

Redefining power management through high-voltage innovation



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Today, we face an ever-increasing demand for electricity to power new systems, many of them mobile, which are raising the standard of living worldwide. At the same time, environmental issues require that we use energy much more efficiently.

While these challenges will require a variety of political and economic solutions to handle effectively, one technical solution is increasingly proving its importance. High-voltage innovations are making the transmission and conversion of electrical power more efficient, so that less power is lost between the source and the end equipment.

These innovations complement changes in electricity generation such as introducing renewable energy sources, as well as energy-saving improvements in consuming equipments such as motors and refrigeration units. The result is a steady rise in power efficiency that saves money and helps reduce the release of greenhouse gases into the atmosphere.

Even small improvements in efficiency can have a significant effect. The U.S. Energy Information Administration (EIA), in its mid-level 2015 projection, estimated that electricity generation in the U.S. will grow 24 percent by 2040—about 1 percent annually. The EIA also estimates that some 6 percent of electricity generated in the U.S. is wasted in supply and disposition—more than 14 million megawatt hours annually in recent years. Reducing just a portion of this waste through efficiency improvements could make it possible to decrease the overall amount of electricity we have to generate.

Advanced semiconductors are among the most important technologies that have already been deployed and further developed to make power generation, transmission and consumption more efficient. Smart controls implemented using integrated circuits and the use of new power semiconductor materials enables conversion of power with minimal losses. Intelligent IC hardware enables power grids, factories, homes, cars and other systems to communicate and control system power usage efficiently. In addition, power management circuits, the backbone of power supplies and battery chargers, are an important factor enabling the mushrooming growth of portable electronics, bringing convenience along with efficiency. Texas Instruments (TI) is well-positioned to leverage its design, manufacturing processes and packaging expertise to create high-voltage analog and mixed-signal solutions that will bring greater power efficiencies in upcoming years.

Why focus on high voltages?

Electrical voltages vary from tens of thousands of volts at the power plant and in regional supply lines down to fractions of a volt used internally by high-speed digital components such as embedded processors. Along the path of distribution are many intermediate voltage levels, with 110/120- and 220/240 volts being the most familiar to consumers. For residential, commercial, industrial and automotive applications, high voltages are those that range from just above the levels of electronic circuitry up to the levels of transportation and industrial equipments—that is, from tens of volts into hundreds.

Power management ICs operating at all voltage levels represent considerable demand for IC suppliers to fulfill—in the area of \$30 billion annually, according to market research firm IHS. New markets continue to emerge for IC products such as alternating current to direct current (AC/DC) converters, inverters, bi-directional converters and DC/DC converters. IC solutions that offer higher levels of integration, increased power density and added intelligence serve to improve overall system performance.

Power conversion is a prime area of opportunity because, along the way from the power plant to the end application, every voltage conversion step involves a power loss. In addition, other conditions being equal, lower voltages lose a higher percentage of power in transmission than higher voltages. For these reasons, it is most efficient to bring high voltages close to, or even into, the end equipment before stepping them down with conversion methods that minimize power losses. The presence of high voltages in the vicinity of equipment and users also requires additional measures for machine and human protection.

The word “equipment” calls to mind factory floors, and in fact, industrial applications such as motors, robots and central control systems are an important area of power innovation. Currently, industries throughout the world are experiencing a transformation in intelligent automation that is coming about so rapidly that it has been dubbed by some as the “Fourth Industrial Revolution” (after the first three revolutions of steam power, mass production and early automation), or Industry 4.0. The enabling factor of this transformation to so-called “smart factories” is the availability of greater machine intelligence and system communications. The prime goal of the smart factory is to improve productivity and reduce costs by doing as much as possible using less energy.

Industry, however, is only one target for improved power efficiency technology. Other areas that can benefit include inverters for solar and wind power generation, data centers and telecommunications infrastructure. Electric vehicles, with battery voltages of about 400 volts, also depend on high-voltage electronics for both charging and operation. In addition, the burgeoning market for all kinds of mobile devices is a major driver of new power technology. Even humble units such as cellphone chargers need to operate efficiently, especially considering that there are billions of them in use today. In short, all electrical and electronic systems, large and small, benefit from safe, efficient power conversion.

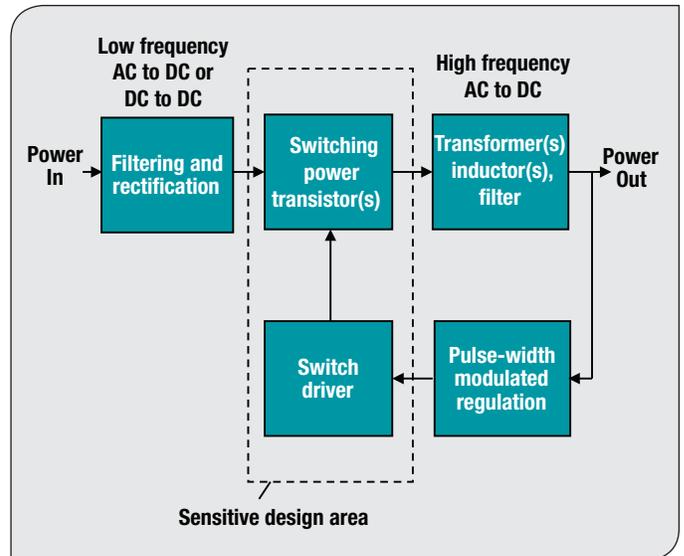
Challenges of high-voltage technology

To keep meeting the needs for greater power efficiency in the future, technology developers must increase IC performance while reducing size, maintaining reliability and keeping costs in line. These requirements demand innovations in

manufacturing processes, on-chip components, circuit design and packaging. Another factor that can make new products more attractive to equipment developers and accelerate the adoption of enhanced power technology is the availability of integrated, all-in-one solutions with in-depth hardware and software design support. TI has a proven history in making highly integrated low-power solutions and continues to innovate and advance in all of these areas, making use of its expertise to create the advanced high-power solutions the market needs today and in years to come.

