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JAN/FEB 2016

Embedded Wi-Fi® Is Easy

With Microchip's Low-Power, Surface Mount Modules

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contents

The Right Timing

If microcontrollers are the brains of a system, then clocks provide the heartbeat. With the acquisition of Micrel's Timing and Communications Group (TCG), we now deliver great synergies for embedded control, linking our microcontroller and analog semiconductor business with advanced clocking solutions. The addition of this new selection of highly integrated, flexible and easy-to-use oscillators, clocks and clock distribution products rounds out Microchip's overall product portfolio to meet many of your development needs.

We offer both low-jitter and low-power **oscillators** for frequency generation, integrate them with Phase Lock Loops (PLLs) to create multiple-frequency **clock generator devices**, and include buffers to realize single-chip generators for multiple-frequency clock trees. This replaces traditional solutions that use many separate quartz crystals and oscillators with just one or two of our clock products. We also provide Microelectromechanical Systems (MEMS) resonators to replace traditional quartz resenators. This enables the only single-package clock generators not requiring external crystals currently available on the market. These extremely reliable MEMS-based clocks, which are identified by a "DSC" prefix in their part numbers, can operate over wide temperature ranges and maintain a high frequency stability up to 10 ppm, making them ideal for industrial and automotive applications. Other products include easy-to-use, low-power and very-small-size Pico-PLL clock generators, such as the PL611s (2.0 × 1.3 mm DFN package) and the PL613 with eight outputs and three PLLs. Our broad SY series of **clock and data distribution** products, including translators, multiplexers and buffers (with and without zero-delay), are differentiated by ultra-low additive jitter and "Any-In" internal termination that simplifies interfacing to any differential signal, reducing components and jitter.

Our clock generators and oscillators are programmable and flexible. Simply create an account on our **Clockworks Configurator** site. You can then design and order samples of your customized parts. The FLEX2, for example, drives up to 12 buffered outputs with exceptionally low jitter, suitable for high-speed networking applications. Visit **www.microchip.com** to find the right clock or timing match for your microcontroller-based designs.

As always, we would be happy to get your feedback on MicroSolutions. Feel free to email us at **MSFeedback@microchip.com**.

Microchip Technology Inc.
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Embedded Wi-Fi® Is Easy

After the Hard Design Choices Are Made, Microchip's Low-Power Embedded Wi-Fi Solutions Ease Your Wireless Implementation

Surface-Mount Modules Offer Small Form Factor, Rich Features and Ultra-Low Power for Today's Applications

Enable Long-Range Connectivity, Longer Battery Life and Lower Costs

Excited by the potential of the Internet of Things (IoT), developers are leveraging advances in low-power, low-cost processing and connectivity to wirelessly enable their systems at an accelerating rate. Originally drawn by the need to connect what were once standalone boxes for industrial control sensing, home automation and medical applications, developers are now connecting everything from remote sensors to light bulbs and fitness devices.

While wireless may well be the best—if not the only—option in many cases, the decision to go wireless should not be taken lightly, given the nuances of RF in terms of system layout, software stack development, device security, connection reliability and determinism, signal interference and degradation, and FCC certification.

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Fortunately, there are vendors with many years of wireless connectivity design and implementation experience that are willing and able to work with developers and innovators to make the integration of wireless a relatively trouble-free, seamless process. That network of support, fueled by consumer demand to be "wire free" has helped drive overall shipments of low-power wireless (LPW) ICs from 1.16 billion in 2012 to over 1.4 billion in 2014, with an increase to over 2.7 billion ICs anticipated in 2018, according to industry research firm, IHS.

Going Wireless: Now What?

After committing to going wireless for your design, there are many more decisions to be made, starting with the type of air interface and whether to go with an IC or a module. The answer to the former depends primarily upon your application's requirements in terms of data rate, range, power constraints and whether or not ubiquitous and seamless connection accessibility and availability is needed.

For example, if point-to-point communication, low power and relatively low data rates are requirements, then Bluetooth® or a proprietary low-cost, sub-GHz interface may be fine. If low data rates, low power, as well as mesh networking and high security are mandates, then ZigBee® is a good choice, though you may also pick from proprietary mesh network options such as Microchip's MiWi™ wireless networking protocol.

However, for ubiquitous connectivity with an industry-standard interface, built-in IP addressability, and the ability to scale data rates over a wide range depending on the application, then the design choices narrow quickly to a form of Wi-Fi.

Simple to use and deploy, Wi-Fi is also simply called "wireless Ethernet"; once you get past the physical layer it's essentially the same as Ethernet, hence the ubiquitous connectivity. It's also a shared medium, so as users climb on board, your design needs to be not real-time dependent or at least able to switch channels. One significant advantage is that more access points are readily available as Wi-Fi continues to proliferate. Also, Wi-Fi has built-in IP, so it was literally built for the IoT. While mesh protocols and direct IP addressability will eventually be available as the respective standards bodies work out the wrinkles, for now Wi-Fi is a good option.

Of course, there are variations of Wi-Fi, including center frequencies of 2.45 and 5 GHz, as well as new work on a 60 GHz standard. For longer range and higher data rates, multiple antennas (SISO to MIMO) can be used in various configurations as in 802.11n, and a variety of security levels is available.

However, for an embedded system dependent on batteries, or a system with generally low-data-rate requirements, it's best to keep it simple and reliable with a relatively basic modulation scheme and optimum air and wall permeability to maximize range for a given power level. These criteria rule out 5 GHz (802.11a), 60 GHz and multiple antenna schemes. The choice quickly narrows down to IEEE 802.11b/g operating at 2.45 GHz. This interface is optimized for low power, permeability and data-rate scalability.

With respect to the IC or module, much depends upon your team's own internal RF design and layout skills, as well as your time to market, volume and cost. This is where the choice of vendor becomes really critical. If you have good in-house RF expertise, your volumes are in the 100K range or below to begin with, your form factor is fairly loose and your time-to-market window is tight, then it's usually wise to opt for a module. Also, modules give you the option of using cutting-edge wireless technology on a consistent basis by simply swapping them out and replacing them with newer versions.

Assuming all goes well, the odds are high that your design and the wireless standard of choice will gel over time, volumes will increase, and you will refine the form factor. At this point a chip-on-board IC-based design modification may be required.

However, if the wireless module vendor upon whom you now rely can't support your choice with an IC that is compatible with the software you've developed and the development environment you're used to, then you may lose time and money ramping up new RF interface, processor and I/O options, while losing any intellectual property and experience gathered during development on the original platform.

Assuming your vendor can support your migration to an IC-on-board, then a module is an excellent choice for initial prototyping and design. It enables you to avoid going through the FCC certification process and will likely come fully loaded with a development kit and associated software.

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Software Stack: On or Off Module?

When you decide to go with a module, many factors other than the vendor selection come into play such as cost, availability, volume, size, and interfacing. The choice of vendor matters not just for software portability and the supply of ready-to-use application software and kits, but also the availability of dedicated support if you have a particularly thorny problem, such as antenna placement.

These are all serious points that will influence your choice of which module to use, but another decision needs to be made. You need to determine if a module with the software stack on board or a module that incorporates the software stack on an external controller—typically a microcontroller (MCU)—is the best option for your design.

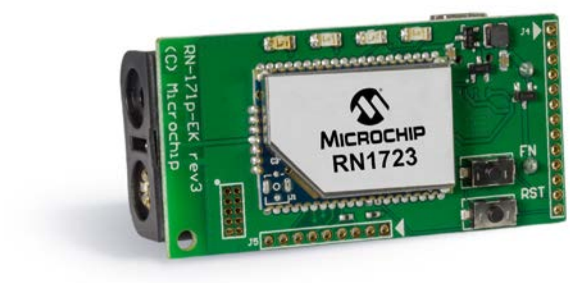
The distinction between the two options is clearly shown in our fully-certified **RN and MRF families of Wi-Fi modules**. These modules offer a small form factor, rich features and ultra-low power, making them perfect for a wide range of wireless applications.

The RN1810 and MRF24WN0MA Wi-Fi® PICtail™/PICtail Plus Daughter Boards allow you to easily develop Wi-Fi applications using PIC® microcontrollers.

The RN series of Wi-Fi 802.11b/g/n modules is designed for the simplest user implementation where the stack is the Wi-Fi module itself. To the system and the designer, the module appears simply as a “wireless serial cable”. This not only makes for an extremely fast design cycle, but also frees up your system’s MCU to run your application, which is most likely your key differentiator anyway. Also, the external MCU can be any size: 4-, 8-, 16 or 32-bit.

In the case of the MRF series of modules, the majority of the stack and the application are hosted on an external PIC® MCU. While this option is more complex for a designer, it does provide flexibility by giving greater access to the stack if needed. This arrangement does require a PIC MCU from either our 16- or 32-bit families.

To help you get started with either series of Wi-Fi modules, visit the **Embedded Wi-Fi page** on the Microchip website, where you’ll find a number of valuable resources to assist with your design-in process. Several easy-to-use evaluation kits are also available. For example, the compact, USB-powered **RN1810 Wi-Fi PICtail™/PICtail Plus Daughter Board (RN-1810-PICTAIL)** and **RN1723 Evaluation Kit (RN-1723-EK)** are ideal for customer demos and for evaluating the RN1810 and RN1723 modules. The **MRF24WN0MA Wi-Fi PICtail/PICtail Plus Daughter Board (AC164153)** enables you to evaluate Wi-Fi connectivity with PIC MCUs on several compatible development boards that are also available from Microchip.



Compact and USB-powered, the RN-1723-EK can be used to quickly add Wi-Fi® connectivity to embedded applications.

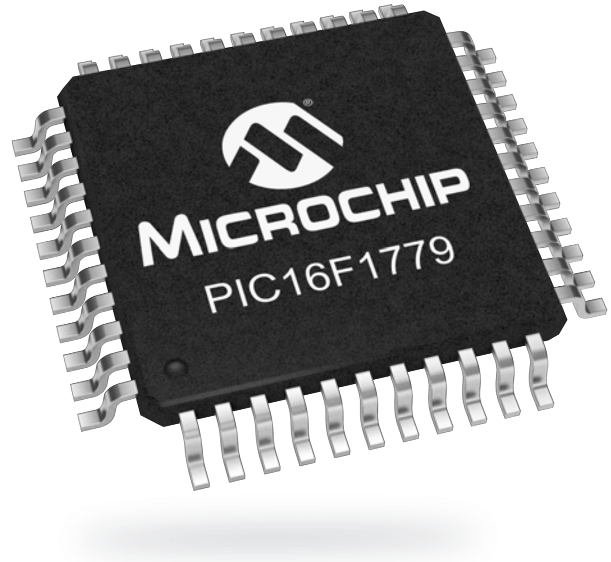
The RN and MRF series of modules and their supporting development tools can be purchased from **microchipDIRECT** or from **Microchip’s worldwide distribution network**.

Smart and Responsive

PIC16F1779 Family Features High Level of Integration of Intelligent Analog and Digital Peripherals for Demanding Power Conversion Applications

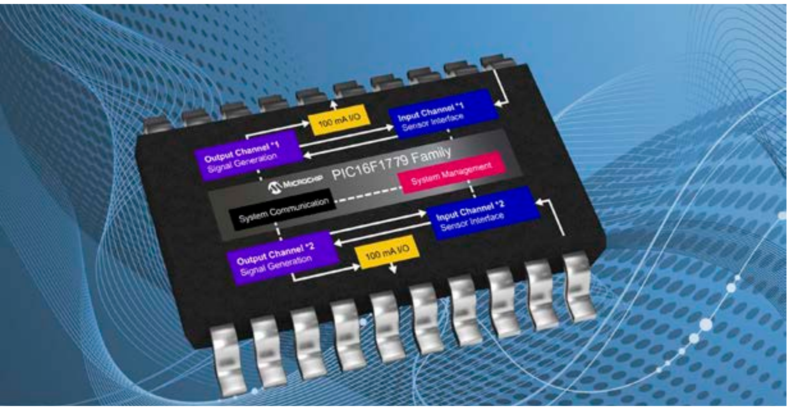
NEW PRODUCTS

Enables LED Dimming Engine Control and Multiple Independent Closed-Loop Power Supply Channels



If you are developing a highly integrated, low-wattage power conversion application, take a look at our new **PIC16(L)F1779** microcontroller (MCU) family. These devices were designed to support these demanding applications by offering multiple independent closed-loop power channels and system management capabilities, while providing an 8-bit platform that simplifies design and helps reduce the number of discrete components in power conversion systems. They include a Programmable Ramp Generator (PRG) peripheral that eliminates the CPU processing related to slope and ramp compensation, improving output stability and system efficiency.

The PIC16F1779 family enables you to interconnect the on-chip peripherals to create custom functions specific to your application. Some of these peripherals are highlighted here:



On-chip peripherals can be interconnected to create custom functions specific to your application.

Intelligent Analog

Intelligent Analog peripherals help to significantly reduce BOM cost, PCB size and system noise. On-chip op amps, high-speed comparators and Analog-to-Digital Converter (ADC) peripherals allow you to lower the component count in your analog signal chain.

Op Amps

General purpose op amps provide internal and external signal conditioning with tri-state operation.

Programmable Ramp Generation (PRG)

The Programmable Ramp Generator (PRG) automates slope and ramp compensation and increases stability and efficiencies in hybrid power conversion applications. The PRG provides real-time, down-to-the-nanosecond, responses to a system change, without CPU interaction, for multiple independent power channels.

10- and 16-bit Pulse-Width Modulation (PWM)

On-chip PWMs offer high resolution with independent time bases to help simplify drive control.

Complementary Output Generator (COG)

This automated complementary output controls key parameters such as programmable rising/falling edge events, polarity, phase, precision dead-band, blanking and auto shut-down.

High-Current Drive I/Os

The 100 mA I/Os help eliminate the need for a MOSFET driver, reducing system BOM cost.

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Zero Cross Detect (ZCD)

Ideal for AC dimming control, ZCD simplifies TRIAC control by providing the ability to measure AC periods and by eliminating the need for additional external components.

Configurable Logic Cell (CLC)

The CLC integrates hardware functions and increases on-chip interconnections of peripherals and I/Os, saving board space and program code.

Communications

Support for SPI, I²C, LIN, DALI, and DMX, as well as for Bluetooth® LE, LoRa® and other protocols via external modules.

Hardware Limit Timers (HLTs)

The HLTs can detect faults in motor, power supplies and other external devices. It can automatically notify the system to make provisions to shut down and/or safely restart. These modes are available in standard 8-bit timer/counters.

The 10-/16-bit PWMs, Digital Signal Modulator and op amp can be combined to create an LED dimming engine that synchronizes switching control and faster turn off, thus eliminating LED current overshoot and decay. This synchronization of the output switching helps smooth visible dimming, minimizes color shift and reduces heat, which increases LED life.

