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NOV/DEC 2016

Security in the Cloud

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Preparing a New Generation of Engineers

Post-secondary engineering education is going through a period of transformation. The Maker movement is providing many students with learning opportunities and hands-on experience with embedded technology long before they arrive on a university's campus. With this in mind, many schools are looking for ways to offer hands-on approaches to learning much earlier in their standard engineering curriculum. Easy-to-learn prototyping tools can keep students engaged and help fuel the creative process when developing capstone and graduate projects—not just in electrical engineering, but also in other concentrations like mechanical and biomedical engineering.

Schools are looking for ways to show these young makers how to take their prototypes to production and, utilmately, to market. Collaborations between business schools and engineering colleges are giving rise to a new breed of pragmatic entrepreneurial courses. Universities are building Maker labs and sponsoring incubators to help students develop projects with an eye to the market. This allows engineering students to apply their knowledge to create practical designs that include business considerations before they actually enter the workforce.

Microchip's Academic Program has been ramping up resources to help educators meet the challenges of educating this next generation of engineers. We have a wide range of tools and technologies that are particularly well suited for use in the classroom and lab, including many new additions from our acquisition of Atmel® that are now being integrated into our product portfolios. Our chipKIT® and Xplained development boards and tools can be used with highly abstracted prototyping environments like Arduino® to allow students to quickly develop their ideas. They can also be used with MPLAB® X IDE and Atmel Studio, enabling students to take their projects to a more industrial level while learning about the more professional tool chains they will use in their careers.

We are ready to help educators provide this next generation of engineers with the skills and knowledge they need to improve our world. Visit our **Academic Program page** to learn about our many resources and to join our Academic Partner Program.

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

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SECURITY IN THE CLOUD

Microchip Collaborates with Amazon Web Services to Facilitate Mutually Authenticated IoT Connections with Cloud Servers

Securing the Internet of Things (IoT) is fraught with complex design challenges. After safeguarding the data inside an IoT gateway or node, the next frontier for system designers is securing device communication with cloud servers. Recognizing this important requirement, Microchip has recently collaborated with **Amazon Web Services (AWS)**—the world's largest cloud services provider—to develop an end-to-end security solution for devices that connect to **AWS IoT.** This convergence of Microchip's embedded networking technology and the AWS cloud helps pave the pathway for implementing security and cryptography during the early stages of an IoT product's development. It adds a high level of security, simplifies the supply chain, and is now one of the fastest and easiest ways to connect your design to AWS IoT.

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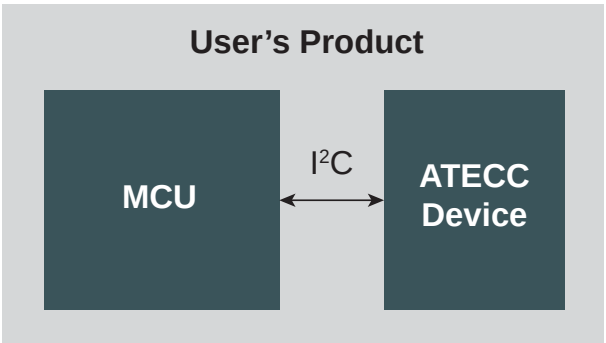
No need to worry – build a secure and scalable IoT solution for deployment on the AWS cloud.

In order to comply with AWS IoT's mutual authentication security model, an IoT device manufacturer must preregister their security authority to establish a trust model. Next, they must generate unique cryptographic keys that are mathematically linked to the preregistered security authority to establish a trust model. Finally, these cryptographic keys have to remain secret for the entire life cycle of a device. This process ensures a high degree of security, but can introduce or increase complexities in the manufacturer's supply chain, especially when third parties offer different trust and compliance levels.

Enter the Security Co-Processor

Microchip's IC solution for securely connecting to AWS IoT is the **ATECC508A** security co-processor, a small (3×2 mm) device that comes preloaded with cryptographic codes and unique keys to ensure that data is safely transmitted from an IoT device to the cloud. It uses Elliptic Curve Cryptography (ECC) technology to create secure hardware-based key storage and ensures mutual authentication with the use of Elliptic Curve Digital Signature Algorithm (ECDSA) techniques and key agreement with Elliptic Curve Diffie-Hellman (ECDH) technology. It is well suited for use in IoT devices designed to serve the home automation, industrial networking, medical and other markets.



