REDUCING POWER THROUGH SILICON

How semiconductors have become the fundamental building blocks for designs looking to address power conservation challenges

Against the backdrop of an ever-greater need for electricity, a combination of practical, commercial, legislative and consumer-driven pressures and trends has forced energy efficiency to the top of the design agenda for electronic engineers, developers, integrators and many others tasked with creating electronic and electrical products and systems. And these professionals are turning to semiconductor technologies and processes to help them address significant power conservation challenges.

Semiconductors can help improve efficiencies and drive down power consumption in one of two ways. Firstly, they can be engineered so as to operate with the lowest possible power. This emphasis on low-power operation is as important when it comes to the ultra-high-end processors deployed in advanced servers as it is for the ultra-miniature devices tasked with providing key functionality and power management in battery-powered IoT products. Secondly, semiconductors - especially when combined with intelligent processing algorithms - can act as enabling technologies for improving the efficiency or reducing the overall power consumption of a larger sub-assembly or system.

Reducing semiconductor power

Constant efficiency improvements characterise the on-going development of power semiconductors and, not least, the MOSFETs that are now at the heart of most applications where power conversion and management is required. It is no surprise, therefore, that semiconductor manufacturers are making significant investments in improving the efficiency of these switching devices.

Power MOSFETs, typically fall into two classes; low-voltage for applications below 200V, and high-voltage for use above 200V. Much R&D focus is on minimising losses by lowering the on resistance-area (RONA) figure of merit. For low-voltage MOSFETs, RONA is dominated by channel resistance and fine surface planar gates, as used in large scale integration (LSI) and memory devices, are helping to reduce losses. Developments such as trench gate and high-density gate structures are delivering further improvements. For higher voltage devices where drift resistance is the primary contributor to RONA, superjunction structures are important factors in loss reduction.

But low-loss power devices are only one part of the story. Further illustration of the need to improve semiconductor efficiency can be found in the area of communications and connectivity ICs deployed in applications ranging from wearable products to healthcare. Typically portable, such applications are expected to operate for long periods between battery charges or battery replacement. Despite this, consumers want more features that can increase the drain on the battery. However, as product form factors shrink, there is less space to add hardware to provide improved functionality, let alone increase battery size to extend usable lifetime. It is critical, therefore, that connectivity ICs operate with the lowest possible power consumption.

Among the latest technologies to address these requirements are miniature, ultra-low-power Bluetooth Low Energy (Bluetooth LE chips). These highly integrated devices deliver all the functionality needed for Bluetooth communications and use on-board DC-DC converters and specially developed low-power circuits to keep power consumption down. The most recent of these ICs are now able to offer transmit and receive operation with peak currents of just 3.3mA, reducing to just 50nA in deep-sleep modes. Applications based on these innovative technologies could run for four years or more on a single CR2032 coin cell battery.

Motor control is one of the areas that demonstrate how the careful selection of

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PETER LIEBERWIRTH, VICE PRESIDENT, TOSHIBA ELECTRONICS EUROPE

semiconductor technology can help engineers to reduce the power consumption of sub-systems and applications. And, with electric motors accounting for around 40% of total global electricity consumption, making motor-based applications more efficient could have a significant impact on global energy consumption.

Among the semiconductors that can help to achieve these goals are dedicated microcontrollers and motor control drivers (MCDs) that offer built-in features for optimising the performance of motion control applications.

Toshiba, for example, has developed MCUs with an integrated 'vector engine' (VE) that allows designers to implement Field Oriented Control (FOC). FOC is a mathematical approach that overcomes the poor low-speed accuracy of trapezoidal control while addressing the high-speed inefficiency of sinusoidal control. Not only is FOC efficient across all motor speeds but, because it is a sensorless technique, the space, weight and energy consumed by a rotary encoder can also be eliminated.

Finally, by building the complex FOC vector control equations into a dedicated hardware engine with customisable firmware, the VE ensures stable and predictable execution of code without the processing overheads (and associated power demands) of more conventional software-based approaches.

Among the technologies that are now being 'hard-baked' into dedicated MCDs are intelligent phase control and active gain control. The former helps to improve the efficiency of brushless DC (BLDC) motors of the types now commonly used across home appliances and industrial systems, including pumps and fans. The latter is targeted at stepper motors deployed in applications that require accurate position control such as ATMs, vending machines and industrial robots.

Intelligent phase control technology addresses the problem of reduced drive efficiency at higher rotational speeds. This comes from the impedance of the motor windings, which leads to a gradual increase in phase difference between voltage and current as motor speed increases. Intelligent phase control techniques automatically adjust the lead angle within the motor control loop in real time (based on a comparison of the motor current and the rotor angle supplied by Hall sensors). This ensures operation at optimum efficiency across the speed range without either the need for complex measurements or software development during application design.

Precise stepper motor control demands that the motor does not stall as this leads to a loss of synchronisation. The traditional way of preventing stalling is to apply a constant current margin, which has a knock-on effect on overall efficiency with unused energy dissipated as heat. Active gain control (AGC) is a stall prevention technology that addresses this issue via a closed-loop control system. This system compensates for changes in motor torque by applying the exact current demanded by the application at any given time. It has been demonstrated that AGC technology can reduce power consumption by as much as 30% when compared to conventional stepping motor control solutions.

Semiconductors can also have an important role in renewable energy systems. One example is an innovative approach for improving the performance of the inverters used to convert the DC output of photovoltaic panels into AC required by the power grid. This approach is based on applying a method known as advanced synchronous reverse blocking (A-SRB) to the half bridges often used in the inverters. Conventional SRB techniques reduce the switching losses caused by blocking reverse recovery charge (Qrr) through the free-wheeling diode, by means of adding a second switching transistor in series with the main switch. A-SRB takes this one step further by also minimising the effect of charging output capacitance (Coss) on switching losses. This is done by pre-charging the main switch to a lower voltage, using a charge pump in the gate driver IC.

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Toshiba has developed a system solution for PV inverters with an output power of up to 5kW that is based around an inverter bridge with A-SRB technology, a microcontroller for controlling the entire system and two analogue front-end (AFE) ICs for controlling both the DC/DC converter input stages and the output inverter. In addition to photovoltaic inverters, the new A-SRB circuit topology can also be applied to other power conversion applications including UPS systems, DC/DC conversion, power factor correction (PFC) and motor drives.

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