

Smart Power Solutions for Data Centers Cut Operating Costs

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Designers can now create sophisticated power solutions for data centres that are efficient, compact and reliable

As a society we are creating, using and sharing unprecedented amounts of data every single day, both in our personal lives and while we work. In addition, the Internet-of-Things (IoT) which connects billions of devices and is growing, is creating data completely unaided by humans. As mobile technology moves into its fifth generation (5G), capacity will exist for more data to be created and moved more rapidly than ever before, adding even more momentum to the trend of data growth.

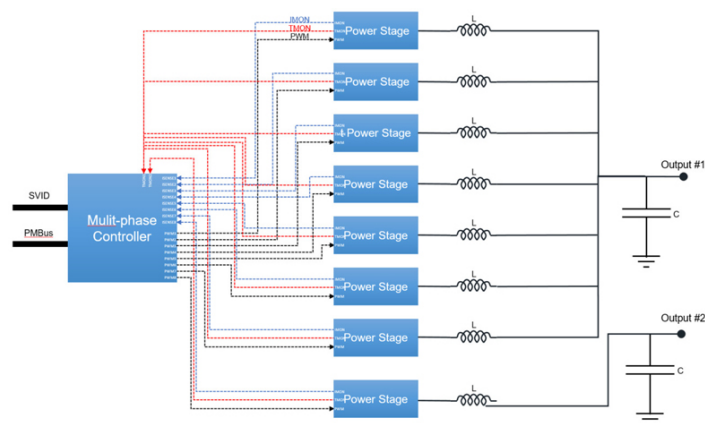


Figure1: Multiphase controllers and DrMOS power stages provide solutions

All of this data needs to be stored somewhere, for processing and record keeping. Increasingly, we are turning to the 'cloud' for the safe-keeping of this vital information. However, the 'cloud' is not some ethereal place, it is very firmly rooted on terra in the form of the huge data centers that are rapidly growing in size and number to cope with the incessant demands for additional storage capacity.

Not surprisingly, data centers require significant amounts of electrical power to operate. Currently, it is estimated that they consume around 3% of electrical power within the US, although this is expected to rise to a remarkable 15% over the next two decades. There are in excess of ten million servers shipped each year, and this number is continuing to grow at around 5% every year to meet the growing demand from emerging applications including VR/AR, artificial intelligence (AI) training and the IoT.

Power efficiency and reliability is probably the most important topic within the data center industry as physical space is at a premium, electrical energy is rising in cost and system reliability is paramount. As efficiency is increased, so operating temperatures fall which, in itself, improves reliability. This also allows power solutions to become denser, saving space – or allowing more computing power and storage capacity to be fitted into the available space.

Despite designing for reliability, components with moving parts such as disc drives and fans will wear and possibly fail during the operational lifetime of the data center, and therefore power systems must be designed to allow for hot-plugging / swapping of these devices so that repairs (and upgrades) can be performed without incurring system downtime.

Technology provides the solution to the power challenge

In order to meet the challenges posed by data centers, power solutions have to become smaller, denser, more efficient and more sophisticated.

MOSFET technology has improved significantly, allowing the integration of a control IC and MOSFETs in a very efficient and compact package.

For example, ON Semiconductor's NCP3284, DC-DC converter has a 30A continuous (45A pulse) capability all within a tiny 5mm x 6mm footprint and, with its ability to operate at frequencies up to 1MHz, the size and weight of external inductors and capacitors can be reduced. This integrated device also includes multiple protection features and programmable soft start.

At the next level of power density are smart power stage (SPS) solutions such as the FDMF3170. These integrate MOSFETs with an advanced driver IC plus current and temperature sensors allowing the design of high current, high frequency, synchronous buck DC-DC converters.

This fully integrated approach allows the SPS to be optimized for driver and MOSFET dynamic performance, system parasitic reduction and MOSFET on-resistance. The FET pair is optimized for the highest efficiency, especially at low duty cycles where modern efficiency requirements such as 80 plus are very stringent.

Highly accurate current monitoring (IMON) can be used to replace inductor DCR or resistor sense methods, thereby eliminating the losses usually associated with such approaches.

