Powering the Robotic Future

Efficient and compact power solutions will change industrial robotics

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The world of manufacturing is changing, driven by various Industry 4.0 initiatives. Amongst these solutions, closely coupled, internetworked robotic solutions have to be highlighted. Closely coupled in this regard doesn't only mean the connection to the Internet or the Internet-of-Things (IoT). The flexible networking of previously sequential, belt-supported production processes using mobile robots, so-called AGVs (autonomously guided vehicles), and the direct collaboration of humans with robots using flexible, collaborative robot systems are of particular significance for the change.

In addition to making production more flexible, industrial companies are striving to further increase the uptime of installed plants and systems and – above all due to rising cost of electricity and CO2 submissions – to use energy as efficiently as possible. Their demands on automation solutions: individual subsystems such as robots, drives, charging systems for mobile autonomous robots as well as power distribution and supply should be constantly available and contribute to improving the energy balance.

Figure 1: The motion control unit is wired to each actuator separately; fitted effectors require their own, separate wiring harness.

Industry 4.0 cannot improve power efficiency alone

Silicon solutions for power systems and drives continue to improve in efficiency, even when staying with well-established silicon-based technologies. This, coupled with the resulting significant reduction of heat loss, and packaging of ever decreasing dimension, enables robotic systems designers to consider completely new ways of designing their products.

In the control system of a typical industrial robot, for example, the power supply and control cabling are located inside or outside the robot arm. The actuators in the robot arm are supplied individually with multi-phase thick power cables which are routed inside or outside around the robot's chassis. The effector usually requires, as an independent system, an additional cable bundle which is connected to a separate power supply and control system externally to the robot arm. However, the power and signal cables of robot and tool are the components of a robot system with the highest likelihood of failure. This is particularly true for externally routed cables

Modern power semiconductors offer an alternative to this classic cable routing. With them, drives

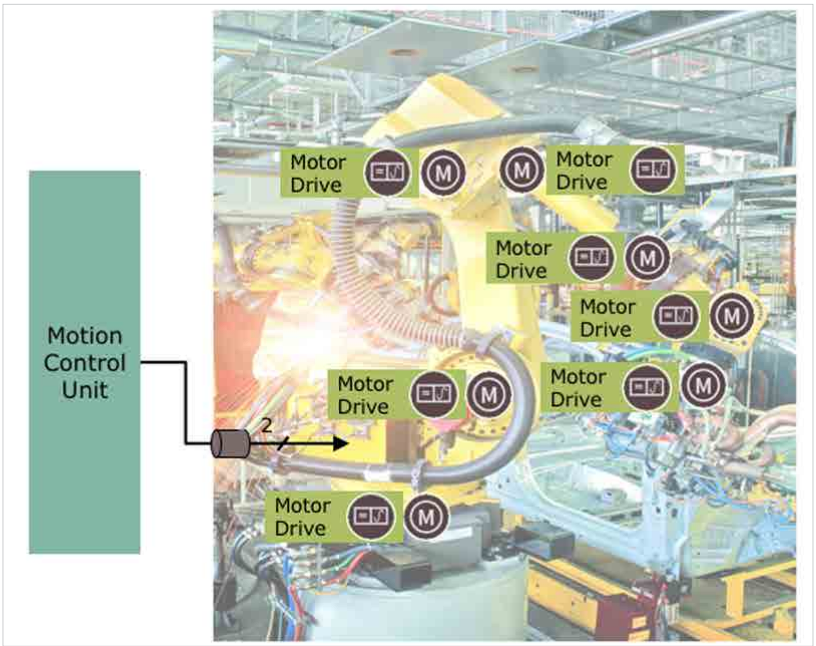

Figure 2: With drive electronics integrated into actuators, simplified, more reliable wiring harness paradigms open up.

can now be integrated directly into the actuators. In this way, a single cable bundle could be used for power distribution. If integration is further advanced, this power supply can also be used for communication – with carrier frequency technologies (power line communication). This would eliminate an additional cable, or: another potential source of error.

With such an optimized cabling harness in place, the possibility opens up to provide power and control to whichever effector is being attached to the robotic arm. A system set up in this way can be made significantly more flexible with a view to changing tasks at a later date. A scalable infrastructure, especially in the area of the built-in manipulators, guarantees future extensions.

