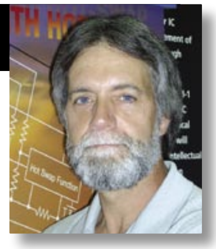
Active EMI power filter and hot swap functions merge



By Bob Lanoue

EMI control can be a complex design task that is dependent on many factors. However, a reduction of differential- and common-mode conducted noise created by the power converter(s) can be achieved by using either passive or active filters. In AdvancedTCA and telecom systems, the redundancy requirement of field replaceable boards into functioning shelves drives the need for a current inrush limiting function on each board. This function is generally referred to as hot swap. This article focuses on the advantage of using certain core hot swap elements, for example, the FET, as the series element in the active differential filter and the current limit sense element for the filter control signal to achieve active EMI control. Using this approach, the designer gets added value: superior noise attenuation and additional savings in board space.

Regulatory agencies, such as the FCC, require testing of complete OEM systems to certify that the noise emanating from the equipment falls below the standard maximum levels established for the category or class of equipment. In the case of power conversion solutions that use switching topologies, the benefits of high efficiencies and lower heat generation will be accompanied by increased electrical noise caused by high switching voltages and currents. The magnitude of the noise depends on several factors:

- Topology and components used
- Switching frequency
- PCB layout
- Magnitude and rate of change in the AC current and voltage levels

Performance levels needed to meet these standards must be factored into the initial design phase of product development. Although some topologies are less noisy than others, most will fail at least the conducted emissions test at the expected power levels in AdvancedTCA boards without the proper design precautions. Active filter solutions can use less board space in comparison to a passive solution when the fundamental switching frequencies are at the low end of the conducted band and the current levels are in the 3-15 amp range.

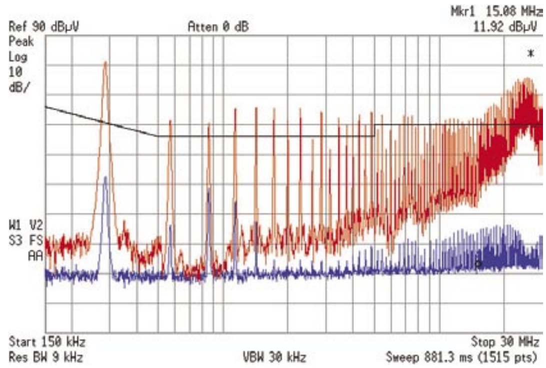


Figure 1

Generally, noise magnitudes and profiles of standard or embedded power converters are not readily available, so the ideal filter solution requires characterization testing to quantify the needs. Standard brick filtering data is sometimes available with a recommended passive filter circuit using discrete components or a filter product. The physical size of those passive solutions versus available board area can become another issue. The AdvancedTCA PICMG 3.0 specification, section 4, defines the power distribution of up to 200 W per board with power conversion of the 48 V or 60 V input bus on each board within the shelf. Every board must be below the EN55022 Class B level of the conducted noise limit. The specification allows up to 16 boards per shelf and requires a minimum 18 dB of additional shelf filtering over the conducted noise frequency range of 150 kHz to 30 MHz to assure the cumulative noise of a fully populated and functioning shelf stays below the compliance system noise limit.

Figure 1 shows a measurement plot for a standard converter using a spectrum analyzer with peak detection sampling and a special filter to separate the differential mode noise component. The pre-filtered (red trace) and post-filtered (blue trace) plots compared to the EN55022 Class B limit line illustrate the effects of the active differential filter circuit. This demonstrates the differential noise peak of the fundamental frequency and the harmonic peak amplitudes in dBuV units.

Furthermore, to achieve high system reliability the PICMG 3.0 specification defines a redundant architecture for the power and communications/data processing bus. PICMG 3.0 specifies that a single board failure will not disrupt system operation. If a failure occurs, the faulty board can be readily identified and replaced in the field with the system operational. Insertion of the replacement board also cannot disrupt the power or communications/data processing buses; hence power management with hot board insertion and the Intelligent Platform Management Interface (IPMI) is needed to bring the replacement board up safely. And this circuitry must be replicated on each board.

