White Paper
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Semiconductor solutions for robotics

A special focus on drives technologies

Abstract

Controllable machines have fascinated humankind since ancient times. The evolution from clumsy and heavy machinery until today's intelligent and safe robots has been driven - among others - by great advances in semiconductor technologies, from efficient power semiconductors to advanced sensor systems. The next evolution of robotics will lead us into a far more interesting and immersive era with more autonomous robots and artificial intelligence (AI) merging into highly complex systems. Social and technological challenges are ahead. This document exposes ideas on how to overcome the technical challenges through the next generation of semiconductor technologies with a special focus on motor drives.

By
Pablo Yelamos Ruiz, Applications Engineer
Infineon Technologies AG

Table of contents

1 Introduction: robotics around us

Robots can be defined as autonomous systems capable of carrying out certain tasks without human intervention, and in many cases in a repetitive way. Of course, once robots are provided with higher artificial intelligence, they can start making autonomous decisions according to human preprogrammed behaviors. Even today, many different types of robots are already around us aiming to simplify the way we work and live. There are several fields of applications in robotics. The main application areas are considered in this document as the following:

Service robots

These robots can be considered as our helping hands in our everyday tasks. Service robots can be found in our immediate surroundings such as our homes and gardens (e.g. vacuum cleaners or lawn mowers), and in professional environments as well. They take over routine tasks to increase our effectiveness. Despite the ease-of-use of the end products, these devices have a highly complex hardware to enable smooth and user-friendly operation. Several motors are required to move the machine and enable it to fulfill the tasks accurately. Advanced functionalities like collision avoidance or room mapping require built-in radars and sensors. Most advanced robots offer intelligent routing with learning algorithms as well. Users can benefit in several ways from the features via optimized time management, sequenced and well composed task fulfillment.

A subtype of service robots are humanoid robots that are designed to look like humans. Joint positions and movements are inspired by the human locomotor system. This is also clear by the fact that humanoid robots usually move on two legs in an upright position. The main motive for research and development in the field of humanoid robots is artificial intelligence (AI). These can be found in many different forms and locations. Utilization of humanoid robots in tasks like welcoming guests at hotel receptions, providing indications in tax offices, guiding in museums or teaching at schools could become very popular soon. The time when this type of robots with a certain humanoid resemblance will invade our homes, depends upon the technical advantages of such a system versus existing solutions, but more probably on the social acceptance of an autonomous intelligent entity.

Figure 1 Service / home robot and automated guided vehicle examples

Industrial robots

These are programmable machines that are used to handle, assemble, or process work pieces in the industrial environment. Most of these robots consist of a robot arm, a gripper, various sensors, and a control unit. They can also carry out actions autonomously depending on how they are programmed.

Automated guided vehicles (AGV) / warehouse robots

A warehouse robot could be considered as an advanced version of a home robot, developed for industrial environments. More powerful than service robots, these are supplied with higher voltage batteries and typically use only BLDC drives with high precision positioning.

Warehouse robots are designed to improve efficiency and productivity in retailer warehouses, for example by transporting items and organizing the stocks automatically. When warehouse size increases, a good number of automatized warehouse robots helping warehouse workers can make a huge difference in the operations. Note that different challenges are faced in an environment with hundreds of robots, and overcoming those require a high level of synchronization of the machines which in turn sets up different design goals for engineers who develop hardware and software for these robots.

Collaborative robots - cobots

In contrast to classic industrial robots that work standalone or together with other machines, cobots are designed to collaborate with humans. A good example of collaborative robots are the small robotic arms. These are designed to work with humans to accomplish certain tasks together with a higher level of efficiency, effectivity and productivity. Cobots take over or backup the job of conventional industrial robots in an increasing number.

These robots include functions to safely help workers on small actions such as screwing or moving small items. Affordable, low cost small robotic arms are predicted to spread into smaller businesses as well as in the more robotized classic automotive assembly industry.
Important to point out that cost reduction is not a standalone success factor in the expansion of cobots, ease of deployment and programming also play a key role. Designers also need to endeavor to easy installation and short time to get the cobot in action. A large amount of software solutions are already developed to help users to program main functions of the system on a top level.

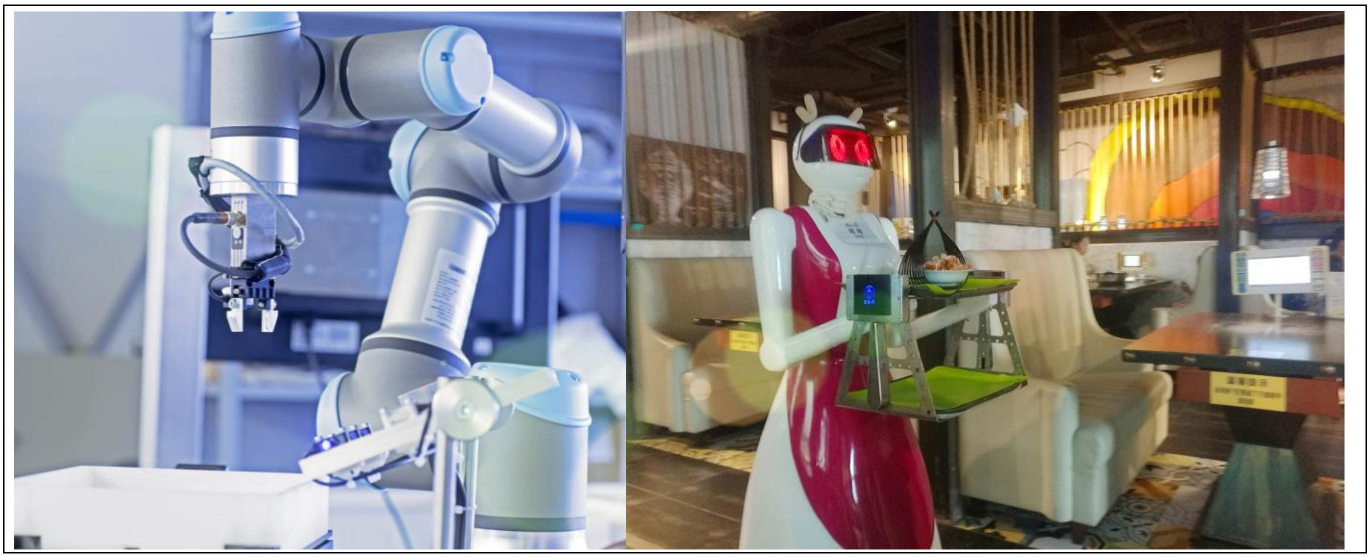

Figure 2 Cobots and service / educational robot examples

Robots could be further categorized; however, these four main types represent a good starting point for analyzing some of the technical requirements and explain how semiconductors like Infineon can accelerate the expansion of robots in the broader public.