With the compact and efficient MOSFET and IGBT power switches such a high level of integration is no longer a problem. The MOSFETs of the PROFET, OptiMOS, CoolMOS and CoolSiC product families and the Trenchstop IGBTs from Infineon cover a voltage and power range of <12 V to 1200 V and <400 W to 20 kW, respectively. In addition, various inverter circuits of the product families CIPOS, EasyPIM and CoolSiC Easy1B are pre-integrated in one housing, which also cover the above-mentioned voltage/power spectrum. All components are characterized by very small on-resistance, compact design and thus maximum power density. This enables a growing integration of the drive electronics directly on the motor.

Integrated gate drivers simplify circuit designs

Compact motor inverter gate drivers are also in demanded since they can keep the bill-of-materials (BOM) count low. The 2EDL family of EiceDRIVER devices complement both discrete MOSFETs and IGBTs in half-bridge applications. Based upon silicon-on-insulator (SOI) technology, these devices are inherently resistant to transient voltages. As there are no parasitic thyristor

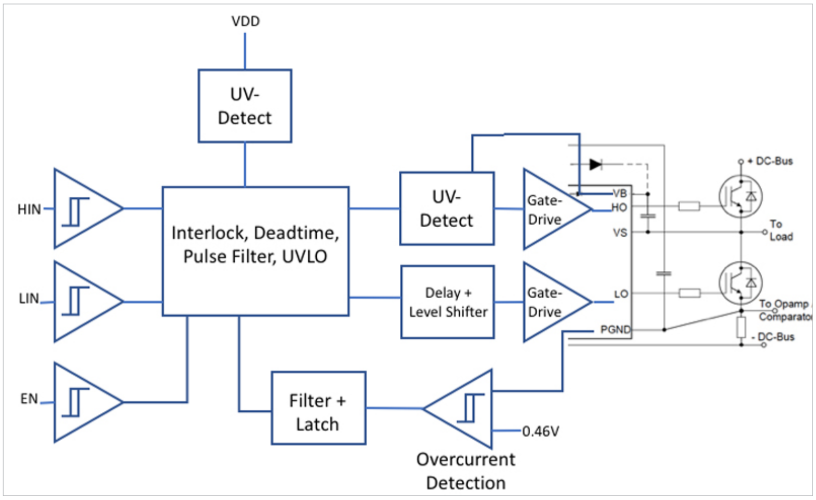

Figure 3: Simplified block diagram of a highly integrated gate drive IC, such as those of the 2EDL family.

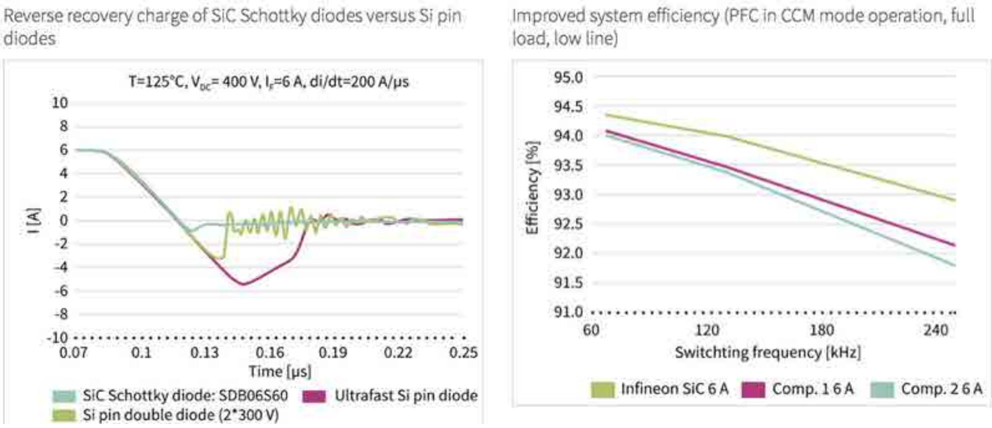

Figure 4: Compared to conventional silicon devices, SiC Schottky diodes have significantly better reverse recovery, and deliver noticeable system efficiency improvements in PFC applications.

structures present in the device, it is protected from temperature and voltage dependent latch up.