The ATECC508A offloads cryptographic code and math from the central processor, saving previous CPU cycles.

The ATECC508A safeguards private keys, certificates and other sensitive security data to ensure authentication and protection against threats such as physical tampering, cloning and backdoor attacks. It is also equipped with hardware cryptographic acceleration to carry out strong authentication, which offloads cryptographic code and math from the central processor of an IoT node. This is a vital factor, as most IoT devices consist of a small, 8-bit microcontroller (MCU) and are battery powered. Therefore, they lack the processing and memory resources to meet the security demands of their cost-constrained designs. The ATECC508A saves precious CPU cycles that would otherwise be required to accelerate the authentication of applications and firmware. This is a significant reason why security solutions that are built on top of a microprocessor (MPU) or MCU haven't seen much success in the IoT market. Their compute-intensive authentication slows down the overall device performance.

amazon web services | Partner Network
TECHNOLOGY PARTNER

> The low-cost ATECC508A also simplifies mutual authentication with cloud ecosystems like AWS IoT.

The low-cost ATECC508A security co-processor also simplifies mutual authentication with cloud ecosystems like AWS IoT by eliminating the complexity associated with software-centric security implementations. Dispelling the perception that hardware-based security solutions increase BOM costs—a notion that generally drives IoT developers toward less secure software-based solutions—the ATECC508A delivers significant cost savings by simplifying supply chain logistics.

How it Works

AWS and the ATECC508 device naturally complement each other with comprehensive mutual authentication security capabilities. The device has strong resistance against environmental and physical tampering including countermeasures against

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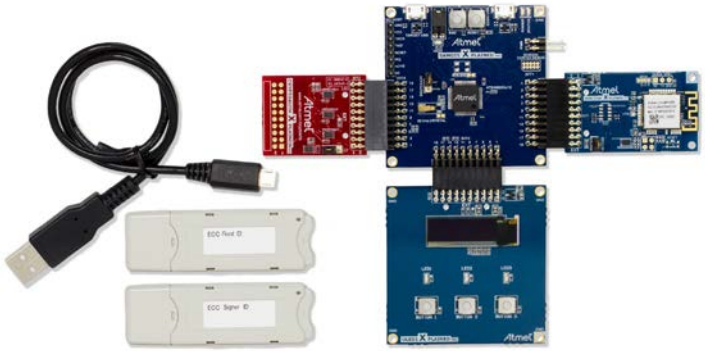
expert intrusion attempts. In addition, the device features a high-quality random number generator, the internal generation of secure unique keys and the ability to seamlessly accommodate various production flows in the most cost-effective manner.

The ATECC508A is simply soldered onto the board and then connected to the host MPU or MCU over I²C. The host MPU or MCU runs an AWS Software Development Kit (SDK) to ensure that the ATECC508A—and the private keys and certificates that come with it—is automatically recognized by AWS IoT. This also allows IoT node-to-cloud environments to be deployed even at smaller scales. To ease your design phase, Microchip provides the **Zero Touch Secure Provisioning Kit for AWS IoT** (AT88CKECC-AWS-XSTK) that allows you to seamlessly connect to the AWS platform while complying with AWS IoT's mutual authentication security model.



Zero Touch Secure Provisioning Kit for AWS IoT (AT88CKECC-AWS-XSTK)

Next, during your prototyping and preproduction phase, the ATECC508A co-processor will generate the individual device identity with unique keys and certificates. When the IoT device connects to AWS IoT, mutual authentication and key provisioning will be automatically carried out. This eliminates the need for you and your OEMs to externally generate keys for each device. The low-cost ATECC508A reduces expenses while accelerating the design-to-production cycle for IoT products.

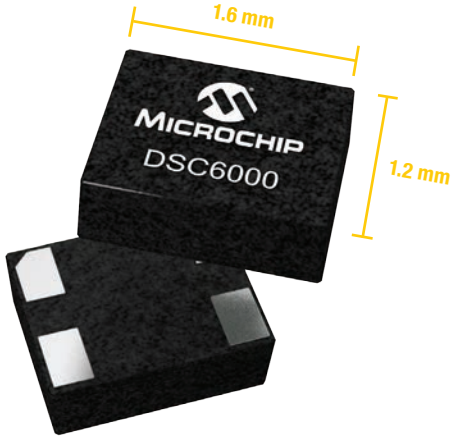
Another crucial advantage of the ATECC508A security co-processor is how it simplifies the manufacturing process and product supply chain. It comes preloaded with unique keys for each device, ensuring that private keys are safe throughout the manufacturing process and that device users can seamlessly connect to cloud servers without any hassle. Alternate approaches to provisioning require a secure supply chain, which means a significant investment in Hardware Secure Modules (HSM) and a secure database infrastructure to store, protect and manage keys. For similar reasons, computer industry-centric Trusted Platform Module (TPM) chips are not well positioned for use in low-cost IoT applications.