As suggested earlier, the hot swap function and differential noise attenuation can both be achieved, in effect, by using a combination of active filtering circuit and the power FET for the current limit control as shown in Figure 2. Along with the associated biasing components, U1 in the figure provides the current limit control, while U2 and U3 make up the active filter control. The compliance noise testing will be performed with the system or board in a typical operational or test mode. The current limit is exercised only under system start-up, board insertion, or a board power fault condition. When the board input capacitance is fully charged and no other fault exists, the power FET is driven into the Rdson state by the hot swap control to achieve a power good condition and to minimize the power loss of the FET. With the dual use of the FET, the hot swap function must dominate control under a fault condition over the filter operation, creating an interfacing design challenge.

The active filter creates a high impedance to the ripple current and works by controlling the FET drain to source voltage and sensing the AC current flowing through the FET via the sense resistor. The active loop modulates the resistance of the FET to effectively make the converter switching load look like a constant current to the bus. This requires bringing the FET barely out of the Rdson region because the magnitude of the ripple current is typically in the tens of milliamps, establishing a slight headroom bias voltage. Using a wide bandwidth analog amplifier for U2 as shown in the schematic drawing in Figure 2, the AC ripple current can be detected across the current limit sense resistor then amplified to drive the gate of the FET. This will change the series resistance in the ohmic or triode region of the FET characteristic curve, driving the sensed AC current component on the bus to zero. The headroom voltage can be set very low by U3, depending upon the FET triode characteristics, to minimize power dissipation versus ripple current reduction or the effective attenuation of the filter. An example simulation is shown in Figure 3 demonstrating the attenuation effects the active filter has on the bus ripple current versus frequency. The appropriate component parasitic elements were included in the simulation.

