Precision Drives Power
A New Generation of Prosthetics

Considering the ARM Architecture for Industrial PCs
Using Ferroelectric-RAM to Build Smart Airbag Automotive Applications
ADLINK

Computer-On-Modules for 6th Generation Intel® Processors

ADLINK, leader in industrial automation, measurement and automation, introduces a new series of products aimed toward small, portable, yet incredibly powerful IoT embedded solutions. Here we have two Computer-On-Modules (COMs), the ADLINK Express-SL and the ADLINK cExpress-SL, the basic size and compact size computer on modules, as well as this Mini-ITX sized module, the ADLINK AmITX-SL.

As they’re aimed at the embedded and industrial market, they are all designed for robustness to last for many years in the field as well as long term availability. During the design, parts are carefully selected to ensure these important factors. They also come with ADLINK’s Smart Embedded Management Agent, or SEMA, the hardware and middleware that monitors the system’s performance and status, it also allows remote board management and aids preventive maintenance thus reducing unscheduled system downtime.

Despite their sizes, each of these three is a fully functional computer, with the option of using Intel’s Celeron, or Skylake i7, i5, or i3 processors, up to 32 gigabytes of DDR4 RAM, and onboard gigabit Ethernet. They are also capable of powering up to three independent 4K or UHD displays at the same time.

There are differences between the three, however.

The cExpress-SL uses the COM-Express compact format with 95 millimeters by 95 millimeters, it has 5 PCIe ports, 4 USB 3.0 ports and 4 USB 2.0 ports, with up to three SATA ports.

The applications for these are bounded only by your creativity.
The slightly larger **Express-SL** is built on the COM-Express basic format, 95 millimeters by 125 millimeters, but has up to four SATA ports, 4 USB 3.0 ports and 4 USB 2.0 ports, as well as 8 PCIe ports. The Express-SL also supports ECC memory with models utilizing Intel’s Xeon processor E3 fifteen hundred v5 family.

ADLINK also provides the optional Extreme Rugged™ version for its computer modules—for markets that require long-term reliability under extreme environmental conditions. To ensure durability, the boards go through a series of robust testing, including the Highly Accelerated Life Test (HALT), making certain that products meet rugged design requirements. These Extreme Rugged™ modules ensure long-term reliability over the full negative 45 to positive 85 degrees Celsius temperature range.

The **AmITX-SL-G**, based on the familiar mini-ITX form factor, offers similar I/O with many interfaces being brought to the I/O panel using standard headers. These I/O include interfaces such as four USB 3.0 and four USB 2.0 ports, three Display Ports, two Gigabit Ethernet jacks and 7.1 audio with SPDIF. One USB 3.0 socket allows vertical connection for use with security keys or similar devices while two expansion sockets with PCIe 16x and PCIe 1x are available for add-on cards where necessary. Finally, even more I/O ports are available on pin headers.

The applications for these are bounded only by your creativity. With their high performance, low power, and small form factor, these can be used for any embedded or IoT application that requires high robustness and reliability paired with high performance processing graphics, significant number crunching capability, and full connectivity. For more information on these modules, please visit [www.adlinktech.com](http://www.adlinktech.com).

Click image to view video.
For this Arrow Product Insights, we present four FPGA evaluation boards from a partnership between Altera®, now part of Intel®, and Arrow. Altera and Arrow, working together, have developed a suite of boards that will help you get your design up and running faster, regardless of whether you’re an entrepreneur working in your basement or an engineer working for a Fortune 500 company developing the next IoT product.

The BeMicro Max® 10 is a compact, low-cost hardware evaluation platform useful in a broad range of embedded applications. It is designed for easy prototyping and expansion. It features two 40-pin prototyping headers, a PMOD, one 6-pin analog input header and the 80-pin BeMicro card edge connector. Enpirion® power devices contribute to the BeMicro Max 10’s small form factor.

But most unique about the BeMicro Max 10 is the Max 10 FPGA itself. The Max 10 FPGA includes on-chip flash memory, capable of storing configuration or user data.

Like all of the boards shown in this product insight, The BeMicro Max 10 has a built-in USB-Blaster and is supported by Altera’s free Quartus® Prime Design Software, Lite Edition.