In modern data center server systems, even the humble fuse has had a makeover. Essential in applications such as RAID systems, disk drive power and server I/O cards, the fusible wire in a glass cartridge is replaced by an intelligent, semiconductor-based eFuse. eFuses use low on-resistance MOSFETs to protect peripherals during normal operation and while hot-swapping is taking place. In fact, they can be used in any application where power glitches or load faults may occur, as well as where inrush / outrush current may require limiting. In addition to providing protection to components, connectors and PCB traces, they are able to be controlled by the system and many can provide useful telemetry features such as monitoring temperature and current.

ON Semiconductor's NCP81295/6 hotswap controllers support currents up to 60A peak (50A continuous) and are based on a 0.8m Ohm internal MOSFET for efficient operation. Housed in a 5mm x 5mm 32-pin QFN package, they offer a latching off or auto-retry version and are suitable for use at temperatures up to +125°C.

Another eFuse - the NIS5021 is a 12V, 12A series device that is often used with hot-pluggable hard drives. It buffers the HDD from any excessive input voltage that could damage sensitive circuitry. An inbuilt voltage clamp limits the output voltage to protect the load, while maintaining a continuous power feed meaning the drive can continue to operate normally.

Complex systems such as servers often require intelligent control of their power systems to ensure proper operation as well as the highest possible levels of efficiency. Load management devices allow power rails to be segmented, thereby enabling granular control. This facilitates power sequencing at startup and reduces operating costs by permitting unused sections of the circuit to be powered down. In turn, the lower power levels result in less heat in the system which increases reliability and longevity. Most load switches also allow for slew rate control and can provide protection under fault conditions.

Using an integrated load switch, such as ON Semiconductor's NCP455xx series lets system designers access these benefits with a minimal increase in system component count. The high-performance devices provide a compact solution, occupying around 60% less PCB real estate versus a discrete solution.

Wide bandgap technology

Perhaps the most significant advance that will positively impact the size, reliability, efficiency and running costs of server power systems, is the move towards semiconductors based upon wide bandgap (WBG) materials such as gallium nitride (GaN) and silicon carbide (SiC). Designed to be inherently more efficient than silicon (Si) based devices, WBG devices are also able to operate at higher frequencies and higher temperatures.

Material	Symbol	Bandgap Energy (eV)
Geranium	Ge	0.7
Silicon	Si	1.1
Gallium Arsenide	GaAs	1.4
Silicon Carbide	SiC	3.3
Zinc Oxide	ZnO	3.4
Gallium Nitride	GaN	3.4
Diamond	C	5.5

} Wide band gap

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Figure 2: Wide bandgap materials comparison

As an example, in a 5kW boost converter of the type typically found in server power supply applications, replacing a Si switch with a SiC switch yields a 73% reduction in losses at frequencies around 80kHz, significantly improving system efficiency. This contributes to a smaller system as less thermal management is required and also allows the system to run cooler, enhancing reliability and enabling greater component and system density.

While it is true that SiC MOSFETs remain more expensive than the equivalent IGBTs, the associated savings in passive components such as inductors and capacitors where values have dropped by 75% leads to an overall BOM cost that is lower for the SiC design, than for the Si design. Importantly and in addition, the energy cost savings yielded can total tens of thousands or even millions of dollars over the life of server installations.

	SiC MOSFET	Silicon MOSFET	Silicon IGBT
Breakdown Voltage	1200	1200	1200
Ron * Area (Relative)	1	100	3 - 5
Switching Loss (Relative)	1	3 - 5	10

SiC MOSFET : Approaching an Ideal Switch
Good combination of low Rds_on and low Switching loss for higher voltage (>600V)

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Figure 3: SiC MOSFET advantages

Summary

The need for huge and ever-increasing amounts of data storage is creating a very competitive landscape within the world of data centers. Real-estate space and electrical energy are two of the biggest costs and as operators seek to reduce these, they are demanding ever more efficient, reliable and smaller power solutions for the servers and storage devices.

While there are many aspects to consider when designing a successful server power solution, highly

integrated devices such as integrated MOSFETS, SPS, eFuses and load management are enabling designers to create sophisticated power solutions that are efficient, compact and reliable. E-fuses play a pivotal role in maintaining uptime as they facilitate hot swapping of devices that are prone to failure such as HDDs and fans.

Looking to the near future, WBG materials promise a step change in size and performance as well as improved reliability and efficiency that will reduce operational expenditure. Having now reached the point where the BOM cost for a WBG solution is comparable to, or lower than, a similar silicon design, the uptake of these devices is expected to accelerate.

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