The PIC16F1779 family of eXtreme Low Power (XLP) MCUs includes nine devices, available in pin counts ranging from 14 to 40 pins and program memory sizes up to 28 KB. They can be used to meet the requirements of a wide range of general purpose and other applications, including lighting, power supplies, battery charging and motor control.

Development Support

This family of 8-bit MCUs provides an easy and low-cost development solution, from code creation to integration into your end application. It is supported by Microchip's standard set of development tools, including the **PICkit™ 3 In-Circuit Debugger** (PG164130), the **PICDEM™ Lab Development Kit** (DM163045) and the **PICkit 3 Low Pin Count Demonstration Board** (DM164130-9). For code development, **MPLAB® Code Configurator**, a plug-in for our free **MPLAB X Integrated Development Environment** (IDE), provides a graphical method to configure 8-bit systems and peripheral features. Devices from the PIC16F1779 family are available now for sampling and volume production from **microchipDIRECT** or from **Microchip's worldwide distribution network**.

All Set

Low-Power Digital-to-Analog Converters Retain Settings without Power via Integrated EEPROM

8-/10-/12-bit, Single- and Dual-Channel MCP48FXBXX Families Include SPI Serial Interface

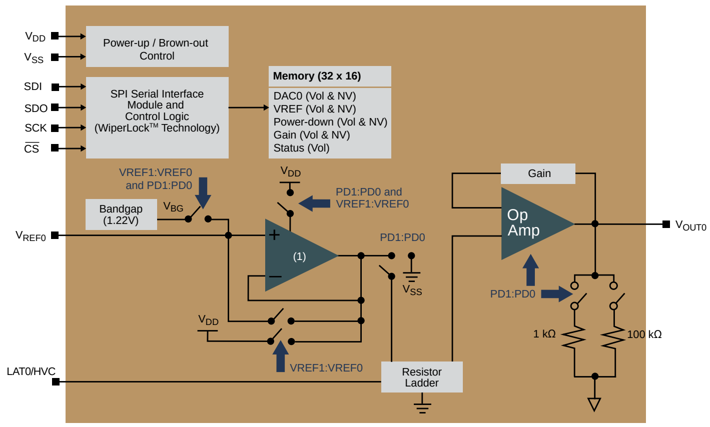
Offering high integration and unique feature sets, the MCP48FXBXX families are the latest devices to be added to our Digital-to-Analog Converter (DAC) product line. While they are ideal for portable, consumer and handheld designs that demand low power consumption, these DACs are also specified to operate in extended-temperature conditions, making them suitable for many industrial and automotive requirements. They can be used for a wide range of applications including set-point/offset trimming, sensor calibration, instrumentation, and motor control.

These low-power, single- and dual-channel DACs feature 8-, 10- and 12-bit resolution and an SPI serial interface. The six-member **MCP48FEBXX** DAC family offers an integrated EEPROM. This option enables DAC settings to be saved at power-down and restored at power-up, reducing microcontroller overhead. The **MCP48FVBXX** family provides lower-cost alternatives for applications that don't require integrated memory.

The MCP48FXBXX low-power, single- and dual-channel DACs support a wide range of applications.

These DACs deliver flexibility as well as power and cost savings.

These DACs deliver flexibility as well as power and cost savings while simplifying your design efforts. The various shutdown modes significantly reduce the device current consumption for power-critical applications. Additionally, these devices feature low Differential Nonlinearity (DNL) error to sustain monotonic output and low Integral Nonlinearity (INL) error for better linearity.



Offered in 10-pin MSOP packages, the MCP48FXBXX DAC families are available now for sampling and volume production from **microchipDIRECT** or from **Microchip's worldwide distribution network.**

Monitoring Multiple Loads

New Power Monitoring IC Provides Highly Accurate Real-Time Power Monitoring in Power-Hungry Designs

Highly Integrated Advanced Features Facilitate System Design and Reduce System Cost of Industrial, Commercial and Consumer Applications

Improving energy usage and monitoring product performance in power-hungry appliances, machinery and systems is an ongoing, industry-wide challenge. Developers of these types of applications need a power-monitoring solution that delivers accuracy, design simplicity and lower costs. As a recent addition to our existing portfolio of power-monitoring ICs, the **MCP39F511N** dual-channel power-monitoring IC facilitates design by reducing firmware development time and the number of ICs required for power monitoring of multiple loads.

The MCP39F511N is capable of providing popular standard power calculations and event monitoring of two electrical loads. This highly integrated and accurate device simplifies your system design and reduces system cost of power-monitoring wall outlets and smart plugs, power strips, AC/DC power supplies and power distribution applications. It includes three Analog-to-Digital Converters (ADCs) for voltage and two current load measurements, a 16-bit calculation engine, EEPROM and a flexible 2-wire interface.

This highly integrated and accurate device simplifies system design.

An integrated low-drift voltage reference, in addition to the 94.5 dB of SINAD performance on each current measurement channel, allows the MCP39F511N to monitor two current loads with just 0.5% error across a wide 4000:1 dynamic range. The ability to measure active, reactive and apparent power, active and reactive energy accumulation, RMS current and RMS voltage, line frequency, and power factor, combined with the MPC32F511N's advanced, integrated features, enables you to reduce your bill of materials and speed your time to market when designing high-performance devices.

The MCP39F511N Power Monitor Demonstration Board is a fully functional, dual-channel, single-phase power and energy monitoring system.

Development Support

The MCP39F511N is supported by the **MCP39F511N Power Monitor Demonstration Board** (ADM00706), which is a fully functional, dual-channel, single-phase power and energy monitoring system.

The MCP39F511N comes in a 28-lead, 5 × 5 mm QFN package and is available now for sampling and volume production from **microchipDIRECT** or from **Microchip's worldwide distribution network**.

A New Paradigm

Award-winning MPLAB® XC PRO Compilers Now Available in Low-cost, Renewable Monthly Subscription License

You Can Now License Compiling Optimizations on an As-Needed Basis

For many years, embedded systems engineers have turned to our integrated tool chain of compatible compilers and debugger/programmers that operate seamlessly within the universal, cross-platform and open-source MPLAB X Integrated Development Environment (IDE) to reduce both their learning curves and tool investments. Our award-winning MPLAB XC line of C compilers offers reduced complexity and provides the best execution speed and code size for all ~1,400 PIC® microcontrollers (MCUs) and dsPIC® Digital Signal Controllers (DSCs), and are available with three optimization levels—Free, Standard and PRO. They support the Linux®, Mac OS® and Windows® operating systems, enabling designers to use their platform of choice for embedded development.

January 2016 marked the release of the first-ever subscription licensing model for an embedded system compiler. The subscription license is available for the PRO editions all MPLAB XC compiler types, including XC8, XC16 and XC32++ (which supports both C and C++ languages). This licensing model will give you increased flexibility during your design cycle by offering a PRO-level compiler license that can be accessed on an as-needed basis. As a subscriber, you will also be able to receive updated versions of the MPLAB XC compiler type you are subscribed to without the need for an active Microchip MPLAB XC High Priority Access (HPA) maintenance subscription. Rather than being cloud-based, the license is installed on your workstation, giving you the additional flexibility of offline access.

This licensing model will give you increased flexibility during your design cycle.

The subscription license is $29.95 per month, per license type. Only one user is authorized per license. Subscriptions can be cancelled and renewed at will through your mySoftware account—which is accessible inside MPLAB X IDE or available on **www.microchip.com**—or left to automatically renew each month. The automatic renewal feature requires an Internet connection and MPLAB X IDE version 3.15 and later. To take advantage of the freedom to use PRO-level compiling when you need it, visit the **MPLAB XC Compilers page** on our website.

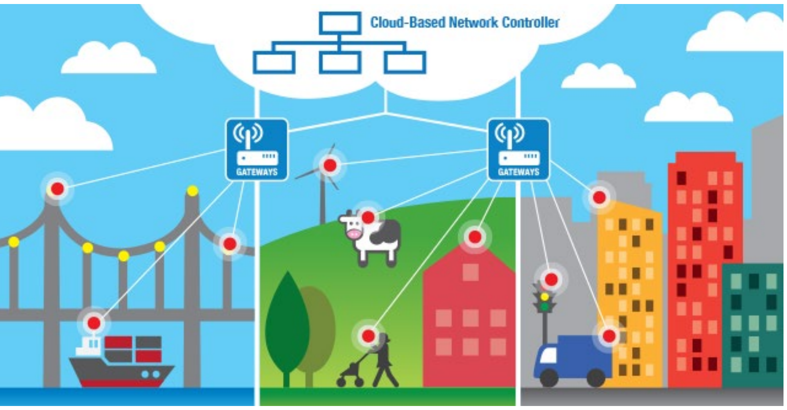
Passing the Test

Microchip's LoRa® Wireless Module is World's First to Pass LoRa Alliance Certification; Ensures Interoperation of Long-Range, Low-Power IoT Networks

Stack-on-Board RN2483 Named Golden-Unit Reference Module for All Future Certifications

The cover story for the **November/December issue of MicroSolutions** featured the wireless, long-range and low-power LoRa® technology and Microchip's LoRa technology solutions. Shortly after that issue was published, we were pleased to learn that our **RN2483 LoRa module** is the world's first to pass the LoRa Alliance's LoRaWAN™ Certification Program.

The LoRaWAN standard enables low-data-rate Internet of Things (IoT) and Machine-to-Machine (M2M) wireless communication with a range of up to 15 kilometers, a battery life of 10 years, and the ability to connect millions of wireless sensor nodes to LoRaWAN gateways. The launch of an accredited certification program is a key step toward the LoRa Alliance's mission to standardize an open specification for secure, carrier-grade, low-power wide area networks (LPWAN). This Certification Program will provide assurance to end customers that their application-specific end devices will operate on any LoRaWAN network, which is a crucial requirement for the global deployment of the IoT using LPWANs.



The LoRaWAN™ network protocol helps to enable Internet of Things (IoT), Machine-to-Machine (M2M), smart city and industrial applications.

The RN2483 module was independently tested by Espotel's accredited test laboratory to meet the functional requirements of the latest LoRaWAN 1.0 protocol specification, for operation in the 868 MHz license-free band. This ensures that designers can quickly and easily integrate their end devices into any LoRaWAN network. The RN2483 module will further be used as the benchmark product by Espotel when further developing the LoRaWAN certification, interoperability and performance testing in their test and research laboratory.

The RN2483 module was independently tested by Espotel's accredited test laboratory.

Before the certification program was launched, Microchip's LoRa development team had performed extensive verification and interoperability tests with all of the major LoRaWAN network infrastructure vendors, so the RN2483 was already considered to be the golden unit within the LoRaWAN ecosystem. Peter Kaae Thomsen, CTO of the leading LoRa Core Network provider OrbiWise, confirmed that the RN2483 module has already been adopted as the reference device used for testing their UbiQ Network Solution.

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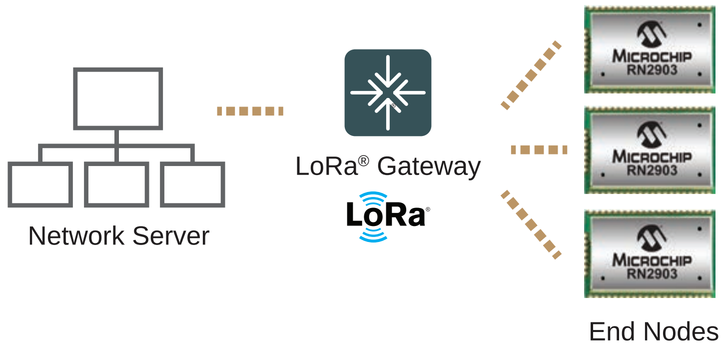
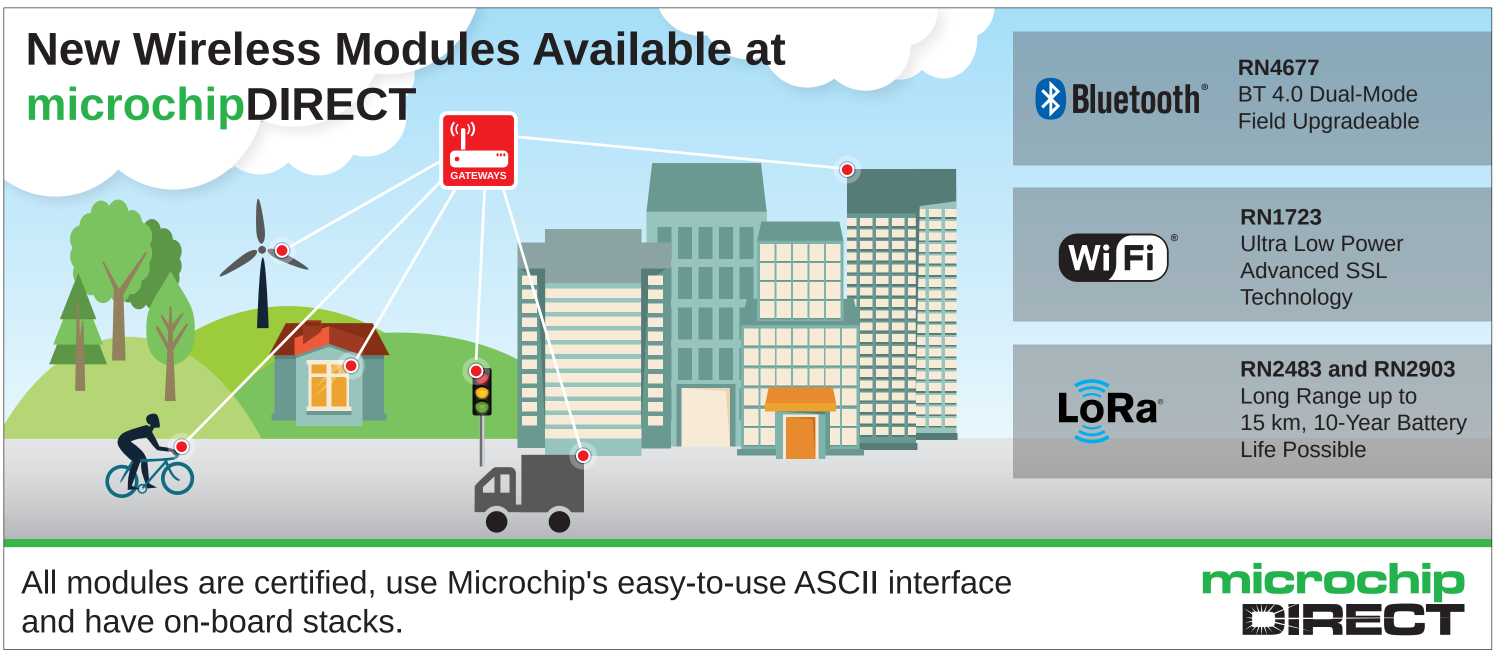
The RN2483 module comes with the LoRaWAN protocol stack, so it can easily connect with the established and rapidly expanding LoRa Alliance infrastructure—including both privately managed local area networks (LANs) and telecom-operated public networks—to create LPWANs with nationwide coverage. This stack integration also enables the module to be used with any microcontroller (MCU) that has a UART interface, including hundreds of our PIC® MCUs. Additionally, the RN2483 features Microchip's simple ASCII command interface for easy configuration and control.