**BeMicro Max 10 features:**
- 8 MB of SDRAM
- Accelerometer
- DAC
- Temperature Sensor
- Photo Resistor
- LEDs
- Pushbuttons
- Several options for expansion and connectivity
- Built-in USB Blaster

**BeMicro CV features:**
- DDR3 SDRAM
- EEPROM and SPI Flash
- LEDs and Switches
- SD Card Cage
- Built-in USB Blaster

The BeMicro CV development kit features a low-cost 28 nanometer Cyclone® V device and is ideal for embedded applications requiring more logic or higher performance than the BeMicro Max 10. It comes with 25K Logic Elements, over 1.7 megabits of on-chip RAM, and 25 variable precision DSP blocks.

**DECA features:**
- Capable of storing multiple configuration images on chip
- Integrated ADC
- Includes sensors: Light, Gesture, Temperature and Humidity
- High-speed DDR3 memory
- Video & Audio capabilities
- Ethernet connectivity
- Enpirion power solution

The DECA development kit presents a robust hardware design platform built around a 50K logic element, flash-based Altera Max 10 FPGA. This development kit allows users to evaluate IoT designs through the optional Bluetooth Low Energy Wi-Fi cape. The DECA board is outfitted with a variety of sensors and peripherals, enabling applications ranging from system management, I/O expansion and communication control planes to industrial, automotive and consumer. With the DECA board, users can now leverage the power of non-volatility and re-configurability in a high-performance, low-power FPGA system.

Combining the ARM® Cortex™-A9 applications processor with industry-leading programmable logic, Altera’s SoC solutions give you ultimate design flexibility with unparalleled ease of use. The SoCKit is a Cyclone V-based SoC Linux development platform. It provides the easiest way to learn about and develop with Altera’s Cyclone V SoC family. The ARM-based hard processor system consists of hardened processor, peripherals, and memory interfaces, while the FPGA fabric provides infinite customization possibilities. The SoCKit board combines the SoC FPGA with a broad suite of additional peripherals, making the SoCKit board an excellent prototyping platform. All boards are available today at Arrow.com.

**Cyclone® V FPGA features:**
- ARM® Cortex™-A9 plus 28nm FPGA fabric on a single die
- Boot Linux
- Expandable though the industry-standard HSMC, such as the ARRADIO single-chip SDR platform
- DDR3 and Flash mass storage
- USB and Ethernet connectivity
- Audio and Video capable
- Graphic LCD: 128 x 64
- 3-Axis digital accelerometer and temp sensor

Click above to watch video
Using F-RAM® to Build Smart Airbag Automotive Applications

By Harsha Venkatesh

Ferroelectric-RAM (F-RAM) memory is used in a wide variety of applications, including industrial control systems, industrial automation, mission-critical space applications, and automotive systems. Safety systems for automobiles are expected to become more sophisticated over the next several years. A principal driver of this trend is expected regulation which will impact both the attach rate and the sophistication of airbags and stability control systems. This article looks at the key technological advantages of using F-RAM non-volatile memory technology in these systems.
Two major changes are occurring in “Airbag” systems. First, all new airbags have a smart sensor that detects the presence or non-presence of a passenger in the car. Every airbag that ejects incorrectly results in a costly replacement with associated maintenance, labor and parts costs associated. A smart sensor that keeps monitoring the weight and presence of the occupant can add a measure of “variability” to the force with which an airbag operates. This could both prevent airbag related injuries as well as help protect the passenger during severe crashes.

The second major advancement seen in the market is the need for collection of “actual information or data” just before an accident in an Event Data Recorder(EDR). This can be very valuable for future litigation / insurance claim related incidents. The EDR function is normally included in the airbag electronic control unit (ECU). This is a natural grouping because the EDR does not have the survivability requirements of an airplane “black box” and the airbag controller is the primary recipient of a variety of important sensor inputs. Vehicle makers are also quick to point out that there is no room for a stand-alone EDR.

These two requirements lead to the need for robust non-volatile memory that has a high endurance and fast access. In the case of a “smart” airbag, the designer wants to deploy the airbags with a variable force upon impact.

The requirement for the memory is to frequently log the actual seat position and the weight and presence / actual position of the occupant. In the case of maintaining the history leading up to the impact—the memory should have enough capacity to store the last 15–20 seconds of information in a rolling buffer. Since a normal car is designed to work for 30+ years, this memory needs to have a fast write time, instant non-volatility, and very high endurance.