2 Electronic system architecture

2.1 System overview

Figure 3 describes a common architecture for robots described in the previous section. Some robots will not include all components discussed here; however, this still represents a good system overview. The 'main CPU' is the central brain and carries most of the intelligence of the system. This processor is responsible for the system coordination. Depending on the specific goal of the robot, this can vary on a broad spectrum with a common expectation: making sure that the robot works properly and fulfills all tasks independently. Therefore, the processor or processors will command the different modules to execute tasks in a scheduled way. The remaining modules execute instructions and report status to the main CPU.

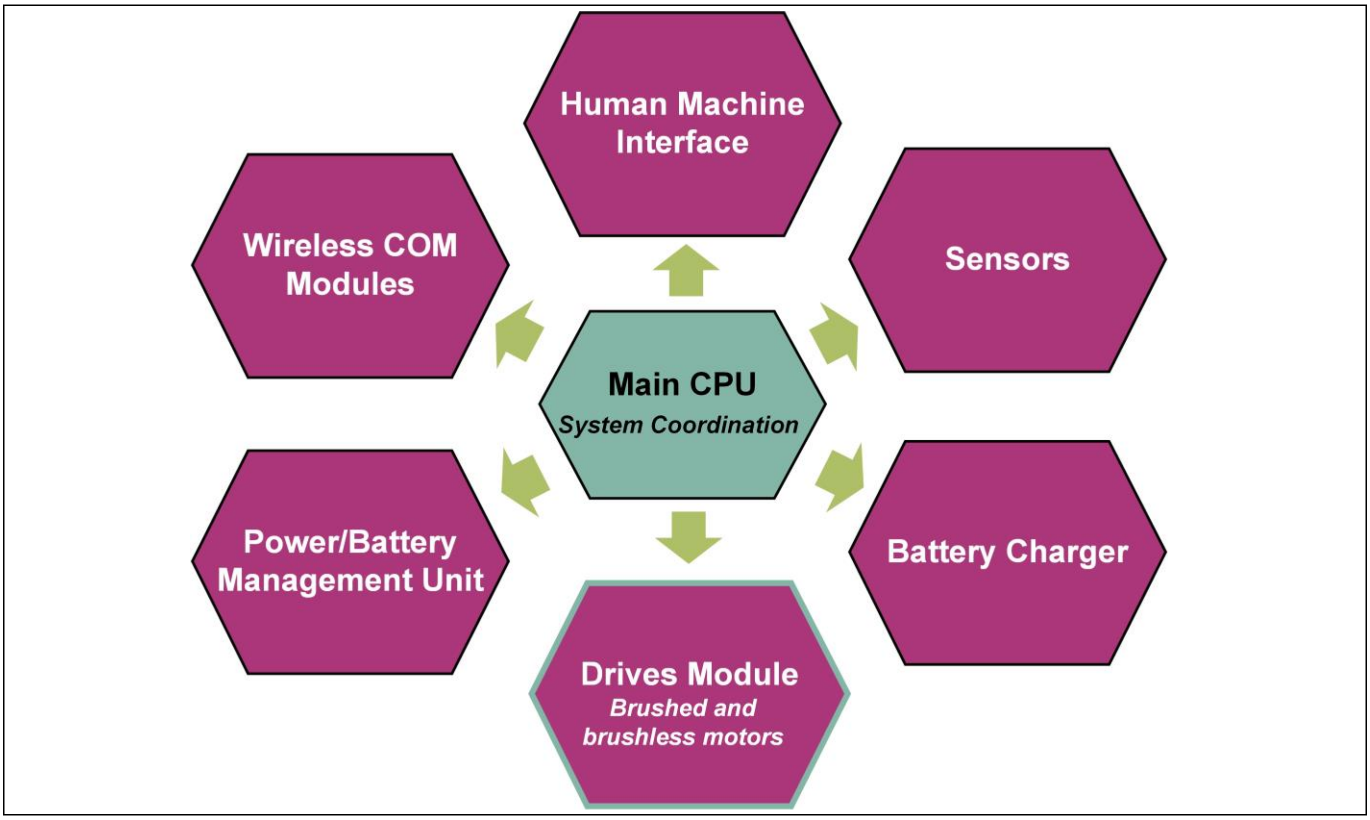

Figure 3 Common robot architecture system block diagram

Figure 4 depicts a deeper delve into a robotic system structure with many possible modules that can be fused into a robot to make it safe, secure, reliable and able to interact with its environment.