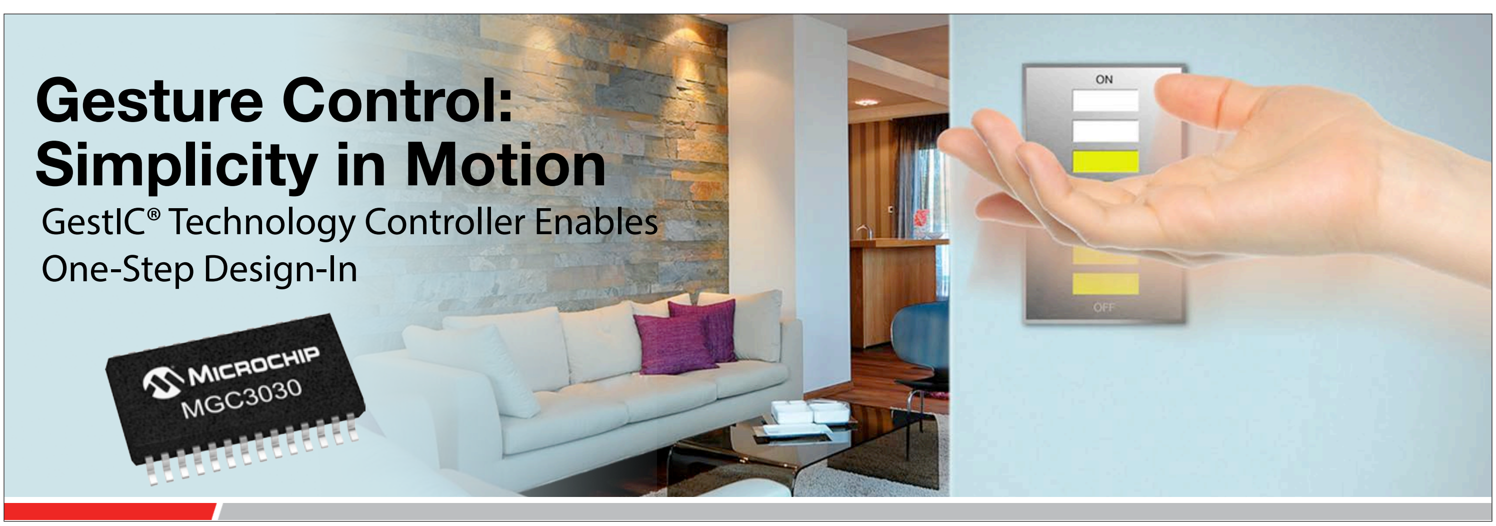
The RN2483 module resolves the wireless developer's age-old dilemma of choosing between longer range and lower power consumption. LoRa technology enables you to maximize both, while reducing the cost of additional repeaters. Additionally, the RN2483 provides you with the ability to secure your network communication using AES-128 encryption.



LoRa Technology Infrastructure Diagram

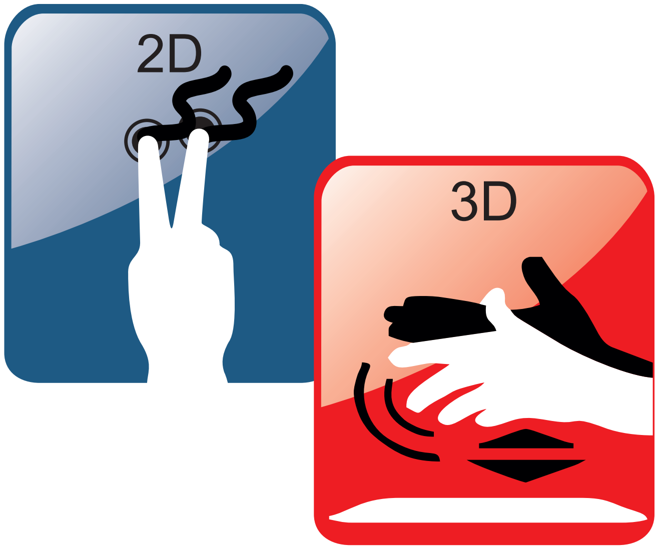
Visit the **Low Power Wide Area Network page** on our website for more information on our LoRa technology solutions. You'll find additional information, including a complete list of LoRaWAN partners, on the **LoRa Alliance website**.





The Next Dimension

Microchip Partners with Silicon Integrated Systems (SiS) on Industry's First Combined Multi-Touch and 3D-Gesture Modules for Displays



SiS to Integrate Projected-Capacitive Touch Sensors with Award-Winning GestIC® 3D Gesture Technology

A new generation of intuitive, gesture-based user interfaces is now available for a broad range of end products. To meet the growing demand for 3D control displays in the consumer, automotive, home-automation and Internet-of-Things markets, Microchip has partnered with Silicon Integrated Systems Corp. (SiS) to provide complete projected-capacitive touch (PCAP) and 3D-gesture interface modules. These modules will make it easier to design multi-touch and 3D gesture displays with our award-winning **GestIC® technology,** which offers a hand tracking range of up to 20 centimeters (cm) from the display surface.

Hand gestures are universal, hygienic and easy to learn. In addition, they enhance safety by reducing the need for precise hand-eye coordination. Microchip developed GestIC technology so that it can be readily combined with multi-touch PCAP controllers. It is the lowest-cost 3D gesture technology available on the market. In addition, GestIC sensors are constructed with standard materials and production methods, such as indium tin oxide (ITO), metal mesh and conductive ink on glass or foil.

Complete projected-capacitive touch and 3D-gesture interface modules ease design of intuitive user interfaces.

The new modules from SiS are the world's first to integrate 2D PCAP and 3D gesture technologies, providing a complete display solution. SiS has 30 years of experience and expertise in PC chipset products, eMMC, eMCP, and projected-capacitive touch solutions. Through this partnership with Microchip, SiS will act as an electronic developer and also provide sensor integration. The resulting modules will allow faster time to market for a broad range of designs, such as those in the automotive and consumer industries.

The resulting modules will allow faster time to market for a broad range of designs.

We are committed to furthering innovation in human-interface technologies, and SiS's modules will ultimately allow our customers to integrate these two interface technologies into their applications faster. With this partnership, the next dimension of intuitive, gesture-based user interfaces is now available for a broad range of end products.

For more information on SiS and its user interface solutions, visit **www.sis.com**. Visit our **Touch and Input Sensing Solutions** design center for more information about our broad range of products for developing your next application.

MOST® Technology in the News

MOST150 Technology Implemented in the New Volvo S90

MOST150 is the first standard to provide a proven, automotive-ready physical layer for Ethernet packet transport inside vehicles in accordance with the IEEE 802.3 Ethernet specifications. It is also the latest MOST technology available from Microchip. Volvo Cars has been utilizing Microchip's technology for many years and recently began utilizing MOST150. The new Volvo S90 is the second Volvo model to include MOST150 technology in its infotainment system. **More Information.**

Audi Deploys MOST150 Technology in Audi A4 Sedan's Virtual Cockpit Infotainment System

Following a similar deployment in its Q7 SUV and TT coupe models, AUDI AG is using MOST technology to network the high-end Audi virtual cockpit system in the latest model year of its best-selling A4 sedans. Specifically, Audi is using the OS81110 and OS81118 MOST150 Intelligent Network Interface Controllers (INICs), which provide 150 Mbps performance and support all MOST network data types. The OS81118 also includes a High Speed USB 2.0 interface (PHY/HSIC), to seamlessly connect with the virtual cockpit's System-on-Chip processor. **More Information.**

Toyota Continues to Add MOST50 Networking Devices to Infotainment Systems with New Lexus RX SUV Deployment

Toyota Motor Corporation is continuing to roll out our MOST50 INICs to power the infotainment systems throughout Toyota's vehicle line. The new Toyota premium Lexus RX SUV is the latest deployment among a wide variety of the Toyota brands, which have been using MOST50 in their infotainment systems for several model years. As the carmaker has in previous implementations, Toyota is using MOST technology to ensure high-quality digital audio streaming throughout its new luxury Lexus RX SUV. **More Information.**

Spring into Learning

Register for On-Site Training with PIC® Microcontrollers at Boston Regional Training Center

Get Hands-on Experience with Microchip Tools

Microchip's Regional Training Centers are high-tech engineering labs that are equipped with the latest embedded control tools and qualified instructors to provide hands-on training on a range of Microchip products and development tools. If you are in the Boston, Massachusetts, area, our Regional Training Center located in Westborough has just announced a series of live, on-site training classes to help you become more familiar with PIC microcontrollers (MCUs).

Look through the list of classes below and follow the registration instructions at the bottom of this page to sign up for the course(s) that interest you. Payment is due two weeks in advance of each class and can be made by check, PayPal or credit card.

Full Day Training: Hands-on Design with PIC10F Microcontrollers

- Date: April 21, 2016
- Time: 9:00 a.m. to 4:00 p.m.
- Fee: $399.00 per person

Learn how to design hardware and firmware using Microchip's 8-bit PIC10F series of microcontrollers. Using a simple example project, you will wire up a prototype, write the code and debug your project on a PICDEM™ Lab Development Kit (DM163045) that you will take home at the end of the class. The prerequisites for this class include a basic familiarity with PIC MCUs, C and MPLAB® X Integrated Development Environment (IDE).

Half-Day Training: Hands-on with Interrupts for 8-bit PIC Microcontrollers

- Date: April 22, 2016
- Time: 9:00 a.m. to 12:30 p.m.
- Fee: $199.00

This class will teach you how to use interrupts to control the servicing of peripherals and to create a simple time slice control system based on our 8-bit PIC MCUs. You will wire up your prototype, write the code and debug your project on a Curiosity Development Board (DM164137) that you will take home at the end of the class. The prerequisites for this class include a basic familiarity with PIC MCUs, C and MPLAB X Integrated Development Environment (IDE).

Full-Day Training: Getting Started with PIC Microcontrollers

- Date: May 18, 2016
- Time: 9:00 a.m. to 4:00 p.m.
- Fee: $199.00

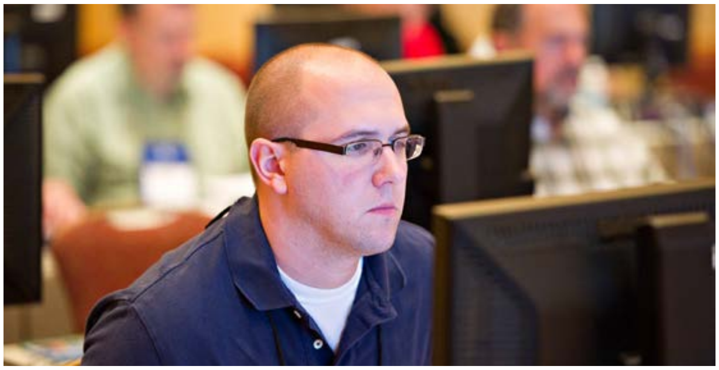
This class will provide you with an overview of Microchip's 8-, 16- and 32-bit families of PIC microcontrollers as well as the various tool options available to develop the firmware. You will learn about the installation, configuration and set up of tool suites and will be guided through the necessary steps to set up, create and build your first project. There are no prerequisites for this class.

(continued on page 17)

Full-Day Training: Hands-on Design with PIC16F Microcontrollers

- Date: June 14, 2016
- Time: 9:00 a.m. to 4:00 p.m.
- Fee: $399.00

Learn how to design hardware and firmware using Microchip's 8-bit PIC16F series of microcontrollers. Using a simple example project, you will wire up a prototype, write the code and debug your project on a PICDEM Lab Development Kit (DM163045) that you will take home at the end of the class. The prerequisites for this class include a basic familiarity with PIC MCUs, C and MPLAB X Integrated Development Environment (IDE).



All courses take place at:

Microchip Technology Regional Training Center
112 Turnpike Road, Suite 100
Westborough Executive Park
Westborough, Massachusetts 01581

For more information and to register for these classes, send an email to **Mchipguru@gmail.com**.

Microchip's Regional Training Centers are located worldwide. If you would like to find out what training classes are available in your area, visit our **Regional Training Centers website** and click on the "Find Classes" link.

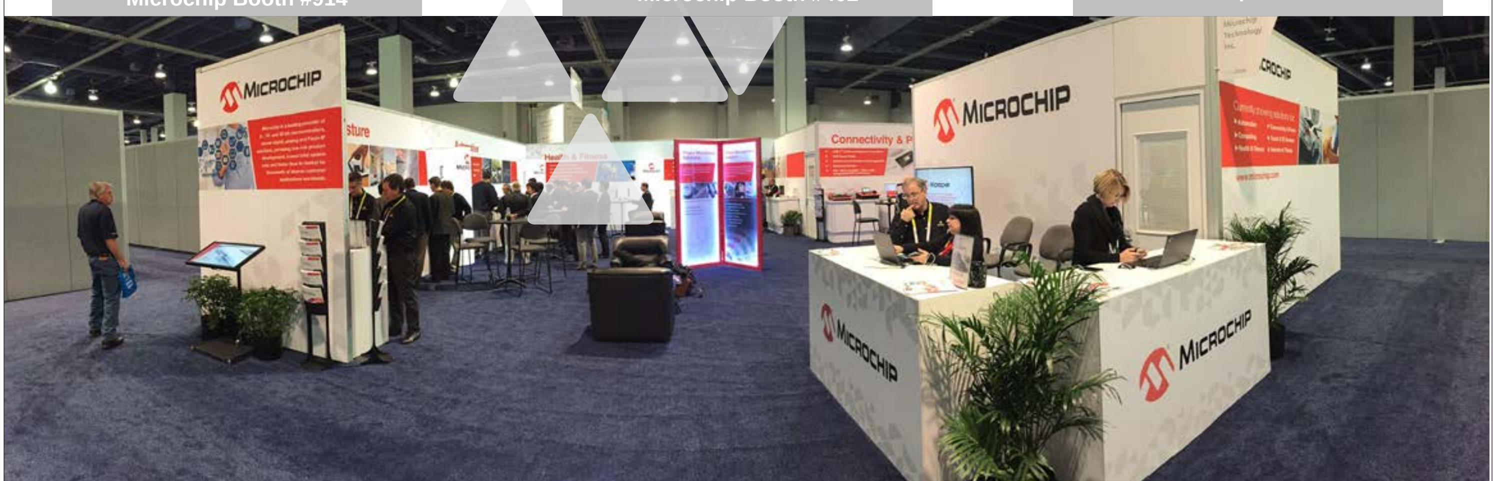
UPCOMING TRADESHOWS

Microchip Technology will be hitting the road in coming weeks. We invite you to visit us at the following events to get a hands-on experience with our innovative products and latest technologies and to discuss your requirements in person with our expert staff. Mention you saw this ad and we'll give you a special gift at the show.

