# Power modules for lab instrumentation

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**PC-based lab instrumentation platforms make automating lab setup and data collection simple and effective. DC/DC converters for instrumentation systems such as Peripheral Component Interconnect (PCI) Extensions for Instrumentation (PXIe) systems have distinctive requirements: low electromagnetic interference (EMI), small solution size, high efficiency, a wide input voltage range, and good line and load regulation. Let's look at these various requirements, and how power modules can help satisfy them.**

## Low EMI

Lab instrumentation equipment has very strict criteria for EMI, since it causes performance degradation and potential failures. Switch-mode-based DC/DC power supplies are the leading cause of EMI, due to their inherent switching action.

**Figure 1** shows the basic connection diagram of a buck regulator. In a buck regulator, the loop formed with inductor L, output capacitor $C_{OUT}$ and low-side field-effect transistor (FET) $Q_{LS}$ has a continuous flow of current. But with the switching action of the FETs, there is a discontinuous flow of current in the loop created by high-side FET $Q_{HS}$, $Q_{LS}$ and input capacitor $C_{IN}$.

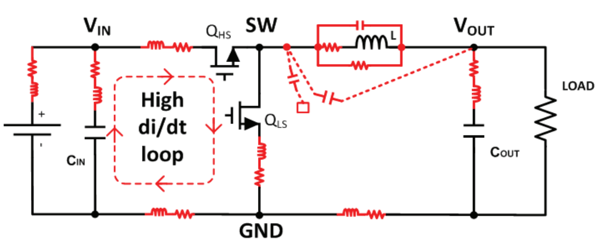


***Figure 1.*** *Simplified buck-regulator diagram.*

The area enclosed by connecting traces dictates how much parasitic inductance will be present in the path of this discontinuous current. **Equation 1** shows that switching current flowing through an inductor produces a voltage difference across it.

$$V = LPAR \times \frac{di}{dt} \tag{1}$$

Thus, this setup inadvertently causes voltage spikes and EMI, as shown in **Figure 2**.

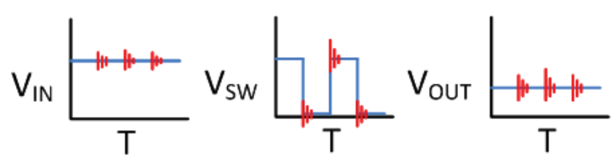


***Figure 2.*** *Voltage spikes and EMI.*

While this is unavoidable, a simple layout with the input capacitor placed very close to the two FETs helps reduce the area of the loop, and thus the parasitic inductance leading to lower voltage spikes and mitigated EMI.

Power modules have an advantage here, since the input capacitor is typically integrated inside the package and is very close to the integrated circuit (IC). Similar logic is also applicable to the bootstrap capacitor integrated in a power module.

## Component selection

As **Figure 1** shows, in addition to trace lengths, bad components with large parasitics can worsen the situation, since they are in the path of a pulsing current. The area of the switch node and choice of inductor directly impact EMI. Too large a switch node, and an unshielded inductor with large parasitic capacitance, can radiate a lot of noise out.

As shown in **Figure 3**, the switch-node area is typically well optimized in a power module, since other passives are integrated.

Current flowing through an inductor results in the creation of a magnetic field. An uncontained magnetic field results in worse EMI. Unshielded inductors have no containment method for this field and are therefore not practical.

Power modules typically integrate shielded inductors that have undergone high levels of stress testing. Integrating good-quality passives helps contain radiated noise and thus reduces the chance of contaminating other sensitive circuitry nearby.

Newer DC/DC regulators are packaged in TI's HotRod™ package technology. **Figure 4** compares HotRod package technology and a standard wire-bond quad flat no-lead (QFN) package.

This packaging technology does away with the bond wires typically used to attach die pads to the leadframe, instead using copper pillars with small solder bumps. Without the bond wires, the parasitic inductances reduce and further help mitigate EMI.