F-RAM is a memory technology well suited to meet these requirements. Like other alternatives, it provides reliable nonvolatile storage. The main advantages of F-RAM are its very high write endurance and its write speed. With F-RAM, systems are able to continuously store data at full bus speed without the need for additional memory or overhead to manage the memory’s endurance with techniques such as wear-leveling. This is because F-RAM is instantly non-volatile, requiring no additional soak-time to store information. Its write endurance is also on the order of 10^{14}. Compare this to most EEPROMs and FLASH which have an endurance of less than 10^{6}.

Airbag Design
Due to the demand for safety and the high cost of replacement, manufacturers have added a variety of additional sensors to monitor and record the person sitting in the seat. These include a passenger occupancy pressure sensor, which is used to enable the airbag subsystem, along with a variety of position sensors to boost the effectiveness of the airbag system. Position data is constantly being updated and must be stored up to the point and even after the point of system deployment. The requirement to constantly log position data and store it in non-volatile memory makes high performance, low-power and high endurance F-RAM an ideal solution.

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>F-RAM</th>
<th>EEPROM</th>
<th>NOR Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI Speed</td>
<td>25 MHz</td>
<td>10 MHz</td>
<td>75 MHz</td>
</tr>
<tr>
<td>I2C Speed</td>
<td>3.4 MHz</td>
<td>1 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>Write Delay</td>
<td>0 ms</td>
<td>5 ms</td>
<td>10 ms</td>
</tr>
<tr>
<td>Write Endurance (Cycles)</td>
<td>1013</td>
<td>106</td>
<td>105</td>
</tr>
<tr>
<td>Lifetime @10-ms Write Frequency</td>
<td>3,171 years</td>
<td>2.78 hours</td>
<td>0.28 hours</td>
</tr>
<tr>
<td>Active Write Current</td>
<td>5 mA</td>
<td>6 mA</td>
<td>15 mA</td>
</tr>
<tr>
<td>Density Range (AEC-Q100 125C)</td>
<td>4Kb-2Mb</td>
<td>1Kb-1Mb</td>
<td>1Mb-256Mb</td>
</tr>
</tbody>
</table>

In the case of a “smart” airbag, the designer wants to deploy the airbags with a variable force upon impact. The requirement for the memory is to frequently log the actual seat positioning and the weight and presence / actual position of the occupant.
Advantages Over Floating Gate Technologies

As the complexity of automotive design requirements increases, the restrictive nature of floating gate memory technology becomes more apparent. For example, the programming process for floating gate-based memory takes several milliseconds, which is an inordinately long time for safety-critical applications. In the kind of fast power outage that occurs in a crash, little information could be stored successfully in a floating gate device.

The programming process is also destructive to the insulating layer and such devices consequently have limited write endurance of typically 100,000 to 1,000,000 writes. In an occupant sensor, for example, data is updated too often for this upper limit. Given a typical requirement to write data once per second, a floating gate device would wear out in less than twelve days of operation. Buffering the data in RAM and writing to a floating gate nonvolatile memory on power down introduces the speed problem that occurs in the EDR, and so is not a viable solution.

In smart airbag systems, while it is not only necessary to store data in the event of a crash, it is also desirable to store pre-crash data prior to an event. Using a rolling log to store pre-crash data is ideal, but this approach proves problematic for floating gate memory devices because of their limited endurance. Since airbag modules have large capacitors which store sufficient energy to fire the airbag, there may be sufficient residual energy to write the data from a buffer after the squib has fired. The amount of data that can be written is limited by the energy available, that is to say the residual energy in the capacitor and the speed with which the memory can be written. A typical 2K byte floating gate memory device can write approximately 4 bytes or 5 ms. To write an entire floating gate memory device, therefore, can take more than a second.

To write an entire floating gate memory device, therefore, can take more than a second.

A Nonvolatile Data Buffer

Because of its high write endurance, F-RAM can be used as a data buffer. The MCU can continuously log events in F-RAM directly during runtime. Since F-RAM is an intrinsic nonvolatile memory, it saves data after the power loss. Therefore, last moment data is never compromised even if the main power supply fails catastrophically. Since data is directly written in F-RAM, a last moment data transfer from SRAM to nonvolatile space such as EEPROM or Flash is not required. Use of F-RAM requires ‘zero’ system power backup for retaining last moment crash data.