Strategies in Light with LED Show
March 1-3, 2016
Santa Clara Convention Center
Microchip Booth #914

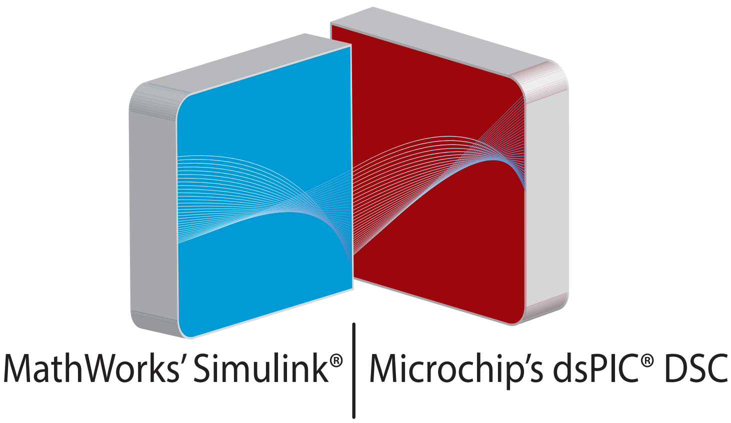
ECEDHA Annual Conference & ECExpo
March 18-21, 2016
Hilton La Jolla Torrey Pines
Microchip Booth #402

IEEE Applied Power Electronics Conference & Exposition (APEC)
March 21-23, 2016
Long Beach Convention Center
Microchip Booth #1127



Heartwarming Deals

You will love the savings that are coming your way with our February **Dev Tools Deals**. To take advantage of these special sales prices, go to www.microchip.com and add the item to your cart. Add the coupon code during checkout. These are limited-time offers, so act quickly to get yours while the deals are still available and supplies last.



MPLAB® 16-Bit Device Blocks for Simulink® (SW007023)

microchipDIRECT Coupon Code: TP1606

The **MPLAB Device Blocks for Simulink** make it easy to develop complex designs using our dsPIC30 and dsPIC33 Digital Signal Controllers (DSCs). This software provides a set of user interfaces to MathWorks' Simulink graphical environment for simulation and model-based design, where code for the application is generated, compiled and loaded onto a target dsPIC® DSC in a single, one-click step. Save $500 off the regular price during our Winter Sale.

MPLAB® X IDE PLUG-INS

MPLAB X IDE Plug-in - Code Profiling (SW100100)

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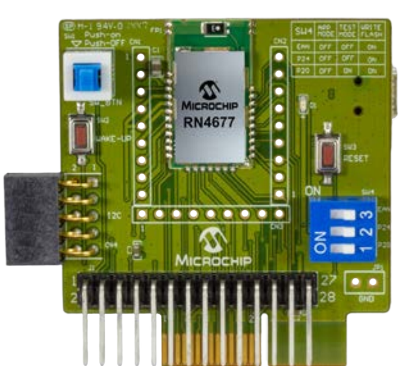
Available for PIC® MCU and dsPIC DSC device families with data capture, the **Code Profiling plug-in for MPLAB X IDE** (v 2.25 and later, MPLAB XC C compiler v1.20 and later) works with the MPLAB REAL ICE™ In-Circuit Emulator to display the percentage of time spent in each application function, enhancing the software debugging capabilities of MPLAB X IDE. It aids in debugging and code optimization by tracking the number of function calls, parent functions, child functions and execution time. It's on sale for $29.95, a 40% savings off the regular price.



RN4677 Bluetooth® 4.0 Dual Mode PICtail™/PICtail Plus Daughter Board (RN-4677-PICTAIL)

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Save over 35% and add Bluetooth and Bluetooth Smart capability to your product. **The RN4677 Bluetooth 4.0 Dual Mode PICtail/PICtail Plus Daughter Board** contains a fully certified RN4677 module that is easily configured using ASCII commands via UART. The board works out of the box when plugged into the USB port of a PC, or the PICtail/PICtail Plus connector allows it to be interfaced to a PIC microcontroller on the Explorer 16 Development Board (DM240001), PIC32 I/O Expansion Board (DM320002) or PIC18 Explorer Board (DM183032).

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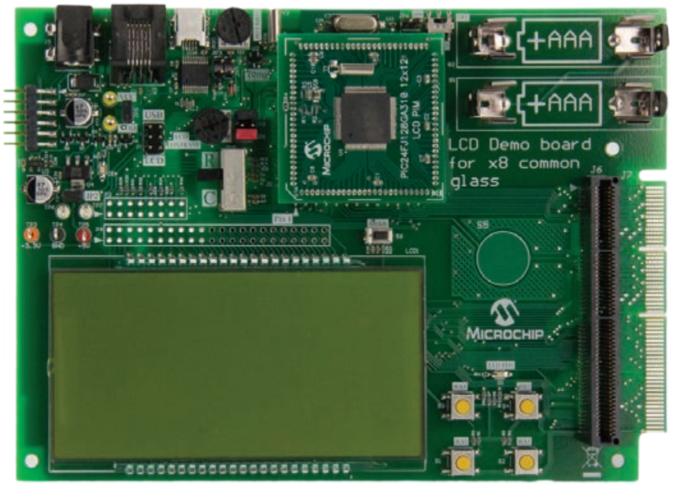

LCD Explorer Development Board (DM240314)

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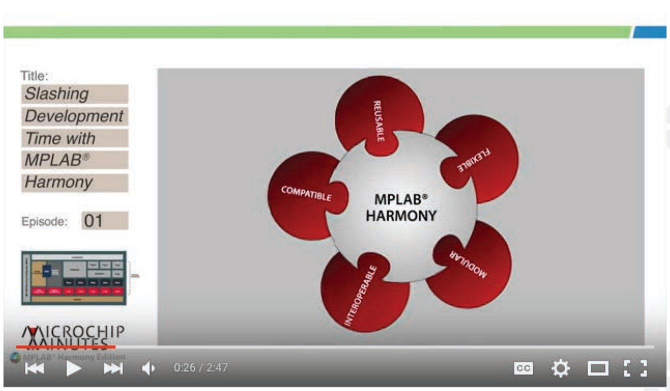
Create rich, informative displays using the **LCD Explorer Development Board** with 8-Common LCD technology. It comes with a PIC24FJ128GA310 Plug-In Module (PIM), but supports all our 100-pin LCD Processor PIMs. It also includes a PICtail Plus connector to allow you to use a PICtail Plus Daughter Board with your selected LCD microcontroller. Save $40 and order yours today.

GOT A MINUTE?

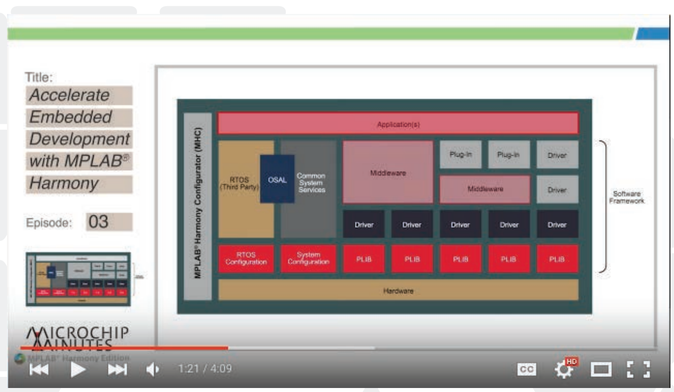
Slashing Development Time with Harmony's Application Demos

The MPLAB® Harmony Edition of our Microchip Minutes video series features short messages about MPLAB Harmony, our award-winning software development framework that integrates both internal and third-party solutions. Each episode will showcase an important feature of MPLAB Harmony for faster and efficient development with 32-bit PIC® microcontrollers. If you want to reduce your learning curve with the MPLAB Harmony software development framework, these brief, yet informative, videos are an ideal way to get started.

Click here to watch the videos on YouTube.



Bring Flexibility & Scalability to Embedded Development



Accelerate Embedded Development

DESIGN CORNER

Key Issues When Designing New Medical Wearable Devices

Q&A with Microchip's Medical Products Group

It is a time of revolutionary change for the medical and fitness device market. Keeping up with the rapid evolution in technology may seem overwhelming, but it can also be embraced as an exciting design challenge. This Q&A developed by our Medical Products Group will help you identify the key issues and trends so that you can select the right solutions for developing your next medical or fitness design.

Question

What is driving the fast growth of wearable medical devices, and what will potentially affect this market in the future?

Answer

Data-driven medical practices have been the focus for medical technology in the 21st century. Three motivators that are driving change in the medical field are:

- Healthcare providers are better able to either prevent or successfully diagnose and treat patients' diseases when more data can be accurately measured from these patients.
- The laws in many countries provide powerful legal and financial incentives for doctors and hospitals to show data that proves the effectiveness of their care.
- Government and private health-insurance providers are requiring that patients spend less time in hospitals or clinics to reduce rising healthcare costs. When patients leave the hospital earlier, healthcare providers will need to collect and measure more data from them than was previously necessary.

These three motivators are creating more demand for new solutions to track and analyze patient data. One of the best ways to get patient data is if the patient is wearing the necessary medical device. Therefore, the development of wearable medical devices is becoming critical.

Question

What main feature sets will smart wearable medical electronic devices need to have? Why? Which electronic components will become very important in these devices?

Answer

There are three feature sets that are important to wearable medical devices: input sensing, security/authentication and low power.

Input Sensing

With more healthcare functions happening in homes, patients need medical devices that offer user innovative, safe, user-friendly and low-power user interfaces. Selecting the right microcontroller (MCU) for these user interfaces is essential. The MCU should enable medical device developers to easily implement modern input-sensing functions such as capacitive touch, sliders and proximity detection, along with haptics, 3D tracking and gesture sensing, and more.

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Security/Authentication

As wearable devices transition from consumer fitness and entertainment applications to becoming medical devices, the demand for medical-device-level security and authentication becomes critical. Unauthorized access to patient data or the control of medical wearable devices must be prevented. Complete solutions, including microcontrollers with an integrated hardware crypto engine, secure wireless products and robust software libraries, are mandatory for defense against aggressive cyber attacks.

Low Power

Wearable devices must also meet extremely low power-consumption requirements to win end-user acceptance and to provide accurate data measurement over extended periods of time. Microcontrollers and other components used in wearable devices must not only have extremely low power consumption for sleep currents, but must also have multiple low-power sleep modes, flexible wake-up sources and intelligent power management to match the needs of wearable devices.

Question

What technical challenges will need to be faced when designing preliminary data analysis functions to be done by the smart, wearable medical electronic device?

Answer

Some consumer wearable devices currently use large, compute-intensive 32-bit microcontrollers to handle consumer functions and basic measurements, such as step count. If this same type of architecture is used in the next generation of medical wearable devices, then these wearable designs will end up using even more expensive 32-bit MCUs that also draw more current than is acceptable.

The next generation of medical wearable devices must be able to measure preliminary biometric data, such as heart rate, temperature, blood oxygen level, perspiration, pressure, and many other health indicators. To do this, the MCU used in a medical wearable design will need more measurement peripherals than have previously been necessary.

A better, long-term approach would be to use a lower-cost, low-power 8-bit or 16-bit microcontroller with integrated analog and digital peripherals that function independently from the microcontroller core. If the biometric measurements and some preliminary processing are done by these core-independent peripherals, then next-generation wearable devices will only require a smaller, low-power microcontroller.

Question

What are the key wireless communication technologies used on wearable medical electronic devices? What are the advantages and weaknesses of each technology, and what function does each perform?

Answer

Bluetooth®, Bluetooth Low Energy and Wi-Fi® technologies are commonly used to enable wearable devices to connect with smartphones, tablets, PCs and other intelligent devices. Developers of new wearable devices must look for ways to satisfy the requirement to get to market quickly by significantly reducing the time required for RF design work and regulatory approvals.

Wireless communication technologies are part of the bigger issue of the Internet of Things (IoT). Wearable medical device designers need to ask themselves questions such as, "How am I going to offer an end-to-end IoT, cloud-based solution to my customers? Am I going to develop and support my own cloud-based service, or should I partner with one? How will I accomplish all of this and more with my limited design resources to be considered credible in the world of IoT and cloud-based wearable devices?"

Wearable device designers need to keep these questions in mind as they look to component suppliers for help in implementing complete wearable IoT solutions. Visit our **Medical and Fitness Applications Design Center** for comprehensive information on how Microchip can assist with your medical wearable device design.

Live Updates Made Easy

Microchip Easy Bootloader for PIC24 and dsPIC33 Enables Over-the-Air Firmware Updates

As the number of always-on industrial, computer, medical/fitness and portable applications continues to grow, designers need an easy solution for implementing live updates for devices out in the field. The Microchip Easy Bootloader for PIC24 and dsPIC33 (EZBL) was developed to minimize your maintenance and engineering effort. This collection of Microchip firmware APIs, example projects and PC-side build tools enable in-the-field updates and reprogramming of devices that use our 16-bit PIC® microcontrollers (MCUs) and and dsPIC® Digital Signal Controllers (DSCs).

The EZBL helps you create modern, richly-featured bootloaders.

The EZBL helps you create modern, richly-featured bootloaders and compatible applications that can reuse bootloader code. It even facilitates the creation of embedded ICSP™ programming hosts to fully reprogram secondary processors.

Highlighted features:

- Multiple target support for almost all PIC24 MCU and dsPIC33 DSCs
- Code reuse
- Automatic linker script creation
- Decoupled communications
- Robust self-preservation
- Interrupt vector management
- Application support functionality
- Code secrecy compatible
- Full source with no-cost Microchip license

For more details and to download the latest version of the EZBL files, visit the **Microchip Easy Bootloader for PIC24 and dsPIC33 page** on the web.

Advanced Power Monitoring

High-Side Versus Low-Side Current Sensing

As energy efficiency and safety have become major concerns for designers of today's electronics, the need to closely monitor currents has increased. This article will focus specifically on the use of a shunt resistor to monitor current.