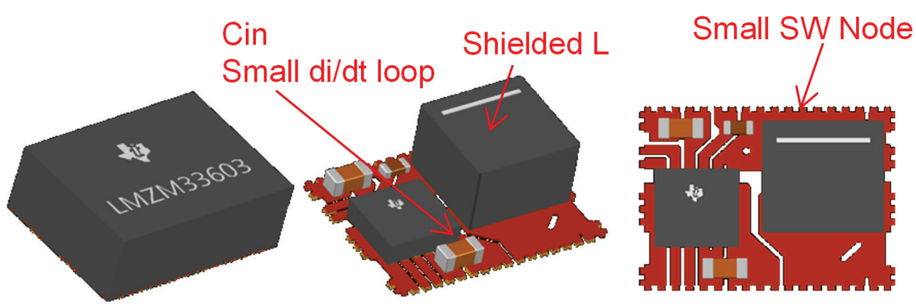


***Figure 3.*** *Power module internal construction.*

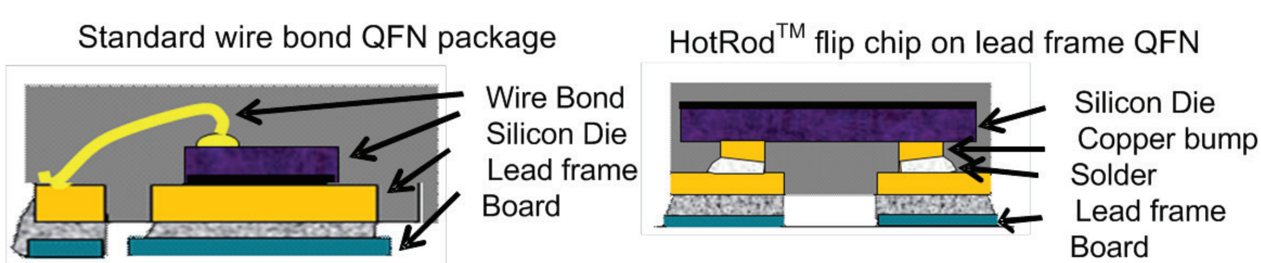


***Figure 4.*** *HotRod™ packaging technology.*

## Frequency synchronization

EMI is a product of the buck regulator's switching action, which implies that the switching frequency (FSW) will be of interest to keep the EMI low. In a system where multiple buck regulators power various rails, there can be a "beat" frequency from the interaction of these various switching frequencies. Because the beat frequency can occur at random frequencies and its harmonics are also unpredictable, the mitigation of EMI in complicated instrumentation systems is thus very challenging.

To help resolve this issue, power modules such as TI's LMZM33603 and LMZM33606 come equipped with a frequency synchronization input pin that enables all buck regulators in a system to switch at one common frequency. This feature not only helps avoid beat frequencies, but keeps the FSW harmonics at known frequencies. It then becomes much easier to design an input filter to mitigate EMI. **Figure 5** shows a typical schematic using the LMZM33606 power module.

## High-efficiency requirement in a small solution space

Bench-top instrumentation equipment uses a smaller chassis, which can result in a space-constrained system. These chassis might be smaller than 3U and often a half rack width. An example of a PXIe chassis with an integrated system module could have only five slots: three hybrid and two PXIe only.

Power modules become a practical choice in such space-constrained environments. Using them where applicable greatly reduces space constraints and the resulting time to market. The power tree in **Figure 6** shows the power modules and discrete regulators that can be used for the backplane power in a bench-top PXIe chassis.

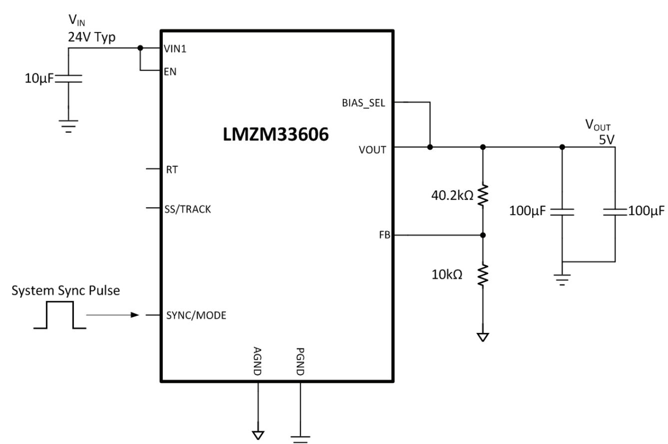


***Figure 5.*** *Typical schematic for a 5-V output.*

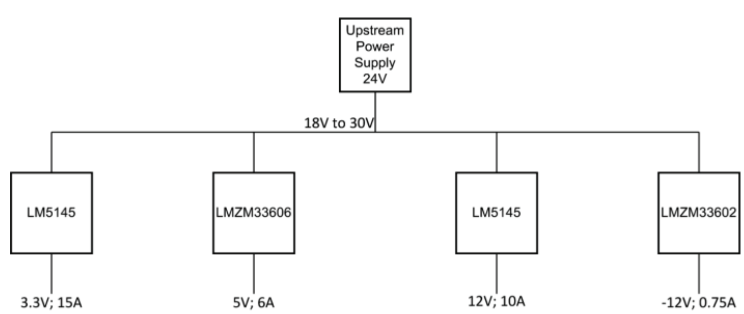


***Figure 6.*** *Example power tree for bench top PXIe chassis.*

Power modules may not be able to power all of the voltage rails due to load current limitations. In a system that requires more current capability, you would have to choose other devices. TI's WEBENCH® tool is a good way to learn more about other devices and obtain design schematics, along with important parameters such as efficiency, bill-of-materials (BOM) size and BOM cost.