Typical Block Diagram of Airbag-Systems

No Write Delays

Some events need to be recorded as often as 100 to 1000 times a second to capture every detail. However, this is a key challenge for existing EEPROM- and Flash-based recorders. EEPROM stores data on a page-by-page basis, and it requires a few milliseconds store time delay between two page writes into EEPROM. This limits data logging capability. ‘No Delay’ writes in F-RAM allow a system designer to capture and write real time data at the system bus speed.

Fast Writes and Low Power Consumption

High-speed serial SPI and I2C interfaces and/or high-speed parallel synchronous access in F-RAM enable a controller to write data in F-RAM in a less time due to the best in class speed specifications for nonvolatile writes. Low power F-RAM also requires only a fraction of the total power required by other nonvolatile memory technologies.
Data reliability of the EDR is important to attain the goals of accuracy, survivability, data retrieval, and most importantly, durability. Since this memory space is used for logging critical sensor data, high reliability and data integrity are a must for automotive applications.

Maturity
Technology maturity is a larger concern for the automotive market than for other types of applications. EEPROM and Flash technologies are well-understood, with established quality control infrastructures at major suppliers. The introduction of new technology naturally causes hesitation, as the technical community must become comfortable with its reliability and availability. With over 500 million units shipped in automotive environment (also in under-hood applications at extreme temperature grades of 125°C), F-RAM has matured to the point where automotive customers can feel comfortable and confident.

F-RAM can lower system cost, increase system efficiency, and reduce complexity while being significantly lower power than Flash, EEPROMs, battery-backed SRAMs, and other comparable technologies.
Considering the ARM® Architecture for Industrial PCs

By Wolfgang Heinz-Fischer,
International Business Development,
TQ-Group

For office use the standard is x86 technology, but what about for industrial applications? If you take into consideration factors of performance, power and temperature range, could other architectures be an alternative for industrial PCs?

An industrial PC (IPC) must satisfy different requirements when compared to an office computer. Depending on the application area, these requirements can differ greatly. Currently, 99% of all office computers are based on x86 technology, while an industrial PC is usually an x86 processor in a ruggedized format. This identity applies to most industrial PCs on the market with little thought given to whether this is correct.

However, if you consider the special requirements of an IPC, it pays to broaden your horizons. For instance, if the industrial PC only needs to handle high-speed data transfer and is used as a “headless” system, a completely different architecture from x86 may be the best solution.

In the telecommunications area, for example, the processors used are very often based on the Power Architecture from IBM or NXP. Why not implement an industrial PC using a QorIQ from NXP? If your goal is to have a system that has a substantially lower power dissipation at the same transfer rates and is available for at least 15 years, the QorIQ is certainly a viable alternative for telecom-specific industrial PC applications.

The ARM Architecture is more applicable to general industrial PC applications, so for this article, we will only compare ARM and x86.
The x86 and ARM

ARM processors today are very similar to an x86 processor in terms of functionality. Take graphics, for example: for Ethernet and USB, ARM processors offer a series of special functions and some advantages, especially in industrial applications.

The pros and cons of each architecture are very dependent on the user’s requirements. A substantial part of the system is the application software. If the application software is Windows-based, it is almost impossible to find a way around an x86 solution, because until now, systems other than x86 systems have only received lukewarm support from Windows. Additionally, an appropriate BSP (board support package) is needed, making it difficult to replace systems.

The typical application areas for an industrial PC include industrial automation, robotics, process control and visualization, test rigs for industry or safety engineering and quality assurance. The typical, industrial-like application is often a harsh environment with expanded temperature range requirements, and high amounts of dust and moisture. In addition, the devices are subjected to increased shock and vibration, for example, when used in a factory involving punch press machines.

Dealing with System Heat Dissipation

Protecting an industrial PC against dust and moisture can be accomplished using appropriate housing technology and the relevant protection classes. Here, the processor technology plays no role whatsoever. However, if a system needs to satisfy protection class IP65, (“Dust Tight”), another aspect must be considered. If the housing is sealed to satisfy this requirement, removing heat from the system is critical, and the less heat generated, the better.

This is where an ARM system earns considerably more points than a corresponding x86 system with comparable performance data. For example, a TQ embedded module with an NXP i.MX6Q quad-core processor consumes about four watts of power; while an Intel Atom E3825 ‘Bay Trail-I’ dual-core processor uses roughly five watts. Of course, it is possible to dissipate the heat of the system fans, heat pipes or designing the outside walls of the housing as heat sinks. However, this means higher costs and lower life cycle times for the device.