If you are ready to start building a secure and scalable IoT solution for deployment on the AWS cloud, you will find all the resources you need at **www.microchip.com/ecc508**. For more information, contact your local **Microchip sales office**.

Perfect Balance

NEW PRODUCT

MEMS Oscillators Provide Best-in-Class Combination of Low Power and High Performance in a Tiny Package



New DSC6000 Family Is Ideal for Internet of Things and Mobile Applications

Micro-Electro-Mechanical Systems (MEMS) oscillators have enormous benefits over traditional quartz-based oscillators, especially as the products in which they are used become smaller and lighter. Space-constrained mobile and Internet of Things (IoT) designs also demand timing solutions that offer small device footprints, low power consumption and precision timing. Microchip offers the industry's most complete MEMS-based timing solutions to meet the most challenging design requirements. As the latest addition to our MEMS oscillator and MEMS clock generator families, the DSC6000 family combines industry-leading low power consumption and the smallest surface-mount packages with exceptional frequency stability and jitter performance over temperature.

The single-output **DSC6000** are the industry's smallest MEMS oscillators with the lowest power consumption over a full frequency range of 2 KHz to 100 MHz. They are excellent choices for use as clock references in small, battery-powered devices such as wearables and Internet of Things (IoT) devices in which small size, low power consumption and long-term reliability are paramount. They also meet the stringent mechanical durability and reliability requirements within Automotive Electronics Council standard Q100 (AEC-Q100), so they are well suited for under-hood applications as well.

These new MEMS oscillators are housed in 4-pin DFN packages as small as 1.6 × 1.2 mm.

> These are the industry's smallest MEMS MHz oscillators with the lowest power consumption over a full frequency range of 2 KHz to 100 MHz.

These new MEMS oscillators are housed in 4-pin DFN packages as small as 1.6 × 1.2 mm and consume just 1.3 mA (typical)—less than half the current consumption of the lowest-power quartz-based oscillators. They also have a maximum operating temperature range of –40° C to +85° C and ±25 ppm maximum drift over this range. They can sustain 500 times more shock and five times more vibration than a quartz oscillator, ensuring rock-solid stability in most operating environments.

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Development Support

NEW PRODUCT

ClockWorks® Configurator is an online configuration and sampling tool that will help you easily select the right oscillator for your design in terms of frequency, package size, ppm and temperature range. We also offer the **TimeFlash Field Programming Kit**, which provides instant frequency generation by fusing the One-Time Programmable (OTP) memory in a blank DSC6000 part that can be ordered separately. Evaluation boards programmed to your specifications are also available upon request through any Microchip sales representative or authorized worldwide distributor.

To learn more about the DSC6000 family of MEMS oscillators, visit **www.microchip.com/DSC6000**. The DSC60XX and DSC61XX are in production and can be ordered from **microchipDIRECT** or from **Microchip's worldwide distribution network**.