For shunt-based current monitoring, you first need to determine where to monitor the current in your system. There are two basic options: high-side and low-side current monitoring. For high-side current monitoring, the shunt resistor is placed between the power supply and the load, as shown in Figure 1. For low-side current monitoring, the shunt resistor is placed between the load and ground, as shown in Figure 2.

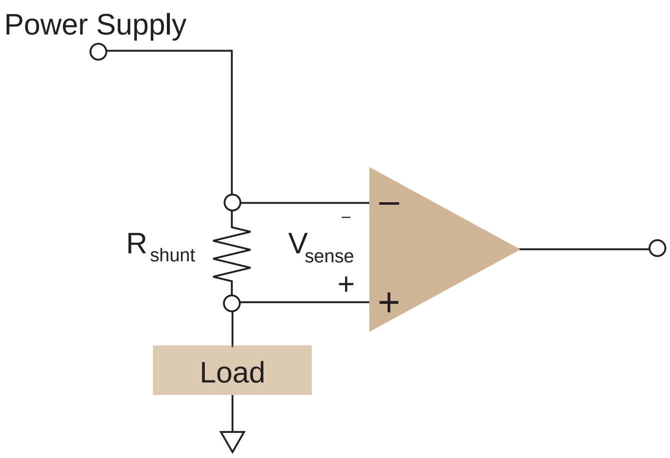

Figure 1: High-side Current Monitoring

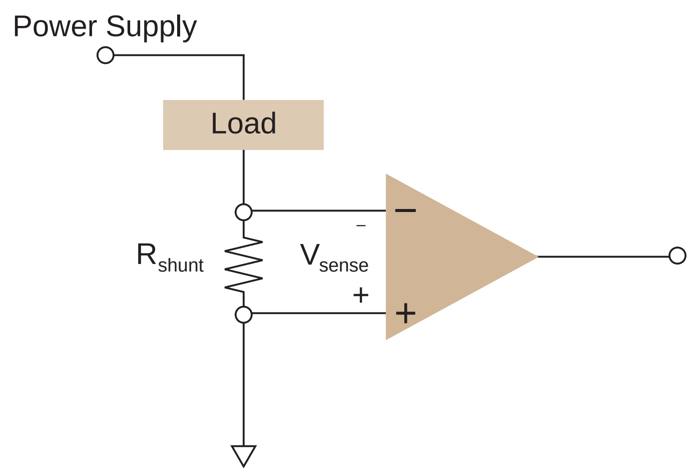

Figure 2: Low-side Current Monitoring

Both of these approaches have their pros and cons. High-side current sensing has the benefit of being able to detect current-related faults, such as short circuits or an open circuit that could affect the load. Also, with high-side current sensing, the load can be referenced directly to ground, as we'll explore later. The main disadvantage of high-side current sensing is that the common-mode voltage is relatively high, based on the supply voltage, so a high common-mode amplifier is required.

As opposed to high-side current sensing, with low-side current sensing, the common mode is referenced to ground. This allows you to use a cheaper, more readily available single-supply, low-voltage amplifier. Selecting the best amplifier for this

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situation depends on price versus required performance, as the amplifier's offset voltage, offset drift, common mode and power supply rejection and transient response may all be critical considerations. One disadvantage of low-side current sensing is that the shunt resistor is placed between the load and ground, which can cause ground loop issues since the load may not be at the exact same ground potential as the rest of the circuitry.

For high-side current sensing, the amplifier must be able to support the higher common-mode range, as well as handle any voltage transients that may occur on the power line. You can use a standard operational amplifier configured as a difference amplifier, as shown in Figure 3. However, there are some limitations to this approach. First, the input resistance is relatively low and determined by the external resistors. Also, the input currents aren't matched, which will limit the common-mode rejection. This will also be limited by how well matched the resistors are, which can lead to subpar performance.

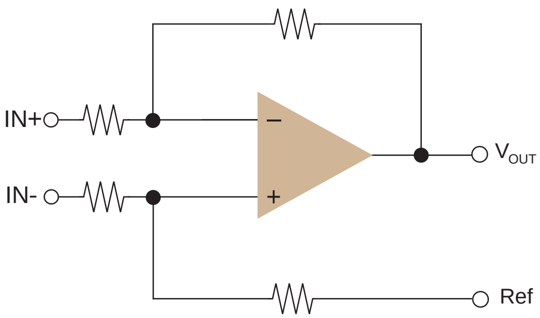
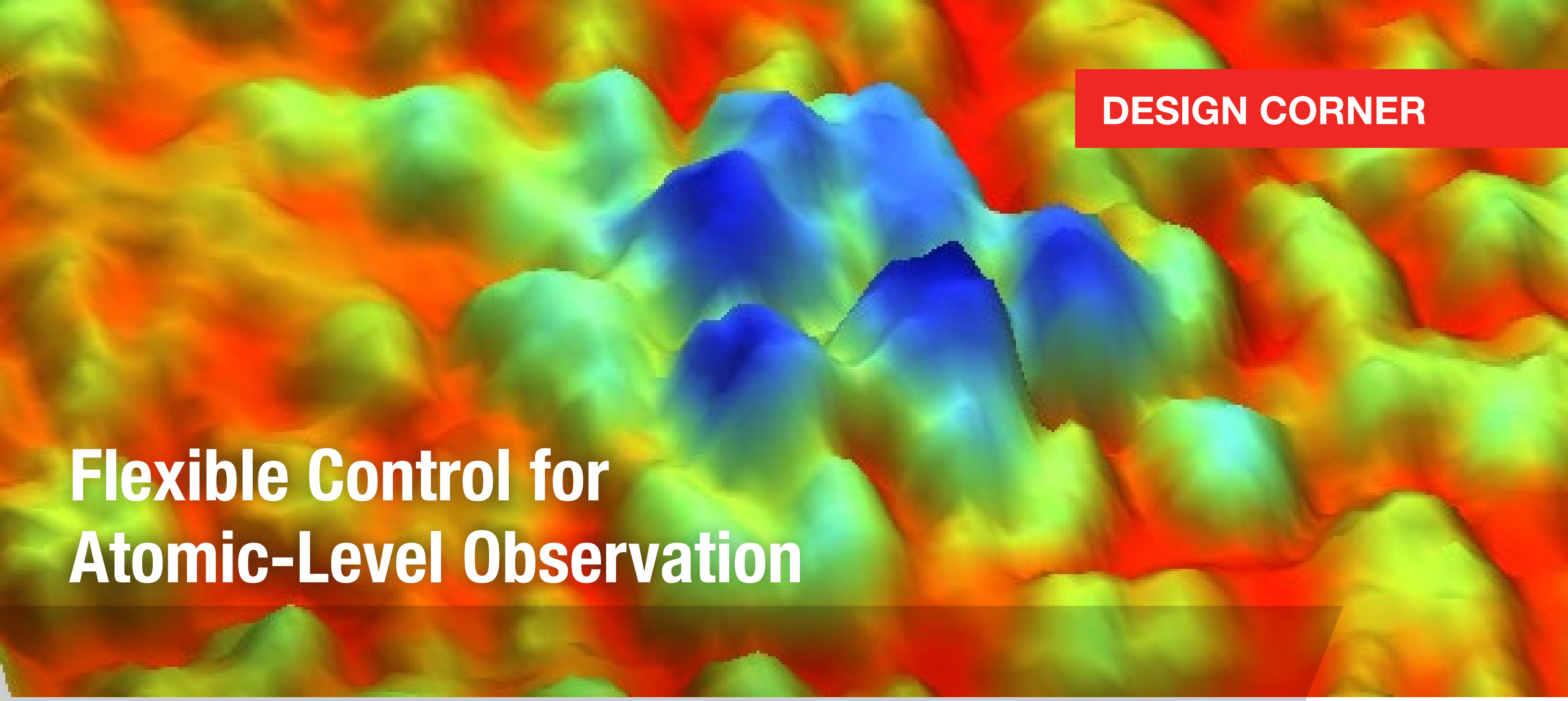


Figure 3: Difference Amplifier

Due to these limitations, amplifier manufacturers have created specialty devices for high-side current sensing, ranging from relatively simple voltage or current output amplifiers to more advanced solutions, such as Microchip's PAC1921. The PAC1921 is a dedicated power monitoring device that provides a configurable analog output that can present power, current or voltage. All information is also provided on the 2-wire/I²C compatible interface. Visit the **PAC1921 product page** on Microchip's website to learn more.



Flexible Control for Atomic-Level Observation

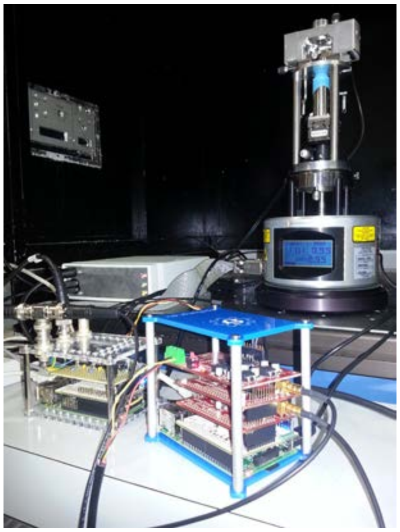
Extending a Raspberry Pi® Mini PC with Real-time Capabilities for Advanced Atomic Force Microscopy Applications

Contributed by Elbatech Srl, FabCrea Srl and the National Research Council of Italy

The ability to observe things at the atomic level was achieved just a little more than 30 years ago. At that time, Nobel Prize-winners Gerd Binnig and Heinrich Röhrer of IBM Research – Zurich developed a new, high-resolution scanning instrument with a sharp tip, ideally capable of isolating an individual atom to enable very close-range examination of samples. The first Atomic Force Microscope (AFM) was developed a few years later, based on their pioneering work. It features a cantilever that also includes a sharp tip on its free end that can be gently brought into contact with the sample under investigation. When the distance between the tip and the surface is small enough, the cantilever exerts interaction forces on the sample, leading to deflection. To detect this deflection, the tip-sample interaction forces must be accurately measured.

The AFM system must be able to maintain a constant attraction or repulsion force between the tip and sample, using a preset level. This force is tiny—about a nanonewton or less. Once this is achieved, topographic images of the sample surface can be obtained by changing the x-y coordinates of the tip and scanning the surface, in a rasterized, line-by-line method using piezoelectric actuators. These precise movements enable nanometer position resolution on the scanning plane. The AFM can then record surface images of the sample based on the amount of correction that the feedback loop must provide to maintain the constant interaction forces, despite any "mountains" or "valleys" that might be present.

The Challenge: A Flexible and Powerful Controller



The EpsilonPi offers a powerful and versatile solution for AFM applications.

Any AFM system is primarily based on a control loop which measures the deflection of the cantilever and then changes the distance between tip and sample by following a specific rule. This process is normally implemented through a control chain comprised of an Analog-to-Digital (ADC) stage featuring 16-bit data acquisition at speeds up to several hundred kHz, a real-time linear control algorithm and a Digital-to-Analog (DAC) stage for driving the motion of an actuator down to nanometer resolution. AFM manufacturers face the challenge of simultaneously achieving high performance for the main control loop and extended flexibility in the drive logic. In fact, there is a growing demand

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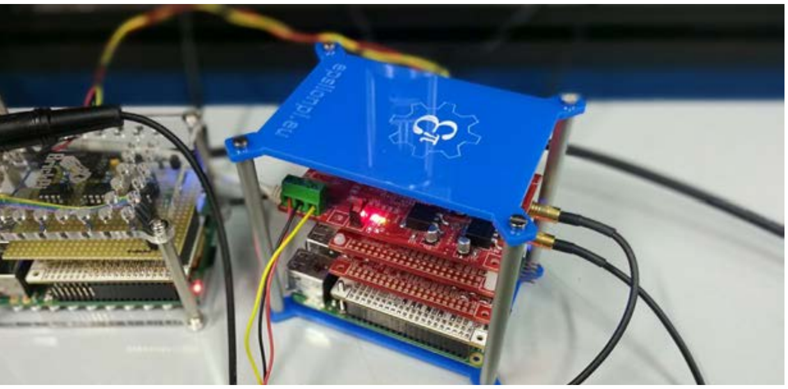
for an AFM controller that gives the user the ability to design a low-level experiment that chains a set of "working segments" and allows the controller to switch among them in response to specific preset triggers (e.g., maximum force, elapsed time or displacement).

The Technology Approach: EpsilonPi

The **EpsilonPi technology** platform provides an Internet-of-Things (IoT) approach to advanced signal conditioning and acquisition. Each node of the EpsilonPi network is comprised of a Raspberry Pi® mini PC plus a shield or "hat" (a plug-in board directly connected to the microcomputer by means of its native connector interface) that is powered by a Microchip dsPIC33EP Digital Signal Controller (DSC) to offer extended function capabilities. The Raspberry Pi delivers the full set of features of a standard Linux® based PC, including high-level network communication over Ethernet, while the dsPIC® DSC-based board provides fast and reliable I/O communication with hardware peripherals. The base stack can be further extended with sister boards to implement specific functions, such as fast AD and DA conversions. The dsPIC DSC is programmed to act as a logic state machine via its on-board firmware. The EpsilonPi stack can be remotely driven on the network using its open command-based interface to set the state parameters and transitions.



The EpsilonPi technology platform provides an Internet-of-Things approach to advanced signal conditioning and acquisition.

The EpsilonPi solution uses the robust and high-performance **ZeroMQ** network library as its primary messaging system. The hardware interface features a **dsPIC33EP512GP806** (or dsPIC33EP512MC806) DSC, which was selected because of its generous memory, speed and number of built-in hardware modules. The dsPIC DSC-based "hat" is connected to the Raspberry Pi board and communicates with it via the

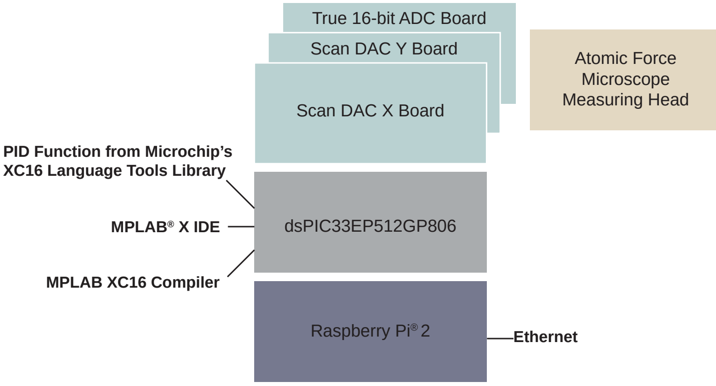
UART interface for commands and via the SPI2 interface for high-throughput data transfer.