This can also lead to extra costs and a lower service life for an industrial PC using an x86 processor. The internal structure also plays a decisive role. SO-DIMM memory chips are used in most industrial PCs. While they offer Working in Extreme Temperature Range Conditions

In many cases, the use of an industrial PC places greater emphasis on the temperature range. It is possible to operate a standard system reliably in an environment of extreme temperatures if appropriate countermeasures are used, such as installing the computer in an air-conditioned cabinet.

Why not just use a system that can handle these requirements from the beginning? Intel is delivering processors that are designed for these extreme temperatures but this does not apply to all Intel processors. ARM processors, on the other hand, are usually designed to meet these extreme temperature requirements and have an advantage in this arena. Almost all NXP ARM processors can withstand temperatures from -40°C to +85°C. In contrast to this, only the Intel Atom E3800 (Bay Trail-I) is available with an extended temperature range; the off-the-shelf Intel Core 5000U (Broadwell-U) and the Intel Core 6000E (Skylake-H) processors can only be used at standard temperatures from 0°C to +60°C.

Handling Vibrations and Shocks

Industrial PCs are used in harsh environments, which means that the system is exposed to extreme mechanical shocks or vibrations. In this case, all connectors must be designed to be appropriately robust, a characteristic that applies to all systems regardless of the architecture. In addition to this, there should be no moving parts like fans or hard disks.

A Solid State Disk (SSD) is a good hard disk replacement for harsh environments. Not having a fan implies a suitably sophisticated passive cooling solution.

The typical, industrial-like application is often a harsh environment with expanded temperature range requirements, and high amounts of dust and moisture.
While ARM processors win points for long-term availability, industrial quality and energy efficiency, the x86 shows its strengths in performance, graphics and storage.

### ARM Architecture

**Must Haves**
- Temp -25°C+85°C (optional -40°C+85°C)
- Long-term Availability: 10 Years+
- High Data-Throughput
- High Operating Reliability

**Optionally Required**
- Small # Product Changes / Updates allowed
- IEEE1588
- Fieldbus applications
- Small form factor
- Graphics and CAN
- Wide availability of OS

### Intel (x86) Architecture

**Must Haves**
- CPU Performance
- High End Graphics
- I/O Flexibility and performance
- Memory
- Microsoft Windows

**Optionally Required**
- Security engine
- Big Cache
- Wide range of pin compatible modules

### Freescale (NXP) Power Architecture

**Must Haves**
- Full I-Temp -40°C+85°C
- Long-term Availability 10 Years+
- Highest Data-Throughput
- High Operating Reliability

**Optionally Required**
- Small # Product Changes / Updates allowed
- Security Engine
- IEEE1588
- Easy connection to FPGA
- Small form factor
- Graphics not required
- Microsoft Windows not required
Using ARM processors, you can realize considerably smaller systems with similar performance data.

**Requirements for Integrated interfaces**
Typical industrial interfaces such as CAN, Profibus, EtherCAT and serial interfaces are not readily available for an x86. A camera can be connected by way of USB or Ethernet/GbE. However, the camera must be equipped with the appropriate interface. But how do you connect a camera with a direct camera interface? And what about connecting an LCD, something that can easily be required for panel PCs or HMIs.

In many applications, the entire computer unit must be accommodated in an extremely small space, such as industrial PCs installed on DIN rails. Using ARM processors, you can realize considerably smaller systems with similar performance data.

**Assessing Long-term Availability**
Another requirement from the industry is the long-term availability of the system and keeping the system structurally identical over many years. Railroad applications, for example, set the requirement at 15 years. Industrial PC systems with an x86 processor, while often functionally identical over many years, are not structurally identical.

This means that a system change is necessary, something that in the final analysis translates into time and money. Identical ARM-based systems are available for a long time because of the long-term processor availability and assuming the system provider can assure appropriate long-term availability for all other components of the system.

**The System Question**
Every architecture has its own advantages and disadvantages. The arguments in favor of x86 solutions are high flexibility, easy system replacement, outstanding graphics performance and the wide range of products offered. In addition, the software available favors an x86 system.