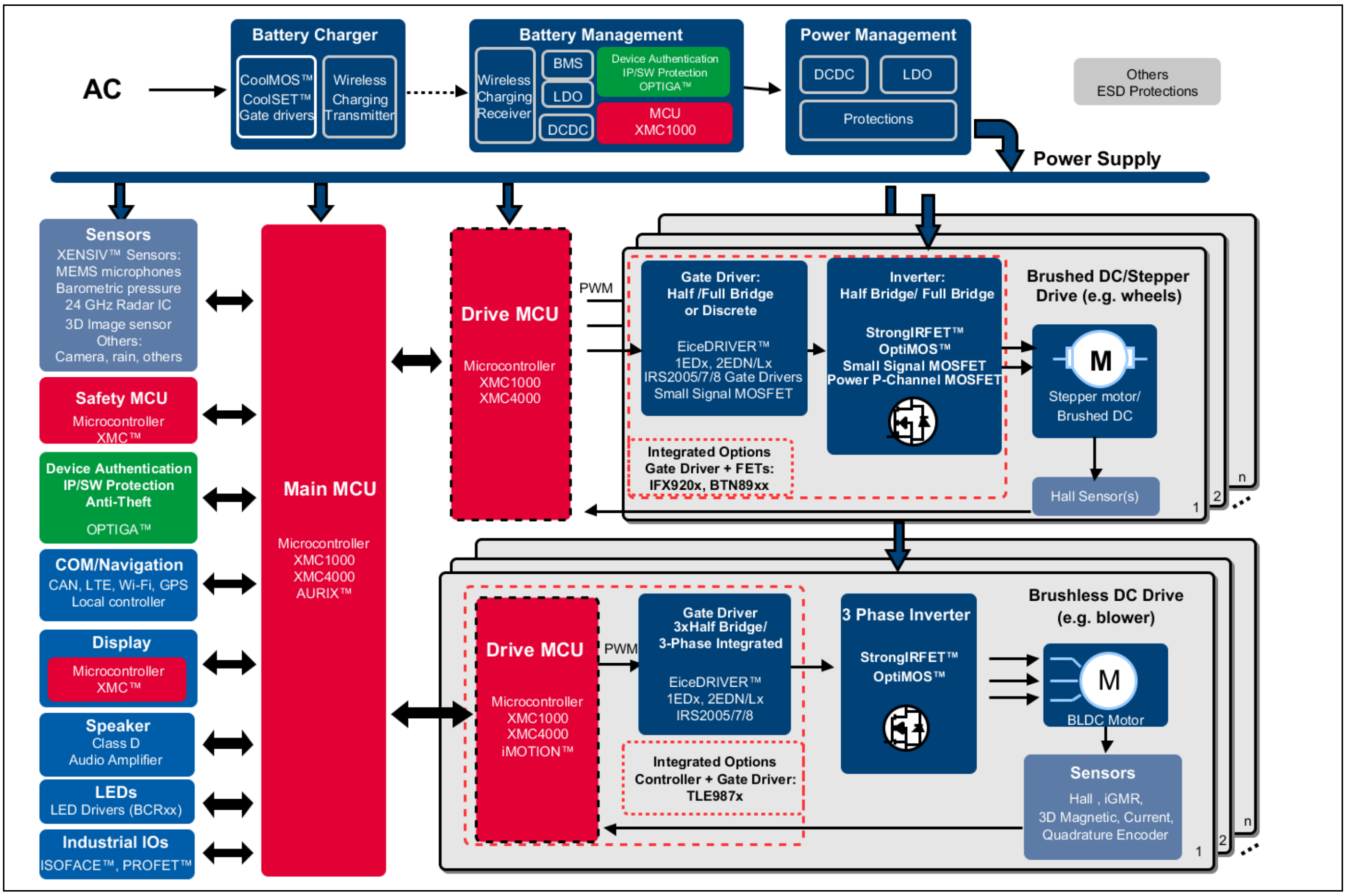

Figure 4 **Detailed block diagram of service robots**

Most common main components in service robots are the following:

Power/battery management unit

Most of the systems discussed here are battery driven, whether it is a robotic lawn mower or an educational robot. Despite the presence of lead acid batteries due to lower cost, lithium batteries are becoming dominant in the industry due to their higher energy density and lower performance degradation with time. A battery management unit takes care of the overall condition of the battery (including health and safety aspects), and also protects it against system overvoltage or overcurrent.

When designing the battery module, security is definitely a factor to consider. Device authentication and IP or software protection can be achieved with Infineon's innovative OPTIGA™ security chips. Batteries also rely on general purpose microcontrollers such as XMC1000 family based on ARM® -Cortex™-M0 processor and low voltage MOSFETs (OptiMOS™ and StrongIRFET™) to implement auxiliary functions like metrology or monitoring in the battery system.

Apart from a battery management unit, a power management unit supplies power to the different components in the robot by controlling in a stable manner the required voltage rails - 12V, 5V or 3,3V- for the rest of modules. Infineon offers a great portfolio of semiconductor solutions from buck converter controllers such as IFX90121, IFX91041 to linear regulators - fixed and adjustable – such as IFX1763, IFX54441, IFX54211 or IFX30081.

Wireless communication (COM) modules

Robots are interconnected to other systems like other robots in the environment or control units that command complete robot fleets in real time. Warehouse robots for example require communications like Wi-Fi to exchange information about location and route with other warehouse robots at any time to prevent collisions. In many cases, a local controller will handle the communication, working as a gateway between the main controller in the robot and the external world.

Human machine interface (HMI)

Most of robots considered here have a certain level of interaction with humans. Sometimes it is only a simple display like in lawn mowers. More advanced possibilities in educational robots like high resolution displays similar to a tablet are common, and also LED lights can be also used to provide information or feedback to the user. Infineon offers integrated linear LED driver ICs like BCR430U that can help to design this in a few steps.

Once the robot is provided enough intelligence to be able to interact verbally with the user, both voice input and output devices are required. Let's take educational robots as an example. Both speakers and sometimes an array of microphones are utilized here to enable to robot to fulfill its interactive task of education. Infineon offers Class D amplifier solutions like IR43xx - PowIRaudio™ family featuring high performance audio capability and highly integrated MEMS microphones from the XENSIV™ family of sensors that offer highly integrated high performance voice interface with high SNR value and low distortion.

Sensors

Many types of sensors can be built in to robots. The most common ones are position sensors (Hall sensors, encoders), speed, angle or current sensors in drives. However, as the robot needs a precise understanding of its environment, different types of sensors are required such as radar sensors for motion sensing (distance and direction), barometric pressure sensors or 3D image sensors for object recognition. This wealth of advanced features boosts the robot's autonomous capabilities, especially when it is deployed in a complex environment such us crowded warehouses.

Battery charger

In some cases, battery driven robots include an on-board charger so they can be directly connected to the AC grid. In these cases, a charger is included in the robot to generate a high voltage DC level that the power management unit will process further down. A wide range of products are offered by Infineon in the battery charger segment from high voltage MOSFETs (CoolMOS™) to integrated controllers (CoolSET™) and high voltage gate drivers (EiceDRIVER™ family).

An emerging trend is the inclusion of wireless charging capability. This is of especial importance in systems that are required to work continuously. In such systems the time of charge is time that the robot do not perform. Using wireless charging enables the robot to charge while still performing. Infineon has solutions for wireless charging as well - auxiliary controllers such as XMC1000 family based on an ARM® Cortex™-M0, power switches such as OptiMOS™3 BSC12DN20NS3 and half-bridge gate drivers for class D amplifiers or low side drivers such as 1EDN8511B for class E version.

Drives module

Robots movement is enabled by drives and motors. When looking at the different categories of robots presented in the previous chapter, it is easy to imagine how many different types of moves are possible. For example, a small lawn mower or service robot needs to move only slowly and with relatively low accuracy. A small motor, rated to a few watts, is enough for that situation, so with cost optimization of the drive system in the focus the designer will select a brushed motor.

Another example is the arm drives of cobots. Cobots need in many cases 5 to 7 independent axes that need to move precisely between different positions and sense any counterforce created by an obstacle. As accurate positioning and torque sensing are required, the designer will decide for a brushless DC (BDLC) motor for such drives together with a set of position sensors (e.g., Hall sensors, encoders) and speed or torque sensors.

In some cases both brushed and brushless motors can co-exist in a robot. Consumer applications like a robotic vacuum cleaner can benefit from the low cost of a brushed motor used in the wheels, while requires a BLDC motor for the high speed air blower function.

3 Drives in robotics

In this section some concepts and proposals will be discussed based on the benefits offered by semiconductor technologies, including energy efficiency, thermal behavior and space saving. We will also touch on how these technologies can help robotics to better perform in both brushed DC and brushless DC implementations.

3.1 Brushed motor drives

Despite their well-known disadvantages, brushed motors are still widely used in service robotics. Many of the drives in robotics do not demand high efficiency, precision or speed, therefore usage of a brushed motor is a reasonable option for this application. Additionally, the reduced cost of brushed motors in comparison to brushless motors and the reduced number of components and control requirements make them even a more attractive choice.

Brushed motors are commonly controlled from a central microcontroller (MCU) that takes care of one or more of these motors at the same time. Control is quite simple and uses on/off signals (e.g., GPIOs) or simple PWM patterns if variable speed is needed to command the movement of the motor. If necessary, one or more Hall sensors can be used to get the angular position of the motor.