They also feature a range of innovative capabilities that would otherwise require several discrete semiconductors such as sensors, operational amplifiers, A-D converters together with complex microcontroller programming algorithms or features. Integrated filters suppress unwanted, EMI-induced short pulses at the inputs, while filters in the supply monitoring circuitry handle voltages spikes for high-side and low-side undervoltage lockout. When used together with IGBTs, an asymmetric undervoltage lockout is implemented. Deadtime is also handled automatically. An interlock function prevents simultaneous activation of two outputs or detects potential short circuits via an integrated protective function before the power semiconductors or even the downstream drive can be damaged

How infrastructure investment benefits from Industry 4.0

In the past, conveyor belt systems have brought enormous advantages in industrial production. Bulk goods could thus be produced quickly and cost-effectively. Today, however, manufacturers are increasingly demanding product adaptation and differentiation due to the strong competitive situation. This can no longer be guaranteed with a rigid production process, creating the need for more flexibility.

One solution for flexible production processes are driverless transport vehicles or mobile robots. They are used to transport semi-finished products to robotic stations where individual production steps are carried out. AGVs increasingly need their own energy sources for mobility, i.e. batteries that need to be charged. In low activity or low battery mode, they automatically connect to a charging station until they can resume operation. This can be contact-based by means of galvanic coupling or contactless by means of inductive energy transmission.

In larger factories uninterruptible power supplies (UPS) are absolutely essential for coping with high power requirements when starting up the production line or for critical production conditions in which power failures have to be cushioned. Here it makes sense to actively use the energy stored in the batteries of the AGVs. In the factory of the future, they are therefore a useful addition to UPS systems and can, at least partially, contribute to uninterruptible power supply and thus make it possible to reduce the expensive UPS battery inventory, which is rarely used under normal circumstances. Industry 4.0 and Internet-based systems are therefore the key to reducing infrastructure investments, as an intelligent charging infrastructure for AGVs can lead to smaller UPS systems.

SiC-based Schottky diodes deliver measurable efficiency improvements

To enable this approach, AGVs will not only need to be capable of charging from AC outlets, but also generating AC to inject

back into the electrical network. This can be achieved using a combination of a bi-directional, zero-voltage switching (ZVS) phase shift full bridge (PSFB) DC-DC convertor, coupled with a totem pole continuous-conduction mode (CCM) power factor correction (PFC) solution. Here, as before, low-losses are essential to ensure optimal efficiency.

Silicon carbide (SiC) is providing opportunities to achieve these savings when compared to more traditional silicon solutions. SiC is ideally suited to high-voltage, high-power and high-temperature applications due to its remarkable electronics properties. These include a wider band gap, larger critical electric field, and higher thermal conductivity than silicon-based semiconductors.

Such devices offer extremely fast turn-on times, making them ideally suited for the high switching speeds employed in PFC circuits. In turn, dynamic losses can drop considerably in typical topologies. The CoolSiCTM family of Schottky diodes are one such example of a product to be considered. With no reverse recovery charge, these devices offer low turn-off losses. When coupled with MOSFET or IGBT switches they lead to a reduction in turn-on loss. Their increased efficiency also results in lower thermal losses. As a result, designers can increase power density, leading to smaller volume power solutions and reduced cooling requirements.

Industry 4.0 is, at last, starting to become more tangible in the world of manufacturing. Networked robots, feedback from sensors, and data from autonomous manufacturing islands can all be monitored and coordinated from a central system. Such networks even allow individual system elements to communicate with one another to make autonomous decisions. However, enhancements in power delivery and distribution, as well as power savings, will not come from improved connectivity alone.

New architectures for robots, utilizing compact, energy efficient silicon solutions, will provide energy savings along with improved reliability, as cable harnesses reduce in complexity and weight. The stand-by power provided by on-site UPS systems can also be newly dimensioned, especially if the mobile battery power of AGVs can be coordinated to participate in the power delivery mix. AGVs will also be capable of longer working times and shorter charging times, thanks to more efficient silicon and silicon-carbide power solutions, as well as resulting from the weight and size reductions these devices make possible.

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