Semiconductor Highlight: Solutions for Complex DC/DC Power Conversion Needs

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Solutions for Complex DC/DC Power Conversion Needs

In embedded DC-DC converters in industrial applications like test and measurement equipment or embedded computing, the system architecture can be quite complex, with many different output voltage and current, ripple, EMI and power sequencing requirements. This article will explore the impact of the choice of the converter power stages in DC-DC applications.

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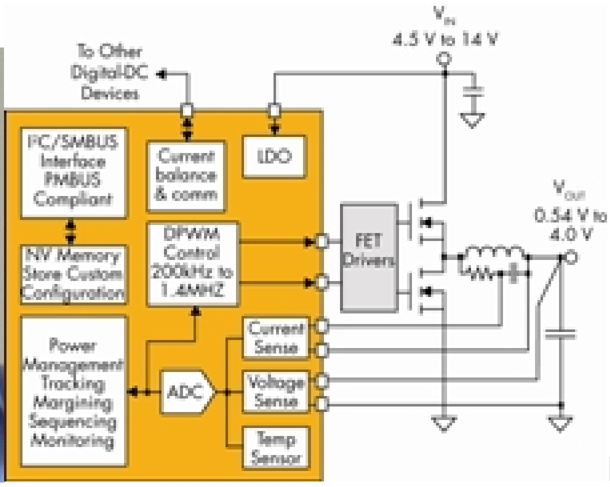
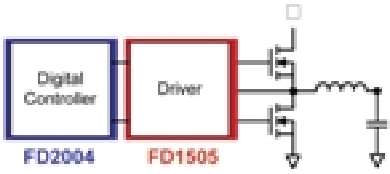
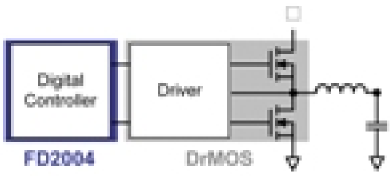


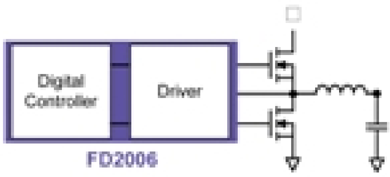
Many industrial systems like test and measurement equipment require embedded DC-DC converters, as the amount of computing power required in these applications is increasing. This computing power is provided by DSPs, FPGAs, digital ASICs and microcontrollers, that all benefit from the move to smaller and smaller geometries. However, this leads to three major requirements: first, the supply voltages are getting lower and lower (and, of course the allowable voltage ripples and load variation). Second, the supply currents are increasing. Third, these ICs usually require separate voltages for the core and I/O structures that need a precise sequencing so they will not cause latch-up.

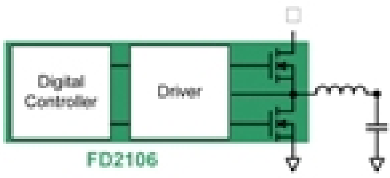
Embedded DC-DC converters must have excellent efficiency. The space available for the converter is small, and this is particularly challenging for the thermal design, as embedded converters rely heavily on copper areas around the components on

the PCB to improve the thermal resistance in the system. This is worsened by increasing load currents, since the dissipated power increases with the square of the current. Hence, power switches with low RDSON and low switching losses at the same time are required. There is a trade-off to be made, since the device with the lowest possible RDSON has higher par







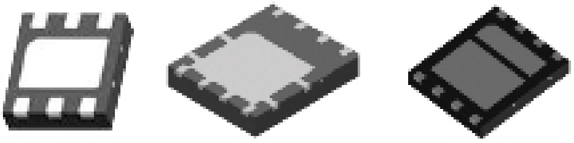


asitic capacitances, hence switching losses, and so it may actually cause higher power dissipation.

Another strong requirement for embedded DC-DC converters is low EMI. The noise generated by these converters can disturb surrounding circuitry, and must be kept to a minimum. Yet, switching large currents (as required by the loads) at high switching speed (to reduce switching losses) inevitably leads to strong switching noise generation, both conducted and radiated (as a magnetic field, mostly). As a consequence, special care must be taken to optimize the power stage component selection and layout, as well as the driver connections in particular. Also, the PWM control topology has some influence.