The General AFM Setup

The EpsilonPi "hat" can be configured and extended as required by a specific AFM application. It sits between the Raspberry Pi (connected via the SPI2 module and UART) and the AFM measuring head. It features:

- Data acquisition performed by a true 16-bit ADC interfaced to the dsPIC33EP via the SPI1 module
- Signal monitoring using one of the dsPIC33EP's integrated 12-bit ADC modules
- Scanning ramps that are generated by 16-bit DACs are connected to the dsPIC33EP through SPI3
- A feedback loop that is implemented using Microchip's PID function available in the **XC16 Language Tools Libraries**

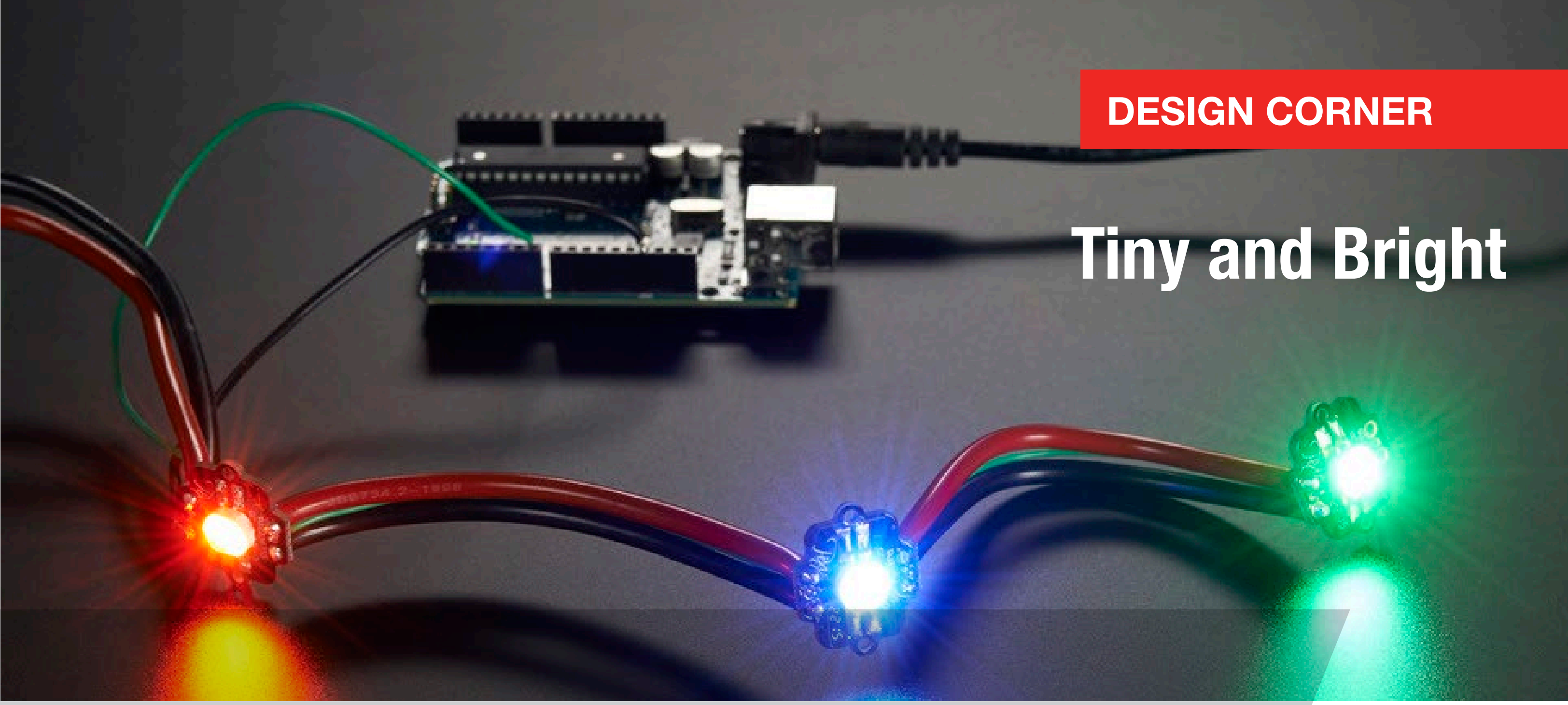
The EpsilonPi's implementation firmware is written in C using the MPLAB® X IDE and the MPLAB XC16 compiler. The client software runs on a target computer and is written in Python3.



EpsilonPi System Diagram

For AFM applications, the EpsilonPi offers a powerful and versatile solution. The fast and reliable Microchip dsPIC DSC effectively manages the control loop chain, while the Raspberry Pi delivers flexibility to the overall system. For more information, contact Elbatech Srl at **info@elbatech.com**.

Tiny and Bright



Pixie 3W Chainable Smart LEDs Get Intelligence from 8-bit PIC® Microcontroller

It all started with an LED jacket designed for Burning Man 2014. When Ytai Ben-Tsvi was unable to find chainable 3W RGB LEDs with the required drive circuitry needed to make his jacket "obnoxiously bright," he decided to create some of his own. He developed the Pixie 3W Chainable Smart LED Pixel, a color LED module that incorporates an 8-bit PIC® microcontroller to add intelligence. An external controller board is used to dynamically change its color and brightness, and a good 5V supply and hefty power wires are recommended to handle the significant current draw. The Pixie's hardware and software are also fully open-source, making the module hackable and fun to use in a wide range of projects.

What's In a Name?

The Pixie, a variation on "pixel", includes its special features in its product name:

3W – Each exceptionally bright RGB LED is driven by 3 watts of power: 1 watt each for the red, green and blue LEDs.

Chainable – The design enables multiple Pixie modules to be chained together and individually controlled. When compared to using traditional LEDs, it eliminates the need for excessive wiring and a microcontroller with many pins driven by specialized peripherals such as a UART or PWM. To create a chain of Pixies, the first LED's input pins are simply connected to the power supply and a single control pin (serial TX) on the controller. Then the first LED's output pins (power, ground and data) are connected to the input of the second LED, and this is done for each additional Pixie in the chain. Each Pixie receives its own data from the controller and then relays the rest of the data down the chain, so the controller does not need to be connected to all the modules to control them individually.

Smart – The Pixie offers some high-end features including gamma correction (8-bit to 16-bit) for super-smooth color gradients, over-heating protection and communication loss protection.

A Simple, Yet Challenging, Design

Ytai discovered that his design consisting of about 20 simple parts did present a number of challenges. With the design pretty much complete, he collaborated with Adafruit to finalize the Pixie and offer a high-quality product. During this process, they were able to address some fairly sophisticated issues. While Ytai documents these challenges thoroughly in his **blog article about the Pixie**, here's a quick overview of some of the design considerations.

Fairly early in the process, it became clear that they needed a small microcontroller to implement all the features they wanted in the design. They selected the 8-bit **PIC12F1571** because it offered just about everything they needed. In addition to its small size and low cost, some of its features include 5V operation, five I/O pins (used for R, G, B, DIN, DOUT), an internal oscillator, a 16-bit, 3-channel Pulse-Width Modulation (PWM) peripheral, a temperature sensor and an extended Watch Dog Timer (WDT).

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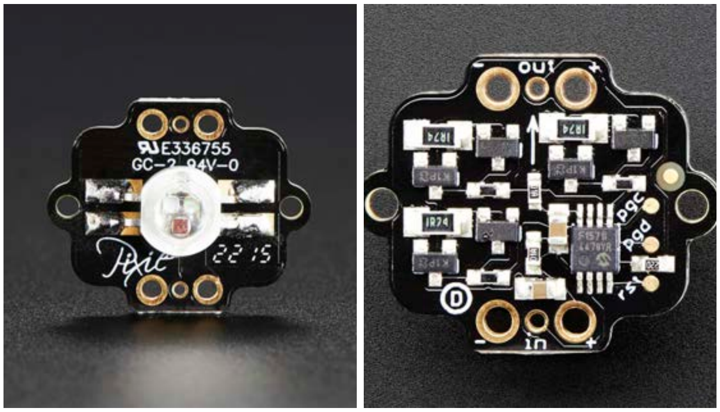
The Pixie's circuit board features exposed pads—labelled rst, pgd and pgc—that can be used to program the PIC MCU to offer a wide range of functionality. For example, the Pixie can be reprogrammed for standalone operation, the DIN/DOUT pins can be repurposed to support different protocols or to directly connect to buttons, and the DOUT pin can even be used for analog input. The firmware is available in **Pixie's Github repository**.



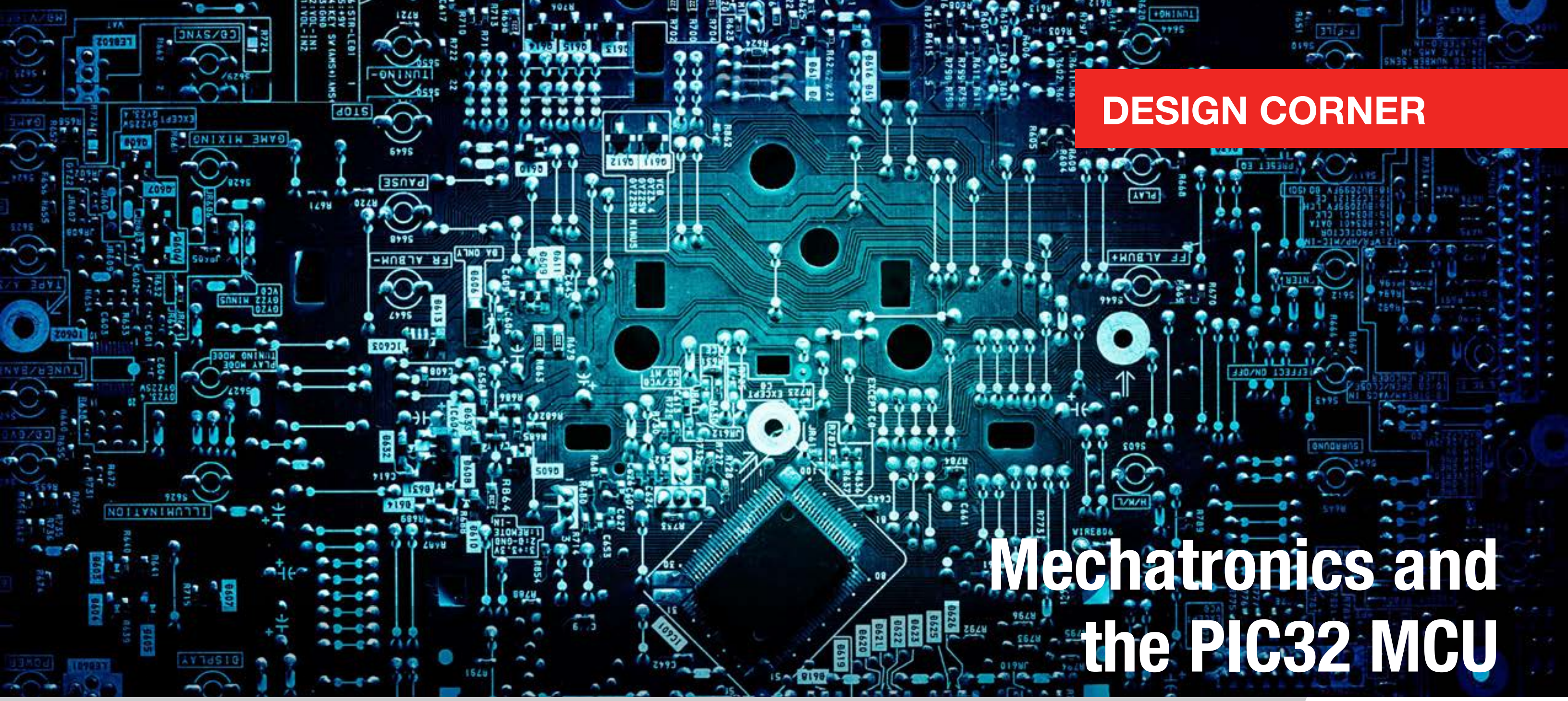
The Pixie 3W Chainable Smart LED Pixel incorporates an 8-bit PIC® microcontroller.

The PIC MCU's built-in, 16-bit PWM peripheral is used to control the RGB LED's color and brightness. It enables gamma correction via nonlinear mapping of the 8-bit color value to a high-resolution 16-bit color, resulting in a very natural color gradient. The PWM peripheral runs at about 500 Hz and generates signals to switch a constant-current drive circuit to provide a consistent level of illumination for each of the LEDs. The external controller uses standard serial transmission to send a byte string containing a color value for each LED in the chain. Each byte represents the brightness of a single color of a single Pixie. Each Pixie in the chain listens for this byte string using the DIN pin, stores the bytes it needs, and then echoes the remaining bytes on to the next Pixie using its DOUT pin.

When the Pixie circuit is driving all three LEDs at a 100% duty cycle, it dissipates approximately 5W of heat. While the PCB has been designed to improve cooling efficiency, the Pixie is not intended to be kept on at full brightness for more than a couple of seconds. To make sure that the LEDs do not get dangerously hot, even accidentally, the PIC MCU's on-chip temperature indicator is used to estimate the board's temperature. If the LED's temperature goes above 70°C, the temperature indicator shuts the LED down and automatically turns it back on when it has cooled down.

The Pixie also takes advantage of the PIC MCU's WDT to help reduce power consumption and manage the potential for overheating if communication with the controller is lost somehow. The WDT resets the PIC MCU if it doesn't hear from the controller's firmware every two seconds, turning off the LED. This prevents the LED from overheating if it gets caught in a high-brightness pulse when communication with the controller breaks down. It will resume when it receives a new byte string from the controller.

If you'd like to add some brightness to your next project, you can learn more about the Pixie and get the design resources by visiting the **tutorial** Ytai posted on Adafruit's Learn site. You can also purchase your own Pixie from **Adafruit**.

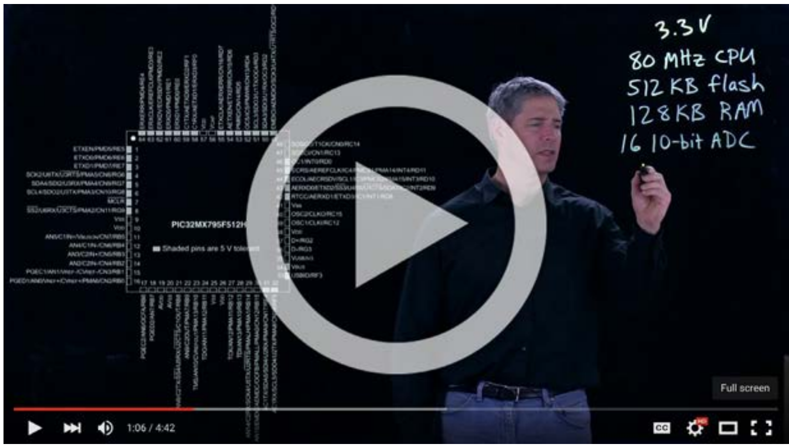


Mechatronics and the PIC32 MCU

Embedded Computing at Northwestern University

In 1997, Kevin Lynch, currently Professor and Chair of the Mechanical Engineering Department, joined Northwestern University. At that time, the annual Robot Design Competition (DC) was already a popular event with undergraduates. Teams of students build autonomous mobile robots to compete on obstacle courses that change every year. Despite the popularity of this competition, Northwestern did not offer a course on mechatronics, the study of microprocessor-controlled electromechanical systems incorporating sensors and actuators. After obtaining funding and support from the University, Lynch developed a new lab and a new elective course—ME 333 Introduction to Mechatronics—that was first offered in 1999. His inspiration came from his training in robotics, as well as his love for a course he had taken at Princeton many years earlier, MAE 412 Microprocessors for Measurement and Control (taught by Professor Michael Littman), affectionately known as "Trains" for its use of model railroads as demonstrators.