Typical drives using brushed motors are low power motors in wheels of light robots (e.g., vacuum cleaners) or for head rotation and other small and lightweight parts' movement (e.g., in educational robots). Through these small/slow movements the robot can provide feedback or interact with humans. None of these applications demand accurate positioning or high speed rotation.

3.1.1 Discrete versus integrated brushed drives solutions

Figure 5 shows a typical drive circuit used in brushed drives. Both uni- and bi-directional (for example, commonly used in wheel drives) motor operations are important. A full bridge (e.g., H-bridge) allows the current in the motor to be reversed depending on the control signal pattern, therefore allowing the motor rotation in both directions.

Discrete components in push-pull configuration are commonly used to drive the power switches. With regard to the power switches, 'N+N' MOSFETs, 'P+N' MOSFETs for simplified gate driver design or even BJTs for a more cost sensitive design can be used.

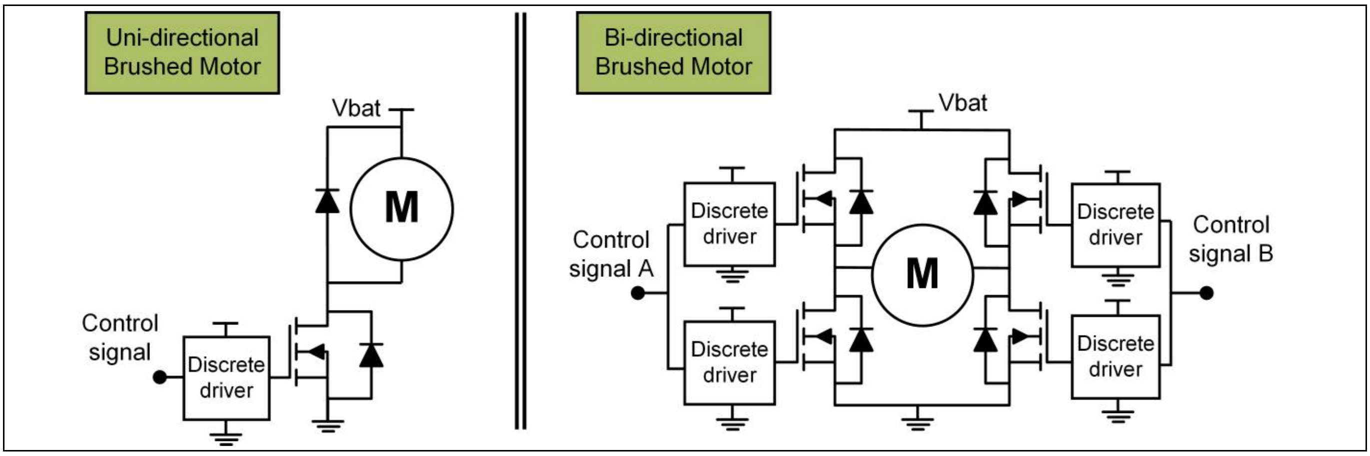

Figure 5 **Brushed DC common drive circuits for uni-directional and bi-directional motors**

The amount of components required for such discrete implementation in most cases sums up to 30 or more. This, in addition to the design complexity, increases the PCB footprint required for the drive circuit. As the number of brushed DC units grows, so does the excessive space required and so the cost of the system. There are several integration level possibilities in such situations to mitigate the challenges:

- **Low voltage MOSFET integrations** (marked with red pecked line in Figure 6): instead of using discrete components for high-side and low-side power switches, integrated MOSFET in both ‘N+N’ and ‘P+N’ can be used:
  - N+N: e.g., IRF40H233 dual symmetrical 40V, 5.9mΩ
  - P+N: e.g., IRF9389: 30V, 27mΩ-64mΩ – easy gate driver circuitry thanks to PMOS on high side.

- **Gate drivers** (marked with green pecked line in Figure 6): an alternative to discrete gate drivers are integrated half-bridge gate drivers that offer a heavily reduced amount of components compared to the discrete solution. Infineon’s product offering includes:
  - Half-bridge drivers: e.g., 2EDL05N06PF from the EiceDRIVER™ family, or IRS2007S

- **Power MOSFETs and gate driver integration** (marked with purple pecked line in Figure 6): this is the highest level of integration in which the gate driver and the MOSFETs are integrated in a single component, either for a single motor (4 x MOSFETs) or for two motors (8x MOSFETS):
  - Single brushed motor low power (up to 6A, V_{IN} 36V): IFX9201SG
  - Two brushed motors low power (up to 6A each, V_{IN} 36V): IFX9202ED
  - Single brushed motor high power (up to 55A, V_{IN} 40V): NovalithIC™ family, e.g., BTN8982TA. These are automotive qualified parts.

MCU Integration

As presented in previous paragraphs, brushed motors are simple to control: in most cases driven in open loop, an on/off or simple PWM signal is enough to drive the motor, and even a position sensor is not always a must. As a result, designers have decided to utilize more centralized architectures of control to reduce the number of controllers in the system. Either the main CPU of the system - as shown in Figure 3 and Figure 4- or a local controller takes care of one or more brushed DC motors. Thus, integration of an MCU with drive components like gate driver or power switches does not provide any immediate advantage as it unnecessarily multiplies the number of controllers in the system.

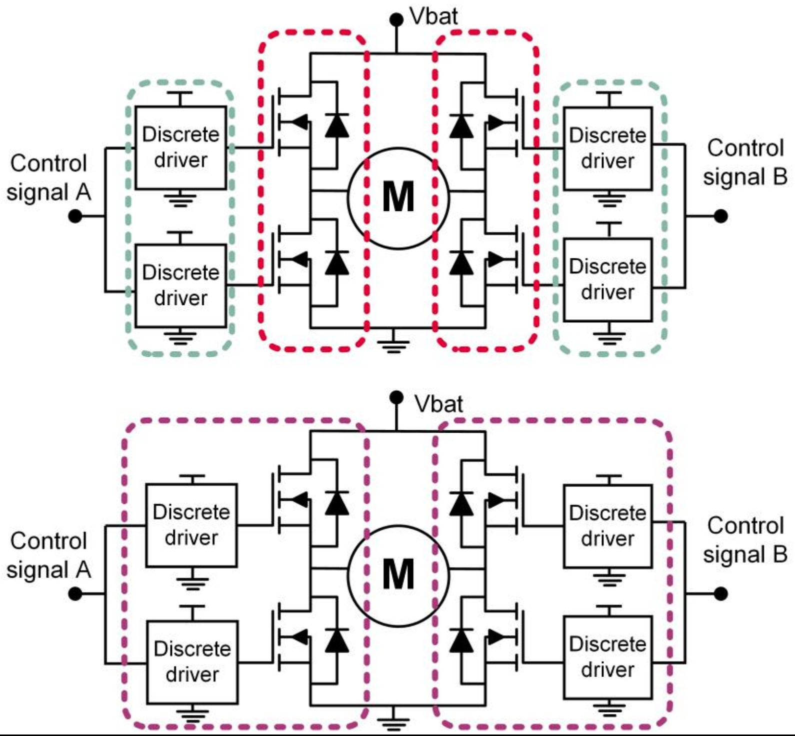

Figure 6 Brushed drives possible integrated solutions

3.2 Brushless motor drives

Many are the advantages of brushless DC (BLDC) motors from which robotic drives can benefit from. Higher efficiency is an important factor, simply because most of the robots are battery powered. BLDC motors have better power density resulting in two benefits: firstly, footprint is reduced on a specific power level when compared to a brushed motor; therefore, the motor can be integrated into smaller compartments in the robot. Secondly, as the motor is lighter, the overall weight of the robot can be reduced automatically increasing the battery autonomy. Those two aspects are crucial in small robot arms or humanoid robots.