**Table 1** compares TI power modules (the LMZM33606 and LMZM33602) and integrated regulators (the LM73606 and LMR33620). As you can see, the space savings are considerable when implementing power modules in the design. These space savings come without any perceptible change in operating efficiency.

| Device | LM73606 (5$V_{OUT}$, 6A) | LMZM33606 (5$V_{OUT}$, 6A) | LMR23625 (-12$V_{OUT}$, 0.75A) | LMZM33602 (-12$V_{OUT}$, 0.75A) |
|---|---|---|---|---|
| Solution size ($mm^2$) | 569 | 300 | 248 | 140 |
| Efficiency (%) | 92 | 91 | 85 | 85 |

***Table 1.*** *Comparison between DC/DC regulators and power modules.*

The module schematic in **Figure 5** is very simple, and with such a low BOM count, the resulting design will occupy very little space. **Figure 7** shows the efficiency of the LMZM33606 across load current at multiple input voltages.

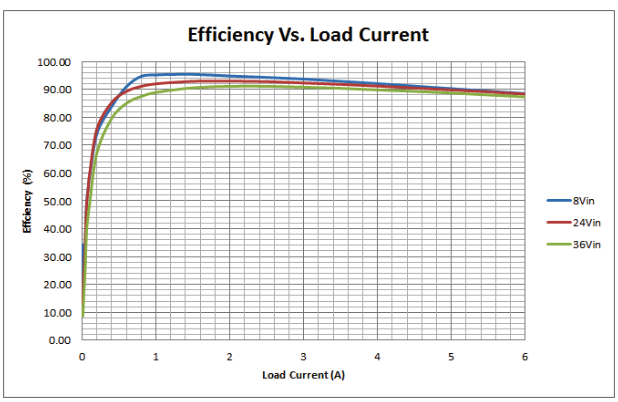


***Figure 7.*** *LMZM33606 efficiency.*

## Good line and load regulation

An instrumentation system could have an unregulated voltage of 18 V to 36 V for the input. Typical line regulation can be 0.1 to 0.2 percent for all rails. Among the various control architectures, the peak current mode (PCM) architecture is one that can achieve such strict requirements. As **Figure 8** shows, the PCM architecture works by sensing the current through the high side field-effect transistor (FET) to create the comparing ramp.

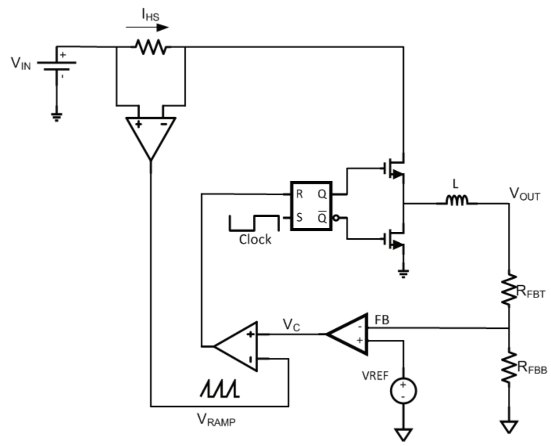


***Figure 8.*** *Simplified schematic for PCM architecture.*

With changing input voltages, the first thing to change is the slope of the current, which works as a feedforward to the system in order to correct the duty cycle upon a change in input voltage. Thus the instantaneous update in duty cycle helps achieve very good line regulation. The LMZM33606 and LMZM33602 are based on the PCM architecture, which makes them a good fit for such systems.

**Figure 9** shows the line and load regulation of the LMZM33606. For a 3-A load, the line regulation is 0.02 percent; for a nominal 24-V input, the load regulation is 0.1 percent.

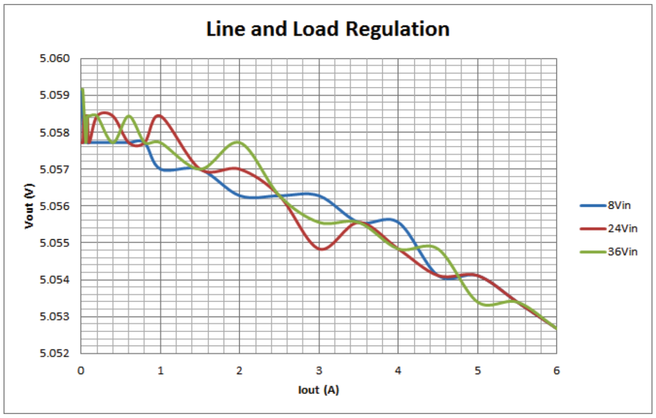


***Figure 9.*** *LMZM33606 line and load regulation.*

Power modules offer benefits beyond space savings and performance. They integrate high-quality passives that go through extensive testing at high temperatures to ensure longevity and reliability. Their features make power modules more attractive for lab instrumentation equipment.

## References


- LMZM33606 datasheet
- LMZM33602 datasheet
- Inverting Application for the LMZM33602/3 application report