An ARM system wins points with the low-power consumption, smaller dimensions, long-term availability and lower price points. For ARM Systems, however, the available software is a disadvantage. The ARM system always needs a special BSP and changing to a new system a more
ARM Vs. Intel—And the Winner is:
Freedom of choice. With so many factors to consider in the selection process, it pays to go with a supplier that carries all the options. Only TQ-Group offers embedded modules that support NXP® and TI ARM® Core-based Processors, Intel® i3/i5/i7 and Atom® Processors, and NXP QorIQ® Power Architecture. We call this “Design Freedom”, and you can experience it at www.embeddedmodules.net or by contacting Vaughn Orchard: (508) 209-0294 vaughn@convergencepromotions.com.

TQ Embedded Modules in this Article

TQMa6X Cortex®-A9 Embedded Module
The high-performance, energy-efficient multimedia module

TQmx50UC (Type 6) Mini-Module “Broadwell”
Intel Core i3/i5/i7
Industrial applications that need high bandwidth connections and multiple display interfaces

TQmxE38M (Type 10) Mini-Module “Bay Trail”
Intel Atom E3800
For rugged environments where low-power, extended temperatures and high speed communications are essential.

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A week ago or so, I had the opportunity to talk to Gagan Luthra, product marketing manager of PSoC and CapSense products at Cypress, about their new PSoC Analog Coprocessor. When I first heard about the development board they’d created for this coprocessor, I must confess my first thought was, “Yet another Arduino compatible dev board but with a PSoC this time” with almost a resigned sigh. My interest was somewhat piqued due to the great reputation of Cypress and their PSoC line, but I was unconvinced of the need to fill what seems to be an already overflowing market. However, delving into it more, I found that the Arduino shield compatibility was a red herring for me. The PSoC Analog Coprocessor is nothing like an Arduino R3, and in this case, that’s a good thing.
Between my conversation with Gagan, some more research, and my own, admittedly high level, tinkering, I found that the coprocessor was more than I anticipated, featuring the well-known flexibility of the PSoC as well as an analog front end that interfaces with the real world and provides filtered data input through integrated ADCs. The necessity of this front end and filter combo is growing rapidly in light of current technology trends such as IoT. Sensors are becoming significantly more prevalent in embedded systems and many of these sensors provide analog outputs. Something that I hadn’t noticed and Gagan pointed out to me, is that this coprocessor can accept any type of analog input and the development board showcases this by implementing a variety of sensors that interface with voltage, current, resistance, inductance, and capacitance outputs. So, it’s unlikely that you’ll find a sensor that you can’t interface with this thing.

The PSoC analog coprocessor is integrated with an ARM Cortex M0+ processor to provide a logic backbone to the digital data coming from the ADCs and out through the DACs. An M0+ processor is efficient but not a real number-crunching powerhouse, so for applications that want GUI touchscreen interfaces or something equally intensive, this will obviously be working in conjunction with a larger host microcontroller. Which, these are cheap enough that it’s okay—while the price changes depending on the one you get, the distributor, and the quantity, these currently start at $1.45, and increase to $2.93 for the current offerings. While many people may want to integrate this with a larger microcontroller, as I tend to work on smaller, low power devices, I personally find the M0+ more than capable to act independently.

For those that aren’t as familiar with Cypress’ PSoC line, there are a couple of other items that I think are extremely important to consider. The PSoC Creator, their name for their PSoC IDE, is completely free for all users, amateur or professional, as well as their compilers. No code size limitations, no compiling efficiency limitations, no time limitations—free. I think this is a very good move for Cypress, something that other manufacturers slowly seem to be agreeing with. For a $50 development board, you can get the full PSoC experience, which makes it an easy entry for new engineers, makers, and even a tantalizing temptation for professionals already entrenched in another platform.

For a $50 development board, you can get the full PSoC experience, which makes it an easy entry for new engineers, makers, and even a tantalizing temptation for professionals already entrenched in another platform.

Both in my explorations and while I was chatting with Gagan, I realized that these sorts of decisions always come down to what we need and what works for us both financially and in terms of engineering time. For me, the fact that an input can be configured to read thermocouples would eliminate a separate IC in a personal project—an IC that costs more than the analog coprocessor. So it almost immediately makes financial sense for me to consider shifting all of my analog pre-processing and logic over to this. So, is this going to be the perfect fit for your next project? I don’t know, but I will say, it would definitely be worth your time to check it out.