Factors like acoustic noise can be a decisive factor as well. Brushed make more noise than brushless motors that can be a problem in certain environments where quite movement is required (e.g., in hospitals).
If the application requires high speed motor like in blowers, the wear out of contact brushes in brushed motors will become a critical issue that does not exist in BLDC motors. So these (BLDC motors) are the common motor choices in such cases.
Nevertheless, we also have to highlight that the control mechanism required for BLDC motors is more complex and the number of components is also greater compared to brushed motors.

3.2.1 Possible BLDC solutions

Brushless motors are well spread in the industry in varying implementations. Most common control methods are block commutation in both Hall-sensored and sensorless (BEMF feedback) variants and Field Oriented Control (FOC), usually in a single shunt configuration.
Two main system architectures are popular independent of the control method: centralized and decentralized systems.

Centralized control
The main processor or microcontroller takes care of the control of one or more BLDC motors. On one hand, the main processor gets highly loaded by the real time control of one or more motors. On the other hand, it has less time-lag and tighter control between the different drives. The design and the layout of robotics components might be complicated in systems where the motors are located far away from the central unit, in particular, cabling can become an issue in high density systems with centralized control.

Decentralized control:

Each BLDC unit is controlled by a dedicated controller that sits next to it. Even though this is a less common architecture, it definitely has advantages and in some systems safety related requirements might impose the usage of different controllers for different drives.

In a similar manner as in brushed DC motors, integration of parts offers possibilities to reduce the footprint and number of components of the system. The most important component integration cases for BLDC drives - shown in Figure 7 – are:

A - Complete discrete system

Non-integrated version with microcontroller, gate driver and power switches in discrete configuration. Gate drivers can be found in single or half-bridge configurations.

B - Dual MOSFETs and three-phase integrated gate driver
This is the first level of integration. Dual MOSFETs integrate two MOSFETs in one package, a high- and a low-side. As the power density increases, the packaging design needs to improve too.
In terms of gate drivers, the most obvious step is integrating into a three-phase gate driver. Additionally, bootstrap diodes can be integrated for reduced component count. Features like increased robustness to voltage transients and protections are also key in case of higher power drives. 6EDL04N02PR for example offers all this features.

C - Dual MOSFETs and microcontroller + three-phase gate driver integrated
Integrating the microcontroller and the drivers together is the next level of integration. Additional features like operational amplifiers or linear regulators can be integrated to minimize the number of external components. This setup would not be applied in systems that have centralized control of several drives.

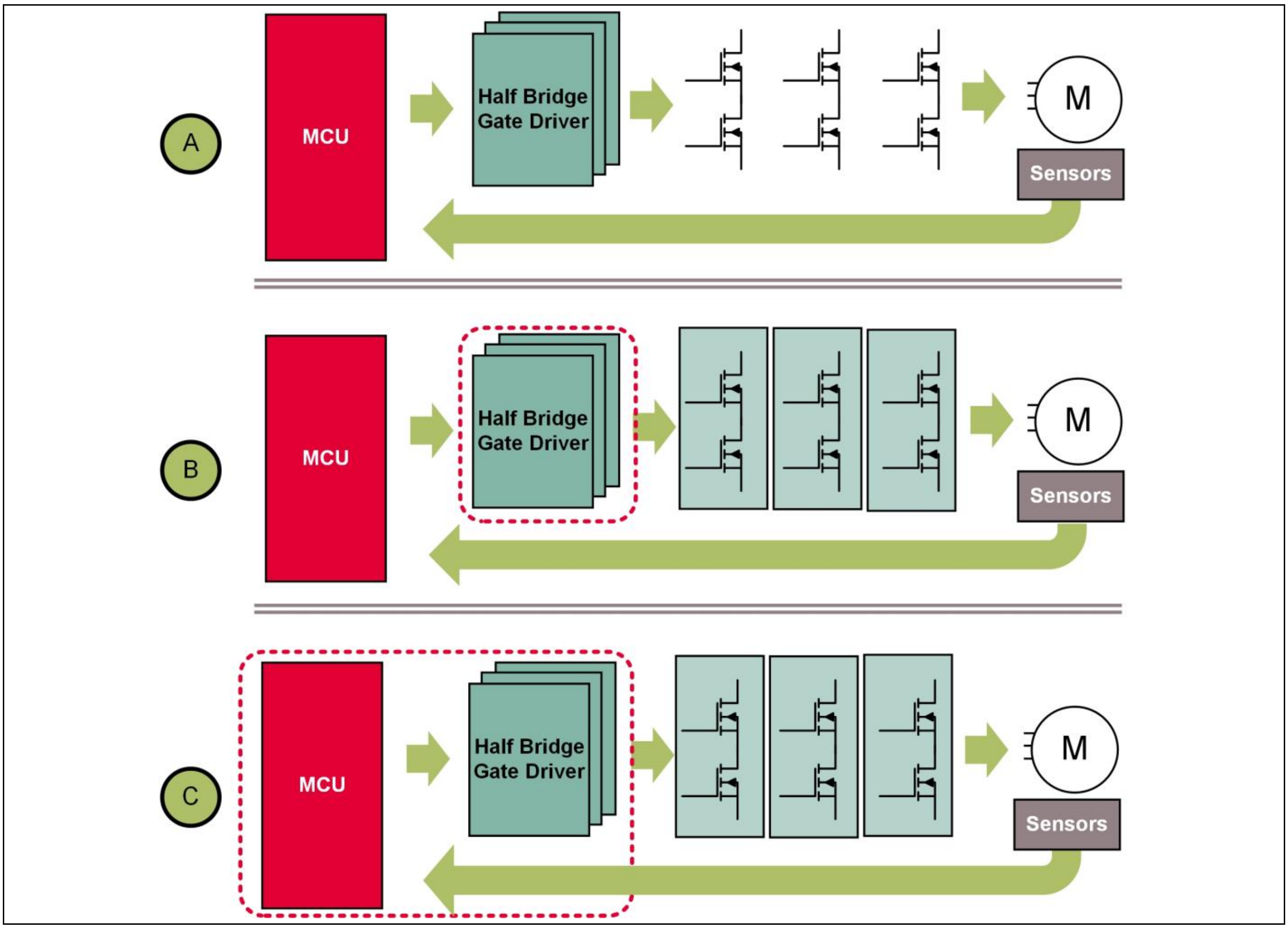

Figure 7 BLDC drives integration options

Although less popular, another possibility for low-power designs is the power block integration. This means the integration of a dual MOSFET (high- and low-side switches) and the gate driver together in one single package.

