x 4.7 µF	4 x 4.7 µF (Used in Datasheet)

Figure 11 - Effect of Additional Input Capacitance.
Note: Output programmed to 5.0 V.