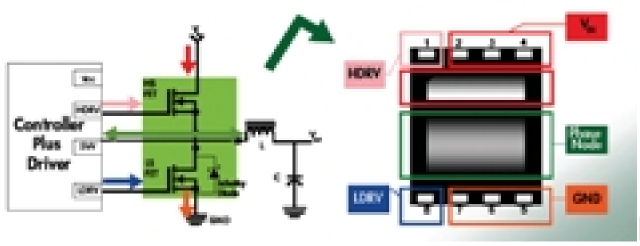
As an example, digital ICs built in a 0.09µm technology, may require a supply voltage of 1.2V ± 40mV. The supply current goes up to 952mA, as shown in the datasheet of this DSP. Another example are the large FPGAs, such as the ones built in a 65nm process, requiring an idle supply current of 4.2 A at 85°C, at a supply voltage of 1.0V +/-50mV. In operation, the current can go up to 18A, depending on the configuration, with very high dynamic requirements, due to the high switching frequencies.

It is quite common to find different ICs in these applications, e.g., a smaller microcontroller (at a higher supply voltage) to take care of all the interface and host functions, with larger DSPs or dedicated hardware to perform the computing-intensive functions. Many times, high-performance A/D converters are used, with yet another set of supply requirements, in particular to improve the noise performance and really be able to use the full resolution and bandwidth of these converters. That quickly leads to a complex power management system with many interdependencies.

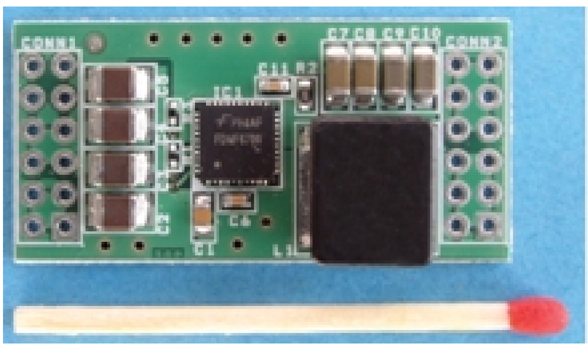


Modular control for improved system design

One application recommendation is to place the DC-DC converters as close as possible to the load. This minimizes EMI, reduces the board space required for wide high-current traces, and improves the dynamic behavior of the converter. This leads to a distributed power management system, where ideally all converters are connected to each other.

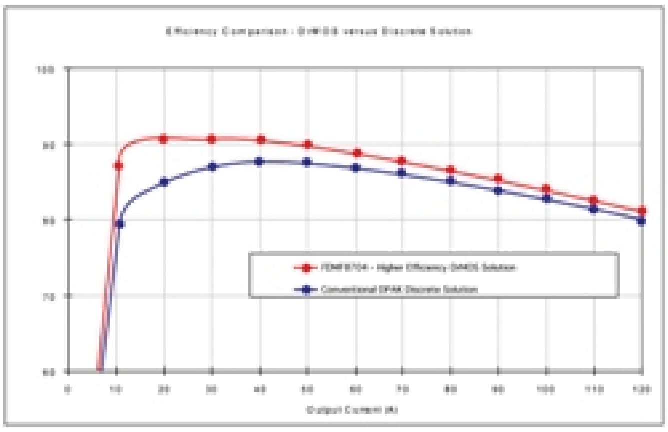


For system voltages with a lower output current, an integrated DC-DC converter is recommended. Here, PCB space and ease-of-use are the most important factors. A digital converter, which has the communication capabilities like the rest of the Digital-DC product family, can be used together with discrete MOSFET or DrMOS-based converters that supply higher currents. In standalone applications, where connectivity to other converters in the system is not required, an integrated converter can be used as well.