Table 1 compiles a list of recommended Infineon products relevant for BLDC drives including MOSFETs, gate drivers, controllers and sensors supporting all three different levels of integration presented previously.

Table 1 List of some recommended Infineon components for BLDC drives

Product Family	Voltage Class	Package	Part Number	$R_{DS(ON)}$ (mΩ)	Comment
OptiMOS™ 20 V - 200 V	40	SuperSO8	BSC010N04LSI	1.05	With integrated Schottky diode
		SuperSO8	BSC022N04LS	2.2	
		S3O8	BSZ025N04LS	2.5	3x3mm package
	60	SuperSO8	BSC014N06NS	1.45	Best in class
		SuperSO8	BSC027N06LS5	2.7	
	80	SuperSO8	BSC026N08NS5	2.6	Best in class
		SuperSO8	BSZ123N08NS3 G	12.3	Cost/performance optimized
		TO-Leadless	IPT012N08N5	1.2	
		D2PAK 7pin	IPB015N08N5	1.5	
	100	TO-Leadless	IPT015N10N5	1.5	
		D2PAK	IPB020N10N5	2	High performance
	200	TO-Leadless	IPT111N20NFD	11.1	Small profile
StrongIRFET ™ 20 V - 60 V	40	D-PAK	IRFR7446PbF	3.9	Cost optimized
		DirectFET™ ME	IRF7480M	1.2	
		PQFN 5 x 6 B	IRFH7084	1.25	
		PQFN 5 x 6 B	IRFH7004	1.4	
	60	PQFN 5x6	IRFH7085	3.2	Cost optimized
Gate drivers	20V	SOT-23	1EDN7550	-	True differential inputs
	100V	VDSON-8	2EDL8114	-	Half-bridge driver
	200V	8 lead SOIC	IRS2011S	-	Half-bridge driver
	600V	DSO-8	2EDL05N06PF	-	Half-bridge driver
	600V	DSO-28	6ED003L06-F2	-	Three phase gate driver
Controller	1.8V to 5.5V	VQFN-64	XMC1404-Q064X0200	-	Includes MATH-co-processor
	3.3V	LQFP-64	XMC4100-F64K128	-	With high resolution PWM (HRPWM)
	3.3 V	QFN-32	IRMCK099M	-	Motor control IC (incl. motion control algorithm)
	1.8V to 5.5V	LQFP-64	IMC101T-F064	-	Motor control IC (incl. motion control algorithm)
Hall switches	Up to 32V	SOT23	TLI4961-1M	-	Extended robustness
	3.0V-5.5V	SOT23	TLI4963-1M	-	
Angle sensor	3.0V-5.5	DSO-8	TLI5012B E1000	-	GMR sensor
Current sensor	3.1V-3.5V	TISON-8-1	TLI4970-D025T4	-	Up to 25A, 1.6% accuracy

3.3 Robotics drives technologies

3.3.1 MOSFET and package technologies

Regarding low voltage MOSFETs, significant developments have been made in recent years. Infineon has been innovating continuously to improve figures of merit of MOSFETs with special focus on reduced $R_{DS(ON)}$ (drain to source ON resistance) and gate charge (capacitance) of the MOSFET, minimizing both conduction and switching losses from one generation to the next.

In drives applications, both conduction and switching losses are in the focus. Depending on the control method, different losses are observed. For example, it is very common to use synchronous rectification. This technique turns on low-side MOSFETs when the current freewheels through their body diodes. This dramatically reduces the conduction losses of the body diode ($P_{Loss} = I_F \times V_F$) as the $R_{DS(ON)}$ value of the MOSFETs gets lower and lower with new generations.

Even when synchronous rectification is used, the low-side diode is demonstrated to be one of the main sources of losses in this type of drive applications. In order to address this issue, Infineon has developed MOSFETs with integrated Schottky diodes that reduce the forward voltage, therefore minimizing the power loss in the diode. These products are referred to as OptiMOS™ FD (Fast Diode) and can be identified by the suffix –LSI, e.g., BSC010N04LSI.

Figure 8 shows a power loss breakdown measured in a three-phase inverter using block commutation PWM (6 steps) with synchronous rectification. The supply voltage is 18 V and the selected MOSFET for the comparison is BSC010N04 in both LS and LSI versions.
One can easily see that both conduction ('Cond-') and switching ('SW-') losses have an important role in both high-side ('HS') and low-side ('LS') MOSFETs. Three main conclusions can be extracted from this data:

1. Switching losses are negligible in the low-side MOSFET as soft-switching is granted.
2. Conduction loss in low-side diode is by far the most dominant source of losses.
3. LSI (Fast Diode) version of MOSFET with integrated Schottky diode reduces the conduction loss by approximately 25 percent. This reduction depends on system conditions like current level.

However, switching losses increase with switching frequency. Common frequencies in robotic inverters range from 10 kHz to 40 kHz. Infineon's best-in-class OptiMOS™ solutions offer low $R_{DS(ON)}$ and low-charge MOSFETs to remarkably reduce both types of losses.