In recent years, switched-mode power supplies (SMPSs) have gained ground in power conversion because they are inherently more efficient than traditional power supply designs. However, perfecting SMPS design is an ongoing art. These supplies create currents at high frequencies that must be prevented from propagating deep into the system and escaping back out into the source. Furthermore, operation of sensitive devices inside the power supply is susceptible to impedances from inside and interferences from surrounding components. For these reasons, SMPS solutions that integrate as much of the system as possible can help reduce the complexity of power supply designs and help lower manufacturing costs. If the solution can include small-form-factor isolation along with the power circuitry, it is better because it effectively shields the system from outside interferences and prevents high frequencies from migrating from within the system onto the line.

Process advances. Manufacturing process technologies continue to advance the voltage and frequency capabilities of silicon for use in



Generic functions of a switched-mode power supply

SMPSs and other power designs. For instance, TI's versatile high-power LBC7HV BiCMOS process is used today in integrated gate driver-power switch solutions rated up to 600 volts. In addition, manufacturers are turning to new materials such as gallium nitride (GaN, built on a silicon substrate) and silicon carbide (SiC) to enable faster switching and even greater efficiencies at high voltages. TI, in addition to its numerous silicon-based solutions, has developed several gate drivers for GaN switches and is starting to introduce advanced multichip modules (MCMs) that include both gate drivers and GaN power switches. Combined with the innovations discussed below, manufacturing process advances offer greater power density and help lower system costs while making electrical supply more efficient.

Integration. An important requirement of new high-voltage power supplies is to rescale them to fit on a board inside the end equipment. To meet

this requirement, TI is aiming to provide single-chip solutions that integrate as many power supply components as are practical, relative to both cost and performance. Whenever full system integration is not economical, or impossible because the functions are built using different processes, integrating two or more devices in an MCM is a viable solution. Along with saving space, system-level single-chip and MCM solutions increase power density and reduce the need for passive materials such as windings and heat sinks. The solutions also simplify designs because they eliminate or minimize the complex internal impedances that make power supply design so difficult.

Isolation. A big challenge in single-chip and MCM integration is how to include isolation. Traditionally, power supplies are isolated using transformers, which sit as bulky components outside the integrated circuits. However, new methods of isolation are in development that will serve to eliminate external transformers and isolate the system from within the chip or MCM. For user safety and equipment protection, it is important that this new technology provide reinforced isolation, which is equivalent to twice or more the basic isolation needed for the system to function. As these integrated methods of providing isolation appear on the market, they will prove indispensable for space-saving power supply solutions.

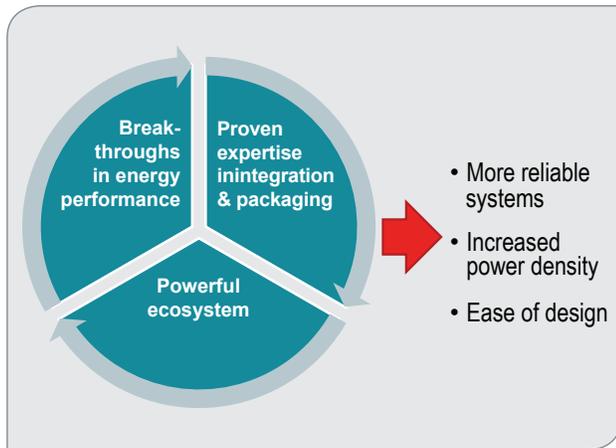
High-frequency programmable controllers. Even the best gate drivers and power switches would be worthless for SMPSs without precise

control; otherwise, slight variances in timing would quickly magnify into big variances that diminish the efficiency of the system. At a minimum, the high frequencies of new SMPS designs call for digital control from high-performance state machines. Innovative software tools help power designers understand how to develop the closed-loop control functions of a digitally controlled SMPS system using a C2000 MCU or UCD3138 digital controller, simplifying the transition from traditional analog control methods.

Advanced packaging. Integrated power solutions require innovative single-chip and MCM packaging that can handle requirements for electrical integrity and thermal stress created by high-voltage operation. Among the issues packaging specialists must understand are types of materials, bonding techniques and methods of protection against degradation. Packages can degrade due to charge spreading from high- to low-voltage areas, electromigration due to high current densities, or excessive heat that must be removed from the package. Degradation can also result from cracking due to thermo-mechanical stresses over the device lifetime, and other sources. These problems are magnified at high power levels, especially when ICs are used in factory floors, vehicles or other harsh environments. TI is addressing these challenges through a combination of extensive material evaluation, comprehensive testing and proactive engagement with materials suppliers.

Providing high-voltage efficiency for the future

As the need for more efficient power management increases, so does the demand for innovative technology solutions. Efficiency comes from exploiting alternative sources of energy, from



How TI is redefining the future of high voltage

building equipments that operates on less power and from better techniques of power transmission and conversion. Innovative IC technology plays an enabling role in all of these areas, with high-voltage power conversion among the applications that offer great potential for savings.

Power management semiconductor technology will continue to advance through ongoing development of manufacturing processes; circuitry; components such as isolators, single-chip and MCM integration; and packaging. Design also benefits from the availability of all-in-one solutions that minimize the effort required to design SMPSs and other power systems. TI, the industry's leading analog IC manufacturer, has a long history of integrating low-voltage power products. By leveraging its broad and deep expertise, and through its continued focus on technology innovation, the company is moving quickly to develop high-voltage solutions that will meet its customers' needs and save energy for a better tomorrow.

For more information:

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