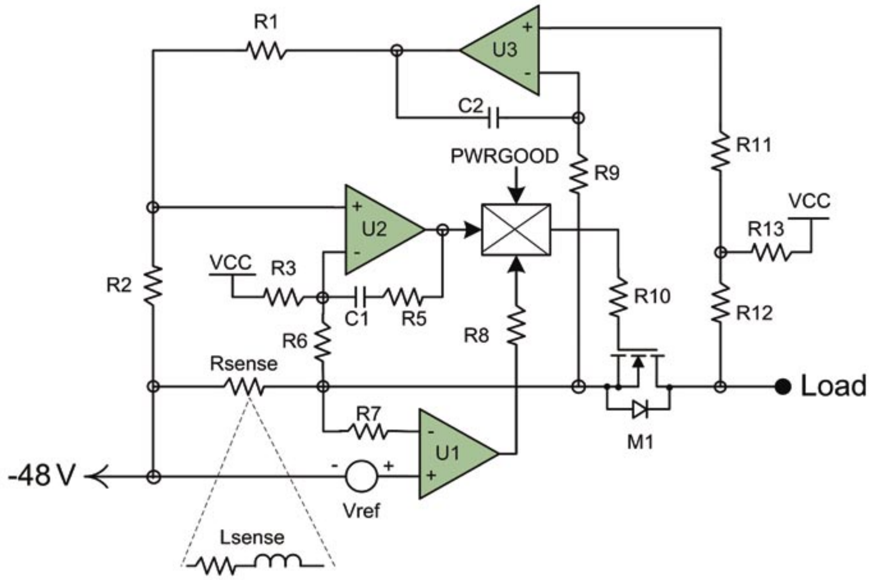


Figure 2

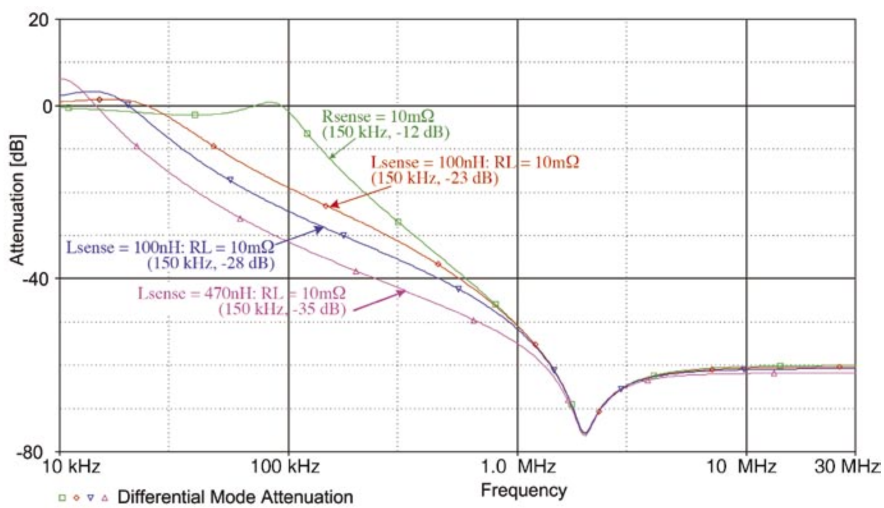


Figure 3

An inductor can be considered as the sense element for both functions, with a DC resistance component equal to the sense resistor needed for the hot swap current limit level. This provides some design advantages as well as challenges. From a noise reduction standpoint the inductor will provide additional passive attenuation in combination with the converter input capacitors, adding an LC two-pole roll-off (40 dB/decade) with a resonance determined by the inductance and total input capacitance. The increasing impedance of the inductor with frequency creates more signal voltage, in effect increasing the low frequency attenuation of the active filter above the frequencies where the reactance becomes significant. Figure 3 shows additional attenuation curves for three different values of inductance as well as the base line using only a sense resistor. Some hot swap designs use a thermistor to sense temperature to improve the FET protection. In this case the temperature coefficient of the copper wire within the inductor results in a lower current limit level with increasing temperature, because the resistance will increase and the reference voltage is constant, lowering the peak power of the FET under fault conditions. Using the inductor as a sense element would create more variation in the current limit than a precision sense resistor, so careful analysis of the component tolerances and safe operation area of the FET and inductor need to be considered. Figure 4 demonstrates a transient simulation of the current limit control waveforms using a sense resistor versus a sense inductor under a hot startup condition. Inductive sensing can affect the loop frequency response and stability

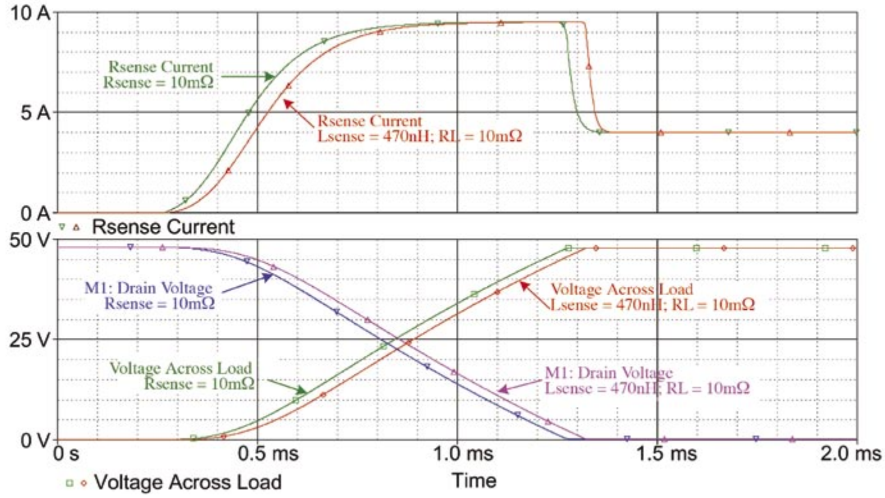


Figure 4

of the controlled current, so care must be taken to maintain adequate phase margin under this closed loop condition.

As previously mentioned, the hot swap control must take precedence over filtering so the filter biasing and control of the FET must be designed not to interfere with the critical protection function. Using the power good state to enable the filter function takes the filter out of the picture when the power good state is not valid. The challenge is designing the interface circuitry enabling the filter function while properly controlling the FET if a fault condition occurs. This circuit will depend on the hot swap controller characteristics, so the circuit shown in Figure 2 demonstrates the basic schematic leaving the interface shown as a functional block.

Active filtering and MicroTCA

With the development of the MicroTCA system specification gaining momentum, the concept of combining the active filter and hot swap should prove to be more advantageous. If a 12-volt intermediate bus is created from a redundant Power Entry Module (PEM) to provide power to the Point-Of-Load (POL) converters, each board will have a hot swap requirement. Although filtering will be needed in the PEM, designers have an opportunity for implementing the active filter as described along with the hot swap required on each field replaceable card. This can reduce the total noise reflected from the switching POLs to the power entry conversion bus.

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