To learn more about Cypress’ new PSoC Analog Coprocessor, click [here](#).
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Precision Drives
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A New Generation of Prosthetics

Rehabilitation Robotics and a new generation of smooth, silent drives are helping the physically challenged walk and run effortlessly.

In 2000, Archeologists in Cairo, Egypt, unearthed the 3,000-year-old mummy of an Egyptian noblewoman with the oldest documented artificial body part—a prosthetic toe made of wood and leather. For the better part of three millennia, prosthetic limbs have changed little throughout history—until recently. New medical and technological advances in the field of robotic assistive prosthetics, called “Rehabilitation Robotics” will forever change the lives of millions of physically impaired people.

By Michael ImObersteg
Convergence Promotions Robotic Drives Division
Synopsis
Worldwide, 3-4 million people are living today with debilitating limb loss. In the United States alone, there are 4.7 million people who would benefit from an active lower limb orthosis due to the effects of stroke, polio, multiple sclerosis, spinal cord injury and cerebral palsy. Recent innovations in a new field called Rehabilitation Robotics are helping people all over the world overcome their disabilities. Rehabilitation Robotics is a field dedicated to understanding and augmenting rehabilitation through the application of robotic devices. This article will illustrate how a mechanical element of the robotics, a break-through motor designed for this type of application, is helping to revolutionize the prosthetic limb.

Rehabilitation Robotics
Robotic assistive prosthetics and exoskeleton technologies (originally funded by DARPA to help soldiers stretch their battlefield endurance and carry heavy loads) have undergone revolutionary changes in recent years. This evolution is has resulted in bringing complete mobility and rehabilitation to patients who were otherwise immobile. New technologies have allowed for material weight reduction, and versatile humanoid movement—the result of embedded intelligent systems with Microprocessor Controlled Prosthetics (MPCs), with sensors that operate the robotic devices with motions similar to able-bodied humans. To assist in this program, Convergence Promotions has been working with a half-dozen of the US’s leading Universities and research centers on their flagship program, the Rehabilitation Robotics Initiative.

RoboDrive—a new lightweight, precision, high-torque solution for Robotics
Challenges faced by the robotic community in the field of prosthetics are seen in other physical human-robot interaction (PHRI) and include power, size, weight, and safety. Also, motors that drive prosthetics have to be smooth, silent and precise. Until now, the motors available to robotic developers are re-purposed motors for industrial and other applications. These motors are too large, too heavy, and lack the precision required to design into new-age prosthetics. The following chart shows a comparison between the standard motors available on the market and RoboDrive technology developed by TQ-Group in Germany specifically for the new generation of collaborative robotics.

A comparison of TQ’s RoboDrive motors with the best commercially available motors show TQ’s RoboDrive motors provide the same torque at half the size and weight, dissipating only half of the losses (performance curve on the left).

Developed by the German Aerospace Center for the Russian Space Station
The Institute of Robotics and Mechatronics of the German Aerospace Centre (DLR) developed Robodrive technology to guide a robotic arm outside the Russian space station. After six years of uninterrupted service, the motor was returned to earth, still in perfect working condition. This technology was made commercially available by TQ for applications requiring the ultimate in high-precision and high-torque motors. Manfred Schedl, the engineering director at TQ RoboDrive and inventor of the motor, joined the German engineering and manufacturing company, TQ Systems, in 2006 and manufacturing of RoboDrive started soon thereafter.
A New Paradigm in Precision and Power

Prosthetic designers can control RoboDrive motors to stop at up to 6.3 million increments for extreme positioning accuracy in position control leg movement, providing a quick, smooth, continuous operation or gait, and the incredible torque produces power to spare. Since one of the goals of prosthetic design is to closely resemble a human leg, it is essential to keep the mechanics as compact as possible (the Rotor and Stator of the smallest TQ RoboDrive is an incredibly tiny 25m). TQ Group has designed these motors with a hollow shaft so that wires, fluids, and other media can pass through the inside of the motor. By eliminating bulky outside wire or cable routing, this feature helps designers reach their goal of casting a natural outward appearance of a real leg.

Dr. Robert Gregg, a University of Texas at Dallas professor and faculty member in the Erik Jonsson School of Engineering and Computer Sciences, applied his knowledge in robot control theory to powered prosthetics, enabling these prosthetics to respond dynamically to the wearer’s environment and help amputees walk. His research team has shown that wearers of the robotic leg could walk on a moving treadmill almost as fast as an able-bodied person.