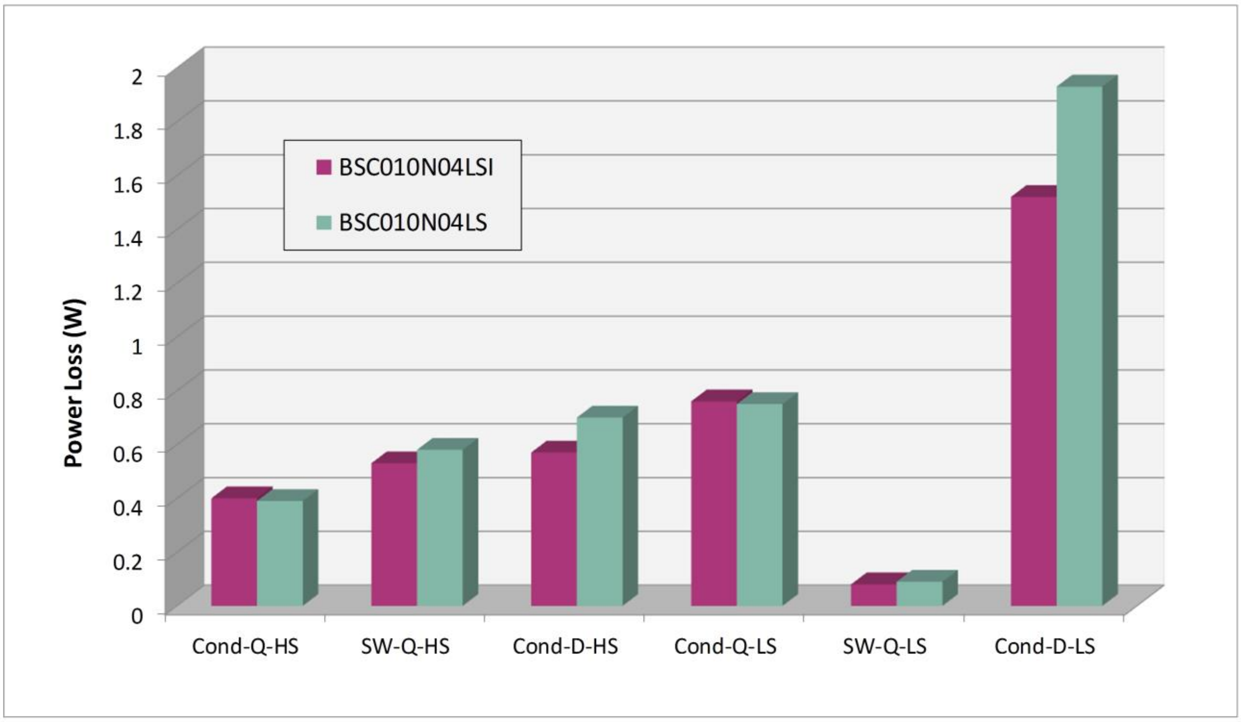

Figure 8 **Power loss breakdown showing conduction (‘Cond-‘) and switching (‘SW-‘) losses in high-side (HS) and low-side (LS) MOSFETs as well as body diode (D) losses. Conduction of low-side body diode is dominant and can be reduced by usage of LSI parts.**

All these technologies reduce the power losses in the inverter effectively. Nevertheless, losses are inevitable and heat will be produced in the power switches. Thermal management is one of the key challenges in drives designs, especially when considering high power density designs like those in small robotic arms. Infineon DirectFET™ packages, as shown in Figure 9, are dual-side cooling packages with direct connection between the metallic package and the silicon die inside, minimizing thermal resistances to the exterior. Also, the die gets directly connected to the PCB on the bottom side.

DirectFET™ packages spread efficiently the heat from the junction to the bottom of the PCB, and from the top through the metal package into the air or an optionally used heat sink for more rigorous cases. In addition to its extra low profile, this package is the perfect choice for space constrained designs. Figure 9 shows a comparison of thermal resistances between DirectFET™ and D^2Pak packages. DirectFET™ has less than half of the thermal resistance (8.1°C/W) than D^2Pak (16.8°C/W).

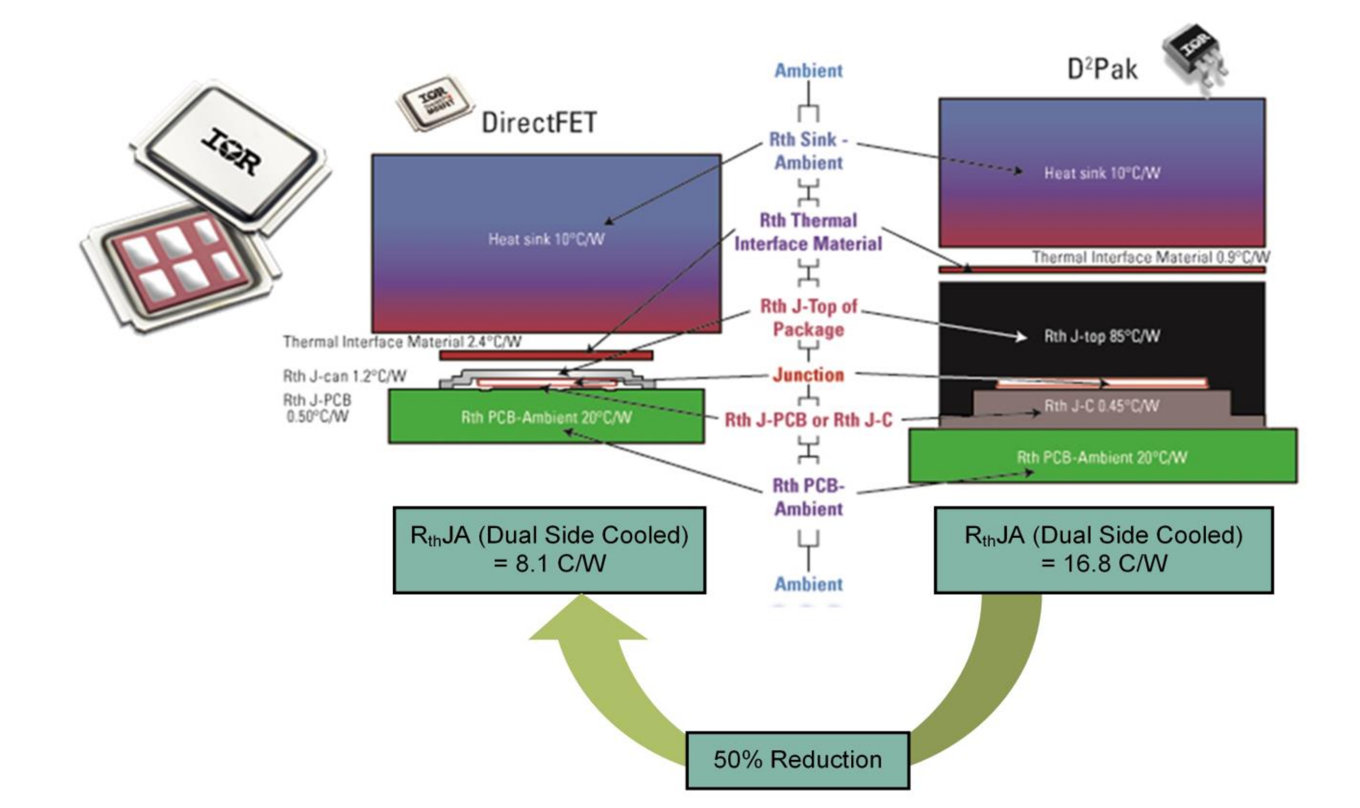

Figure 9 **DirectFET™ packages allow optimized thermal design in high density drives. Comparison of thermal resistances between DirectFET™ and D²PAK packages.**

3.3.2 High switching frequency drives solutions with gallium nitride

Increasing the switching frequency can help to improve the performance of a drive by reducing the torque ripple. This technique is used in other applications such as power supplies to reduce the size of magnetic components effectively. Wide bandgap semiconductors like gallium nitride (GaN) can provide best performance at higher switching frequencies. Reverse recovery of the diode is highly improved in GaN MOSFETs, making it a great choice in these cases.