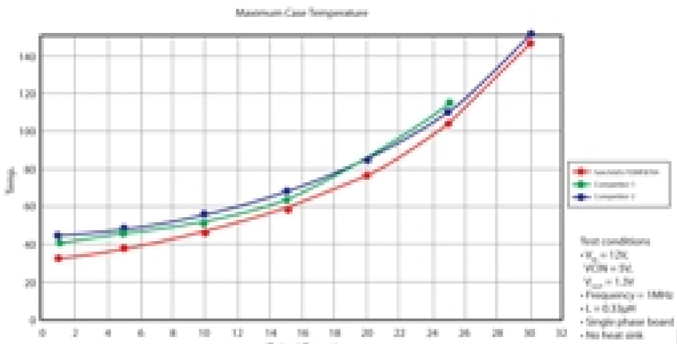


The chain of controllers and converters in a digital power management system can be controlled with a graphical user interface, allowing easy modification of all the parameters and monitoring of the system performance. This software is running on a PC and is connected to the controllers with a USB interface. When the parameters are all fine, they are stored in the controller with non-volatile memory, so the PC is no longer required to run the system.

Thermal design is a very important aspect of the design work.

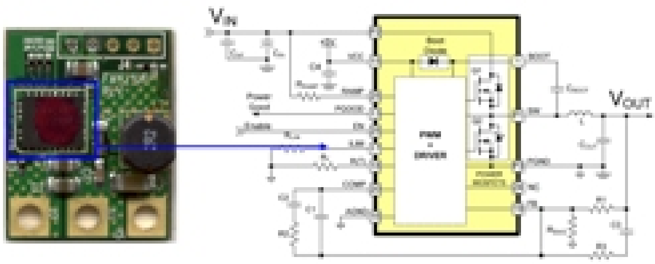


With modern MOSFETs, DrMOS or gate drivers, the thermal resistance from junction-to-case is usually quite good, whereas the thermal resistance from case-to-ambient is determined by the design, and usually is much higher. In most systems, using only the PCB, thermal resistances (case-ambient) achieved are around 40K/W, with very good design being able to achieve 25K/W – significantly higher than the junction-case thermal resistance of 2K/W typical for a MOSFET. So, the thermal design of the PCB is very important, given that both thermal resistances are connected in series and impact the maximum temperature of the PCB, which is usually the limiting factor (with a low junction-case resistance, the junction cannot be much hotter than the PCB).



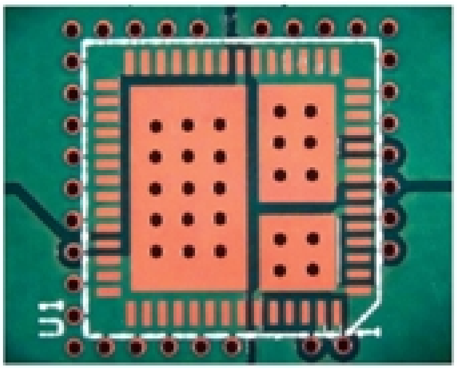
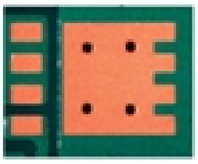
For higher currents, a discrete solution with multiple phases (e.g., 2-3 DrMOS devices) is preferred, in order to spread the heat across a larger surface. Another tradeoff is the switching frequency – if it is not predetermined e.g., by EMI requirements or space limitations (using a higher switching frequency to reduce the size of the passive components), a lower switching frequency will help to reduce switching losses, and consequently the temperature.

With the layout, more metal obviously helps. A thicker top layer helps to reduce the temperature, but may



not be appropriate

for the rest of the PCB, as the cost increases and a finer pitch required for other components may not be possible. Larger copper areas help but consume PCB space. If possible these should be covered with solder since the metal surface will help dissipation more than the lacquer. In a multi-layer PCB, the inner layers can sometimes be used to help spread the heat. Thermal vias (filled with solder) can sometimes be used to spread the heat to the other side of the PCB (Fig.8).

In systems with forced airflow, it is important to arrange the components in a way not to place the   converters in the “wind shadow” of other, larger components. Here, it is recommended to have the controller sit upstream of the MOSFETs since it will usually contribute little to the power dissipation but will work more reliably at lower case temperatures.

Conclusion

Modern embedded DC-DC converters can benefit from many different alternatives, to improve system performance, reliability, and cost. The interdependencies of the choice on the control side between standalone converters or inter-connected digital converters, and on the power stage side between integrated or discrete solutions, have been shown, allowing optimization of the DC-DC converters operating in a network and achieving lowest power dissipation.