“Our approach resulted in a method for controlling powered prostheses for amputees to help them move in a more stable, natural way than current prostheses.”

Humanoid robots can mimic the actions of humans, but modern prosthetics current cannot. While prosthetics have made strides toward becoming lighter and more flexible, they fall short in their ability to mimic human muscle movement in able-bodied individuals. Powered prostheses, or robotic legs, have historically had their pitfalls as well because they lack the intelligence to respond to disturbances or changes in terrain.

UT Dallas Designs a Prosthetic Leg that Closely Replicates the Human Gait

“Post designs didn’t use Robodrive motors, but our next generation leg will. The old leg has a very large gear reduction (200+), whereas the Robodrive motors will allow a gear reduction around 22:1 for better backdrivability and torque control.”

Control engineers view the human gait cycle through the intervals where each movement needs to occur. Gregg, an assistant professor of bioengineering and mechanical engineering, proposed they study the process of walking by measuring a single variable to represent the motion of the body as a whole. For this study, the variable chosen was the center of pressure on the foot, which moves from heel to toe as a person walks.

“The gait cycle is a complicated phenomenon with lots of joints and muscles working together,” Gregg said. “We used advanced mathematical theorems to simplify the entire gait cycle down to one variable. If you measure that variable, you know exactly where you are in the gait cycle and exactly what you should be doing. We did not tell the prosthesis that the treadmill speed was increasing. The prosthesis responded naturally just as the biological leg would do.”

The next step in the research, according to Gregg, will include comparing results of the experiments with robotic legs, using both the time paradigm and center-of-pressure paradigm.

FOOTNOTES

Researchers from the Rehabilitation Institute of Chicago, Northwestern University and the University of New Brunswick were also involved in the study. The work was funded by the United States Army Medical Research Acquisition Activity, the Burroughs Wellcome Fund and the National Institutes of Health through the National Institute of Child Health and Human Development.

“Backdrivability is essential for safe robotic-arm and leg operation around people; operating in unstructured environments; for stable control of contact forces, etc. Non-back-drivability has its place when safety and stable control of Cartesian forces are less consequential (e.g. low-force grippers or graspers). For the most part, grippers and graspers spend their time stationary, either open or locked onto a target object, and non-backdrivability allows the motors to be de-energized during these periods.

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INGENIOUS - The University of Texas at Dallas. (n.d.). Retrieved from https://utdallas.edu/ingenious/legs/

Photo courtesy of UT Dallas
Summary
The future goal of prosthetics and exoskeletons is to provide relief for more than just people suffering from limb loss—the elderly will benefit as well. Today, almost 20% of the world population is over 65, and this figure is predicted to exceed 35% by 2050. This demographic shift will impose an enormous burden of care required to treat the elderly, and robotic solutions will enable them to regain their independence and maintain an enriching, fulfilling lifestyle. In the future, the ability to replace entire limbs with prosthetics will be used everywhere. Not only will these prosthetics be a replication of the wearer’s biological functions, but they will also cast a natural outward appearance and require minimal upkeep. To accomplish these future goals, new technology including motors, sensors, microprocessors, actuators, drivers and the HMI interface have to be continuously developed and improved. Continuing the progress of prosthetic technology calls for funding from organizations willing to provide resources, and Convergence Promotions is helping to lead the movement to accelerate the prosthetic of the future.

The Rehabilitation Robotics Initiative
Led by Michael ImObersteg and Convergence Promotions, the goal of this initiative is to provide motors, documentation, and engineering support to research institutions, companies, and universities developing robotic prosthetics. We are currently working with half a dozen Universities on this program, and we expect the participation to expand rapidly in 2017 as the interest in providing robotic prosthetics and exoskeletons grows.

Contact Michael at (925) 640-7042, or michael@convergencepromotions.com.

For more information on RoboDrive: www.roboticdrives.com

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The RoboDrive technology provides the highest power density at maximum torque range and overload capability in a compact design. The variable concept offers solutions for a variety of demanding drive applications. Alternative voltage levels, increased speeds, and customized torque adaptations are also available on special order.

- RoboDrive motors are available in a variety of sizes, from small (25mm) to large (115mm)
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- Designers can select from solid or hollow shaft models.
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