With increased switching frequency, controllers are required to be adapted:

- PWM resolution must be considered to ensure that the complete loop can stay under the required accuracy. Infineon offers microcontrollers like XMC4100 family with high resolution PWM modules for such high resolution loop purposes, especially when switching frequency increases.
- Also, the processing capability of the microcontroller must be considered when switching frequency increases. Assuming a cycle-by-cycle control, less time is then available to finalize new duty cycle calculations. Infineon has a broad portfolio of controllers with wide range of performance from XMC1000 family ARM®-Cortex™-M0 at 32MHz to XMC4000 family ARM®-Cortex™-M4F at 144 MHz and AURIX™ when higher level of functional safety and performance is required. Increasing the control loop execution frequency leads to better dynamics of the motor resulting in more accurate control.

Infineon's product offering also covers a special MATH co-processor (including both a CORDIC unit for trigonometric calculations and a division unit) dedicated to motor control calculations. This co-processor improves the execution time of control loops in XMC1000 family compared to standard implementation (hardware versus software calculation). A comparison of the execution time of cosine and division functions - often utilized in motor control algorithms like Field Oriented Control (FOC) - is shown in Figure 10.

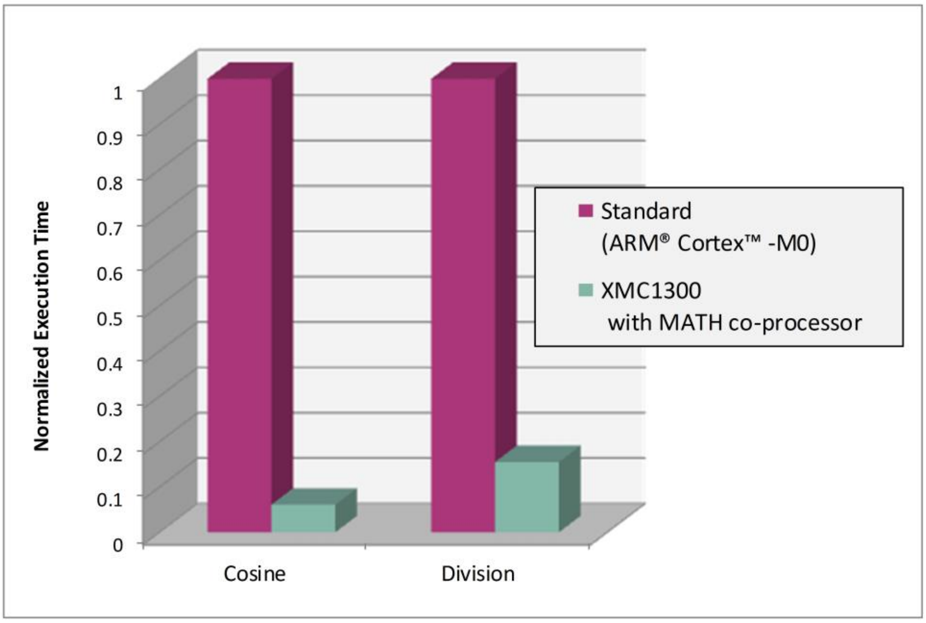

Figure 10 Normalized execution time for cosine and division functions with a standard ARM® Cortex™-M0 without MATH co-processor (Standard) and with XMC1300 utilizing the integrated MATH co-processor and DIVIDE unit.

3.4 Safety in robots

Robots and in particular collaborative robots are regulated by standards like ISO10218 and ISO/TS 15066, guaranteeing that the machine operates safely in any conditions. This might affect some areas of both software and hardware design.

In many cases, a safety controller is designed as depicted in Figure 4. The microcontroller monitors different aspects of the operation of the robot, and works redundantly to the main controller that executes the task. As an example, it can check Hall sensor signals to detect a possible stalled motor condition. In case the motor stops unexpectedly, this safety controller can provide an additional second level of error detection to the main drive controller.

For more advanced safety features, Infineon offers solutions such as AURIX™ family of safety microcontrollers based on lockstep architecture, making it the best choice for SIL2-3 (ASIL B-D) designs.

Safety and security are closely interrelated. Ensuring the security of the system is the only approach to create a safe robot. Firmware upgrades of controllers in the field are a good example. Authentication can prevent that non-original (counterfeit) software images to be downloaded to the system.

4 Conclusions and outlook

In this document we discussed how complex systems robots are. Infineon offers a wide range of solutions in sensors, controllers, power switches, gate drivers and security to help designers develop the next generation of robots.

Looking at the future, the ability of semiconductors to integrate more capabilities and more intelligence into processors will push the development of artificial intelligence (AI) and autonomous functions beyond what we have today. That can transform robots from intelligent units into intelligent fleets in which many robots collaborate to carry out more complex tasks.

Developments in sensors like radar will lead robots to a higher level of understanding of their environment which will help them to behave in a more integrated and corresponding manner with their surroundings, acknowledge persons or objects and interact with them. Also, higher precision and synchronized movements will be required in the future to enable robots to better fit into our world, carry out tasks more easily and really become our everyday helpers. To achieve this, more advanced motor controls with accurate positioning will be essential to ensure a higher level of interaction and synchronization between motors in the robot or different robot units. Only through the smoothness in movements will a robot be able to emulate or mimic human movements. This might also be a crucial factor in social acceptance of humanoid robots.

Considering drives, the popularity of BLDC will increase as brushed motors will not be able to cope with precision and efficiency requirements once more advanced functions are demanded in robots. As of today, the higher performance they offer still comes hand-in-hand with higher overall cost. More integrated solutions, like microcontroller together with gate driver or gate driver integrated with MOSFETs, will simplify designs and reduce cost in the overall system. New wide bandgap devices will stablish the foundation of higher switching frequency drives, helping both in the accuracy and footprint aspects.

The control algorithm development will be standardized and will be provided in many cases in hardware implementations. This will extremely reduce the development cycles, therefore reducing design costs and increasing the usage of BLDC drives.

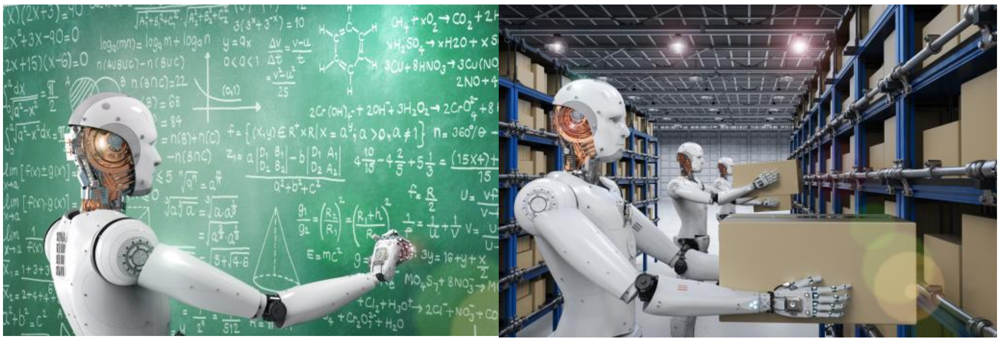

Figure 11 The future of robotics

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