He structured ME 333 to spend the first six weeks covering the electronics of interfacing sensors and actuators with a computer, plus rudimentary feedback control, accompanied by traditional three-hour labs. The last five weeks were devoted to a final project of the students' own design. Students worked in teams of three on both the labs and the final project, and the course culminated with a fair where teams demonstrated their projects in the lobby of Northwestern's Technological Institute. This successful course, which grew in popularity each year, followed this format for about ten years. The computer or microcontroller used by the students was occasionally updated, but otherwise the format and content of the course changed little.



Video lectures were created for ME 333 Introduction to Mechatronics.

Lynch was dissatisfied, though, with the compartmentalization of effort by students when working on the final project. "Typically one member of the team would do the machining and mechanical prototyping, one member would do the electronics, and one member would do the programming," said Lynch. Believing that all mechatronics engineers should be competent in embedded computing, he was troubled that nearly two-thirds of the students completed the course without having a significant experience in programming.

To adress this issue, Lynch coordinated with his colleague, Professor Michael Peshkin, who created two new courses. The

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first course, ME 233 Electronics Design, replaced an existing required course and puts an emphasis on practical electronic design. The second course, ME 433 Advanced Mechatronics, has teams of two or three students work on a course-long project. The addition of ME 233 as a prerequisite for ME 333 allowed Lynch to reduce the electronics content in ME 333, and the addition of ME 433 allowed him to drop the team project. Students interested in pursuing mechatronics further after taking ME 333 are now able to undertake a more significant project in ME 433.

A New Focus

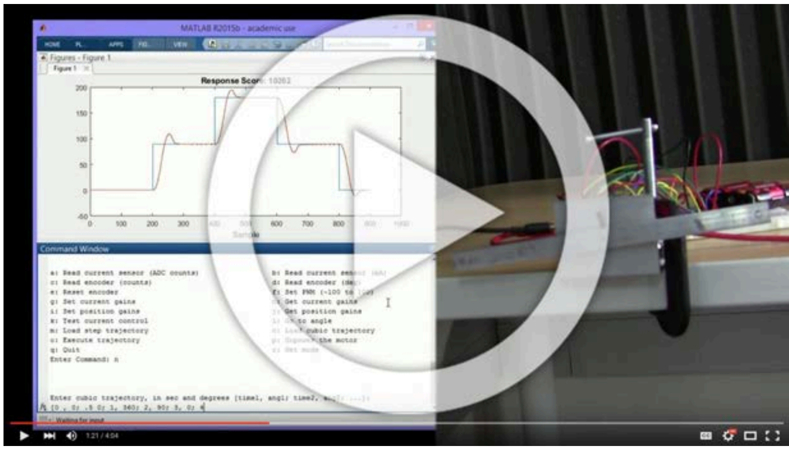
Taking advantage of this new flexibility, Lynch reorganized ME 333 to focus on embedded computing and control using a PIC32 microcontroller, specifically the **PIC32MX795F512H**. Each student individually completes all assignments, including a significant final project. In this final project, students implement the electronics and software for a professional nested-loop brushed DC motor control system, where the outer-loop motion controller, running at hundreds of Hz, uses a motor reference trajectory and encoder feedback to generate a commanded torque (equivalently, motor current), and the inner-loop current controller, running at 5 kHz, controls the Pulse-Width Modulation (PWM) signal to an H-bridge to achieve the commanded motor current. Sensors for the project include a motor current sensor and a motor encoder, and the software uses multiple interrupts and peripherals such as analog input, digital I/O, timers, output compare, and SPI and UART communication. Optional extensions save data to Flash memory and use the Parallel Master Port (PMP) to drive an LCD display.

Students also create a MATLAB® interface to the PIC32 MCU via communication over a USB cable. The interface provides options that allow the user to set feedback gains, test the current-control loop in isolation, specify the coefficients of a motor trajectory, and plot the results of the controller's trajectory-tracking performance. Knowing that commercial motor amplifiers with these kinds of capabilities cost hundreds of dollars is good motivation for the students.

Students develop their PIC32 software from scratch in C, based on concepts learned earlier in the course. Many ME 333 students enter the course with no prior experience in C.

Selecting a Microcontroller

Lynch's approach to teaching embedded control is geared toward providing students with a foundation based on the lowest-level building blocks they will likely need for professional integration of microcontrollers with sensors and actuators. For example, detailed coverage of the design of microprocessors is too low-level for most mechatronics engineers. On the other hand, use of prepackaged Arduino® like libraries is too high level to be the foundation for professional embedded computing. While Arduino hardware and software are useful for quickly getting started with microcontrollers, the software abstractions keep the budding mechatronics engineer at an arm's length from important concepts in embedded computing. "Since ME 333 is taken by MS and PhD students specializing in robotics, in addition to undergraduates, it is important for this course to provide them with a professional foundation," Lynch said.



Students create a MATLAB® interface to the PIC32 MCU.

The PIC32 MCU was selected because it has a modern architecture, is well priced, has a plethora of peripherals and good performance (80 MHz, 512 KB Flash, 128 KB RAM), and has good market penetration, making it an appropriate first microcontroller for the future professional.

The "No Magic Steps" Philosophy

According to Lynch's "no magic steps" pedagogical philosophy, once the lowest-level building blocks have been determined, there should be no missing or "magic" steps that mystify the student. In the case of ME 333 as a course, it meant that there should be no software abstractions to prevent a clear understanding of how the software connects to the hardware. Once the students understand how their low-level code interacts with peripherals, then abstractions in the form of software libraries—such as Microchip's **MPLAB® Harmony** software framework for use with PIC32 MCUs—can be introduced. This philosophy impacted these aspects of the course:

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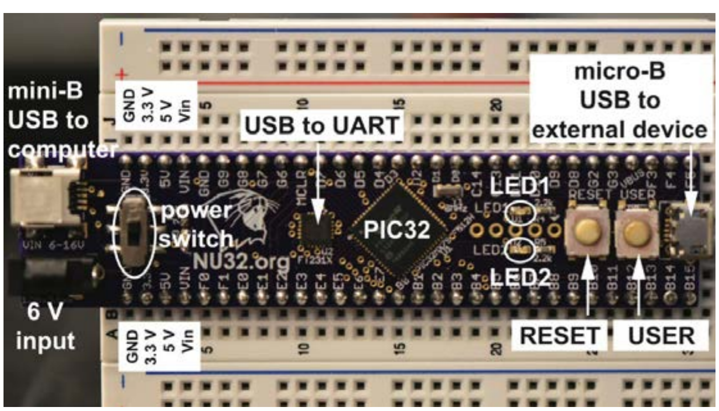
Choice of Programming Language – Assembly programming fits the "no magic steps" criterion, but it is processor-dependent. C was selected for ME 333 because it is processor-independent, while still remaining relatively low level. Students read and write the peripherals' special function registers directly, reinforcing the documentation in the reference manual and data sheet. They do not start with the MPLAB Harmony software framework (although it is introduced in the textbook), because for the beginner, the abstractions that MPLAB Harmony introduces obscure the connection between the software and the hardware.

Command Line Tools vs. MPLAB X IDE – Students in ME 333 use text editors to create their programs, and they compile and load their programs at the command line using a Makefile. Following the "no magic steps" philosophy again, they do not use MPLAB X IDE. The Makefile clearly demonstrates how a program is built from the source text files, while the role of the IDE in the build process can be mysterious to the student.

The NU32 Development Board – This custom, 60-pin, breadboardable, DIP-style development board uses the PIC32MX795F512H. Its primary purpose is to break out the pins of the PIC32 MCU. It also contains voltage regulators to regulate an input voltage to 3.3V and 5V; an FTDI FT231X chip that converts USB to UART communication, allowing the host computer's USB port to communicate with a UART on the PIC32 MCU; an on-board 8 MHz resonator that is used to generate an 80 MHz CPU clock; two LEDs and two pushbuttons; and USB connectors to connect to the host computer and an external device, like a smartphone. The PIC32 device has an on-board bootloader, allowing it to be programmed via the host computer using just a USB cable. The bare-bones board is in keeping with the "no magic steps" philosophy: users must construct their own external circuits to interface with the PIC32 MCU, as they would in a professional setting. It also makes the board small and inexpensive enough to be used as a component in many embedded projects.



The NU32 Development Board features a PIC32MX795F512H MCU.

The nScope portable function generator and oscilloscope.

A Different Learning Format

In the original ME 333 course, students participated in traditional, scheduled, three-hour labs in a facility with function generators, oscilloscopes, electronic components and other tools. In the new ME 333, students use a portable lab kit to do their sensor and motor integration lab exercises at any time and place. Each lab kit consists of a multimeter, a breadboard, a power supply, a wire stripper, wire and various other electronic components, and the inexpensive and portable **nScope** oscilloscope and function generator. The nScope uses the student's laptop as its display. It was developed at Northwestern based on the PIC24FJ MCU and, after a successful Kickstarter campaign in June 2015 that generated over 1700 backers, it is now available to anyone.

Taking advantage of these portable labs, ME 333 uses a flipped classroom format. Videos of lectures were created using the Northwestern Lightboard, an ingenious and easy-to-use device created by Professor Peshkin, and are available on a **YouTube video channel**. This allows students to work on projects during class time while the instructor and TAs circle the room, offering help. Students bring their laptops and lab kits to every class. Brief lectures are interspersed to reinforce the videos and to elicit questions and discussion. "Time spent with students in this format adds more value than repeating a lecture from the previous year," Lynch said.

A New Textbook

In December 2015, Newnes released ***Embedded Computing and Mechatronics with the PIC32 Microcontroller***, written by Lynch and his co-authors Nick Marchuk, Lynch's co-instructor in mechatronics and Matt Elwin, a PhD student. Based on—and

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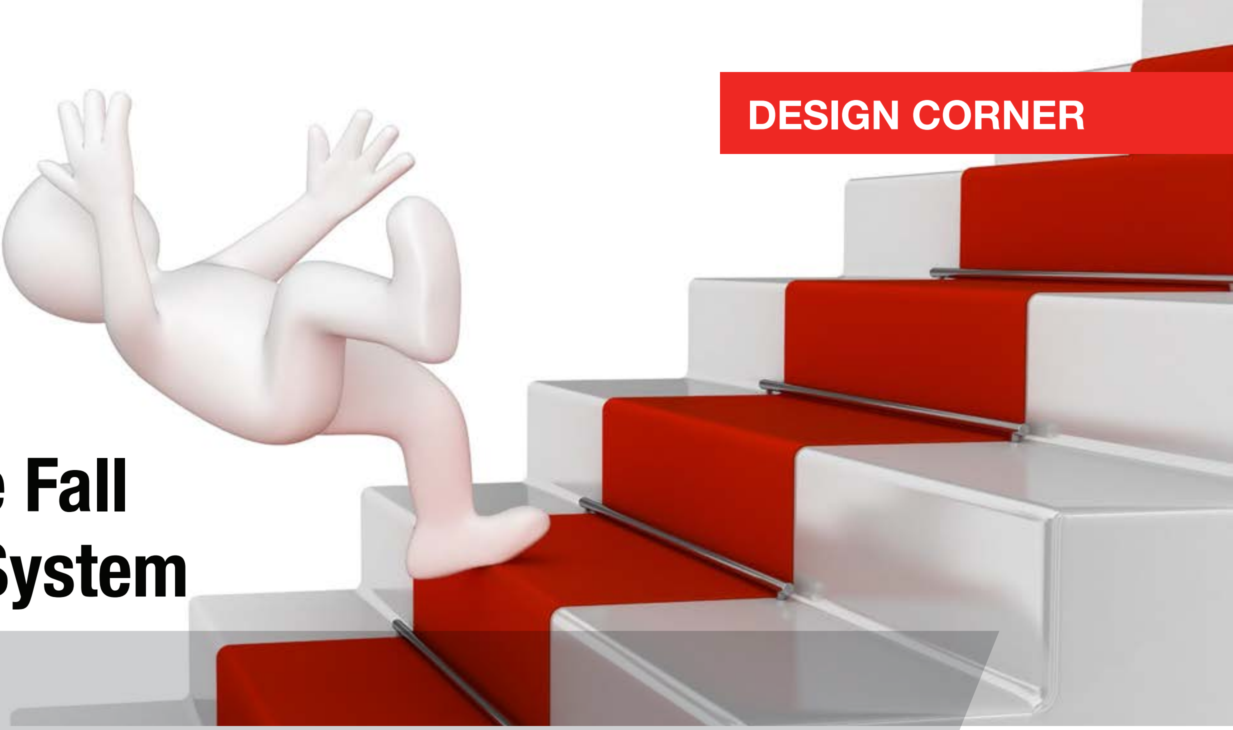
expanding beyond—the curriculum in ME 333, approximately half the book covers the hardware and software of the PIC32 microcontroller, as well as an introduction to programming in C. It provides a systematic explanation of the build process and how the software you write, plus the software Microchip provides, turns into a final executable that connects to the hardware described in the PIC32 MCU's data sheet. A peripheral reference describes in detail the operation of most of the peripherals, including sample code and projects using them. To provide a logical and coherent presentation, the book brings together key material from the PIC32 Reference Manual, the PIC32MX5xx/6xx/7xx Data Sheet, the XC32 C/C++ Compiler User's Guide, and MPLAB Harmony documentation.

The other half of the book covers fundamental topics in mechatronics, such as a circuits review, common sensors, digital signal processing and feedback control with the PIC32, brushed DC motors, brushless DC motors, gearing and motor sizing, and other actuators like stepper motors, RC servos, solenoids, and voice coil actuators. While the book was written as a university textbook, it is also appropriate for serious hobbyists and as a reference for professionals.

Visit the **NU32 website** for more information about the book including free downloads of sample chapters, sample code, and videos supporting the book. You'll also find details about the NU32 development board, the nScope portable oscilloscope, and the Lightboard.

Kevin Lynch is Professor and Chair of the Mechanical Engineering Department at Northwestern University, where he teaches courses in mechatronics and robotics. Before joining Northwestern, he received a BSE in Electrical Engineering from Princeton and a PhD in Robotics from Carnegie Mellon University. He has received Northwestern's Engineering Teacher of the Year award and the Charles Deering McCormick Professorship of Teaching Excellence, the top teaching award conferred by Northwestern. He publishes and lectures widely on his research in robotics, and he is co-author of "Principles of Robot Motion" (MIT Press, 2005). He is a Fellow of the IEEE.



A Wearable Fall Detection System

Interrupt-Driven Design Achieves High Level of Accuracy and Power Efficiency

Contributed by Brent Bogatzke

Approximately one in three elderly people experienced a fall in the last 12 months. When a fall happens, it is critical to ensure a swift response time to help minimize trauma and emotional distress. Automated fall detection systems, which can provide substantial peace of mind for those at risk of falling and their loved ones or caretakers, have traditionally focused on highly accurate algorithms situated at specific body locations. These systems, however, typically neglect power efficiency. Highlighting the capabilities of Microchip's **RN4020 Bluetooth® Low Energy module** and 8-bit PIC18LF microcontroller (MCU) families, the following summary of a senior design project outlines a power-efficient fall detection system that achieves an estimated 120-day battery life using a CR2032 coin cell battery and offers a 98% overall fall detection accuracy.

> It is critical to ensure a swift response time to help minimize trauma and emotional distress.

The Components of a Fall

A fall is typically made up of four basic components. The first is free fall, where the only force acting on an object is gravity, measured as the accelerometer tending towards 0g. The second component, the impact, has been shown in relevant literature to usually exceed 4g. Orientation change, the third component, assumes that the orientation at the start of the fall will be slightly different from the orientation at the end of the fall. Finally, inactivity is the fourth component, where a recovery time occurs (exceeding 1s) before the person begins to move again, as illustrated in Figure 1:

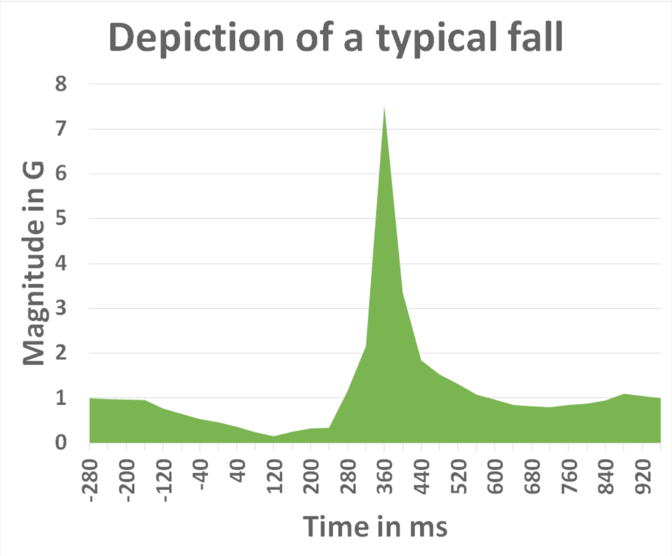


Figure 1 – Depiction of a Typical Fall

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Sensor-Based Smartphone Fall Detection Design Overview

With these basic principles in mind, a fall detection algorithm was designed utilizing both an external sensor as well as the accelerometer contained within a smartphone to increase redundancy and provide opportunities for data validation leading to significant increases in specificity (a measure of the ability to reject falls detected in error). This system extensively uses the concepts of interrupt-driven design and achieves a high level of power efficiency by placing the core MCU, an 8-bit **PIC18LF25K50** with an extensive list of features, regularly into a sleep mode as outlined in the diagram above.

Interrupt-driven design is one of the key ways to achieve a high level of power efficiency, as it allows the MCU to be placed into either an idle or sleep mode for large periods of time. However, it is important to remember that interrupts can also introduce their own problems, most notably due to the fact that the programmer can no longer presume that their main code will actually execute in a timely fashion. This system utilizes six interrupts: three interrupts for the accelerometer, two interrupts for the RN4020 Bluetooth Low Energy (BTLE) module, and one timer interrupt. These interrupts are triggered by the three fall events: free fall, impact and inactivity. Free fall triggers the start of the timer interrupt, which ticks every 100 ms until the algorithm has completed processing. The remaining two interrupts from the BTLE module manage connection events and respond to data requests utilizing sleep modes which consume as little as 300 nA (although as sleep modes as low as 20 nA are possible with the selected MCU).

Fall detection isn't very helpful if there is no mechanism in place to transmit an alert. In this design, the RN4020 module has also been used to connect to the MCU via USART and communicate with a smartphone. Setup is a very straightforward process. It only requires the configuration of a couple of registers to initialize and manage a connection. Once a connection is made, data transmission takes place using the Microchip Low-Energy Data Profile (MLDP). The fall status is transmitted when either a fall or critical fall is detected. As this application rarely requires actual data transmission, the RN4020 module spends most of its time in a sleep state, using connection parameters that only power the transceiver every 16 seconds. This limits power consumption to an average of ~5 µA. The ADXL345 accelerometer consumes a further 40 µA at a data rate of 25 Hz. Accounting for all current sources in the system, a 3.3V CR3032 coin cell battery should be expected to be able to power the system for more than 120 days.

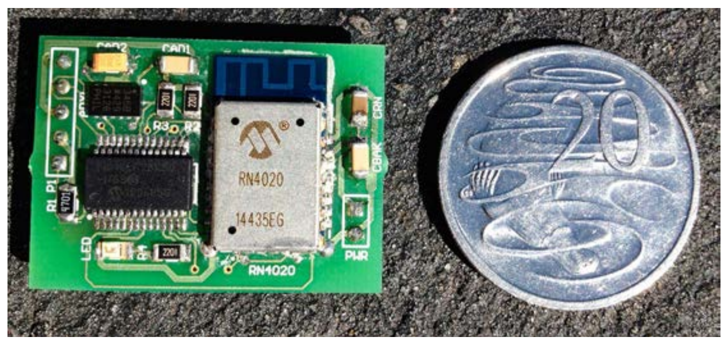

Figure 2 – Fall Detection System Board

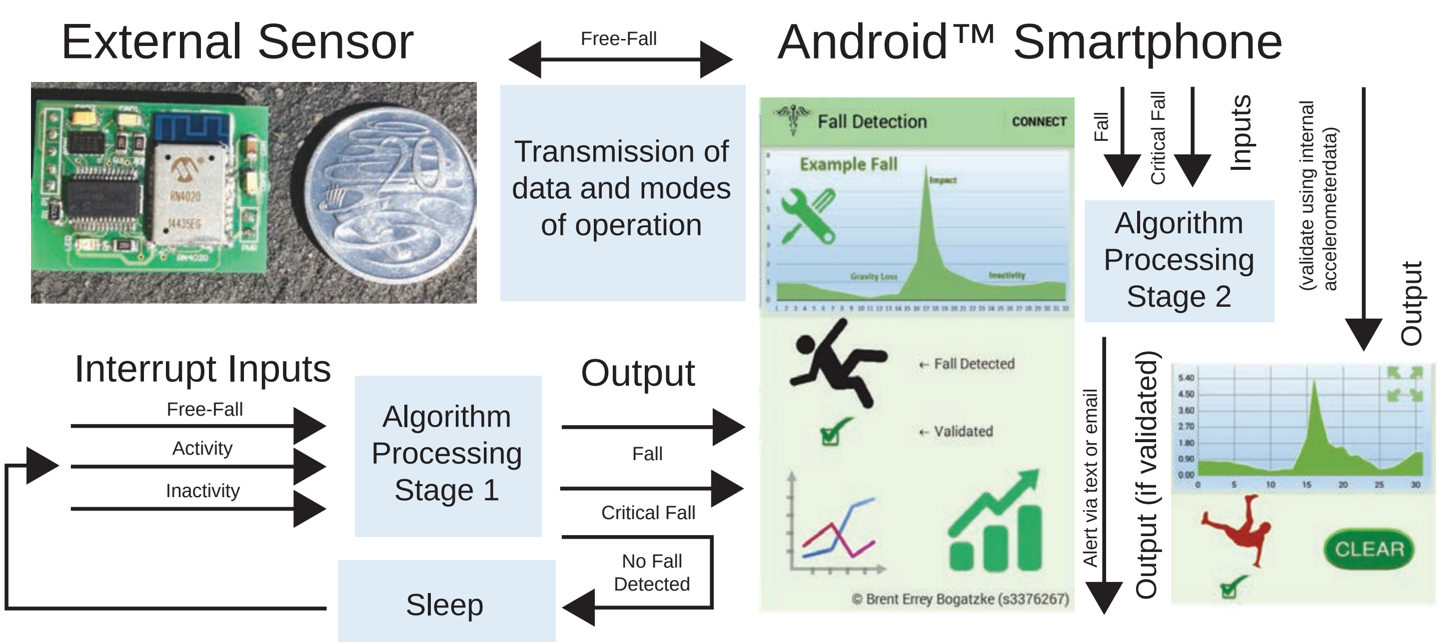

Figure 3 – Fall Detection System Diagram

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Testing the Design's Accuracy

To substantiate and confirm the accuracy of the algorithm developed for this fall detection system, approximately 316 tests were performed by exposing a young test subject to a wide variety of common falling situations with the selected distribution based on existing research. According to the results of these tests, the dual-staged algorithm presented an accuracy of 97.5% and achieved a high level of specificity (100%).

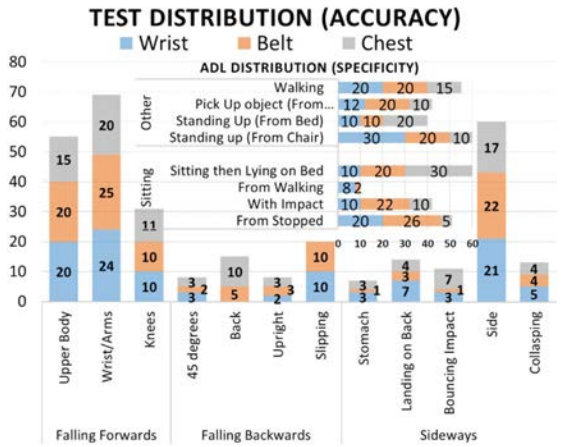
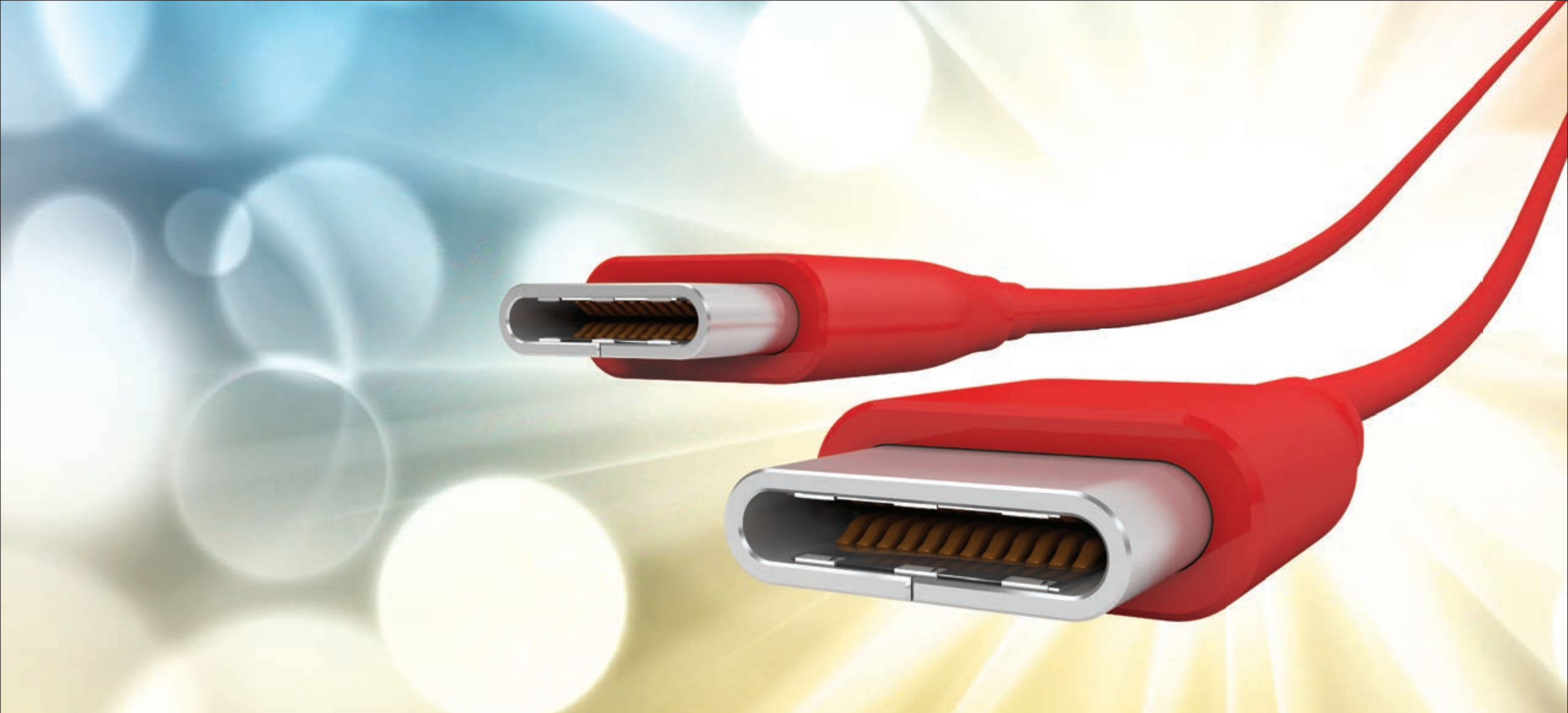


Figure 4 – Fall Detection System Testing Results

Testing was performed with the system located in three separate locations on the test subject—wrist, belt and chest—resulting in a detection accuracy of 94.6%, 99.1% and 98.8%, respectively. However, these results would need to be confirmed in real clinical trials with a wider demographic of test subjects to guarantee this level of accuracy.

As the population ages in a number of societies, this type of system can eventually lead to smaller, more accurate and more power-efficient devices to help address the growing need to record, report and quickly respond to falls.

Brent Bogatzke is an electronics engineer who recently graduated from RMIT University in Melbourne, Australia, with a Bachelor (Honors) in Electrical/Electronic Engineering. He developed the design described in this article as his final year research project. He enjoys programming, hardware design and sensor-based applications, primarily focusing on power-efficient design methods.



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