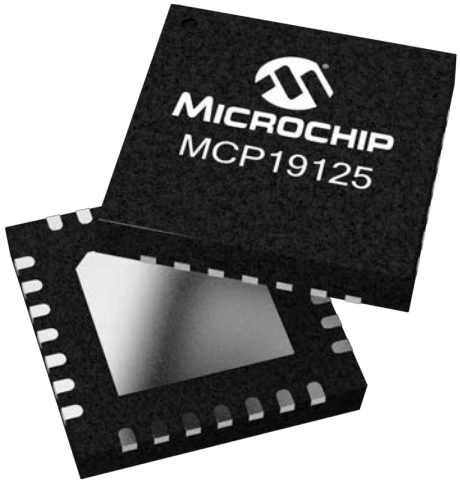
Parameter	Microchip		SiTime	Epson	TXC
	DSC6XXX	DSC1001	SiT8008	SG-210	8N
Frequency	2k–100 MHz	1–150 MHz	1–110 MHz	1–75 MHz	4–54 MHz
Temp. Range (°C)	-20 to 70 -40 to 85	-20 to 70 -40 to 85 -40 to 105	-20 to 70 -40 to 85	-20 to 70 -40 to 85 -40 to 105	-20 to 70
Stability (ppm)	±25/±50	±10/±25/±50	±20/±25/±50	±25/±50/±100	±25/±50
Package Size (mm)	1.6 × 1.2 2.0 × 1.6 2.5 × 2.0 3.2 × 2.5	2.5 × 2.0 3.2 × 2.5 5.0 × 3.2 7.0 × 5.0	2.0 × 1.6 2.5 × 2.0 3.2 × 2.5 5.0 × 3.2 7.0 × 5.0	2.5 × 2.0	2.0 × 1.6
Supply Voltage (V)	1.8 to 3.3	1.8 to 3.3	1.8/2.5/3.3	1.8 to 3.3	1.8/2.5/3.3
Supply Current (mA)	1.3	5	3.7	3	5
Period Jitter (psRMS)	7.5	10	3	N/A	N/A

Table 1: DSC6XXX Family of MEMS Oscillators vs. Comparable Devices

Charging Ahead

NEW PRODUCT

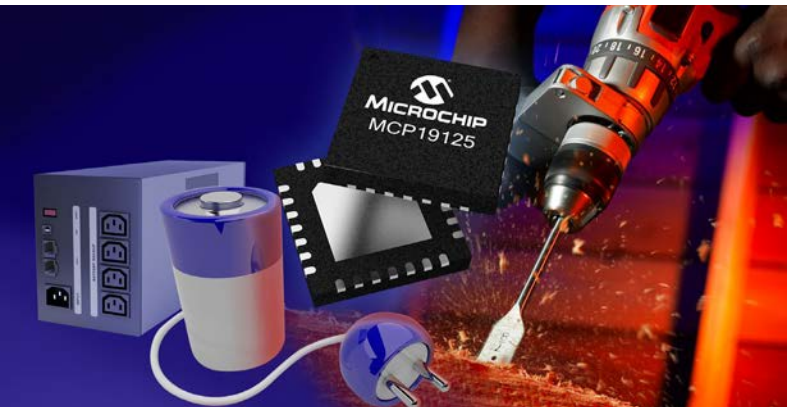
New Digitally Enhanced Power Analog Controllers Improve Digital Support of Battery Charging and DC-DC Conversion Applications



Contain Independent Voltage and Current Control Loops Plus a Full Suite of Configurable Performance Parameters

The need for smarter, more capable battery charging solutions has become vitally important in recent times. Designers have been looking for a product that allows them to run their own proprietary battery charging profiles in compact, customizable charge circuits to meet the demands of their latest applications. In response to this requirement, Microchip has introduced two new **Digitally Enhanced Power Analog (DEPA) controllers** designed to regulate current and voltage, as well as monitor temperature. These new devices, the **MCP19124** and **MCP19125**, improve digital support for battery charging and are ideal for DC-DC conversion in server, consumer, industrial and automotive applications.

The MCP19124/5 are mid-voltage (4.5–42V) analog-based PWM controllers with an integrated 8-bit PIC® microcontroller (MCU). They combine the performance of a high-speed analog solution, including high-efficiency and fast transient response, with the configurability and communication interface of a digital solution. This results in cost-effective, configurable and high-performance power conversion solutions that maximize the strengths of both analog and digital technologies. These controllers enable the development of flexible power supplies that can be customized for your target application while requiring minimal external components.



The MCP19124/5 improve digital support for battery charging and are ideal for DC-DC conversion in a number of applications.

> These controllers enable the development of flexible power supplies that can be customized.

They can handle configurable charging algorithms for any chemistry and offer capabilities for cell balancing and super capacitor charging. No other single-chip battery charging solution that is available today can be configured with any desired charging profile, for any battery chemistry, voltage or cell arrangement. You can also develop your own, unique charging methods and implement them as well. Any voltage, current, temperature or duration can be used to trigger a transition to a new portion of the charge profile. These devices are also well suited for any DC-DC application requiring tight voltage or current regulation and are capable of supporting flyback, boost, SEPIC, or Ćuk topologies.

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The MCP19124 and MCP19125 provide the following benefits:

- A unique combination of independent voltage and current control loops. Either the current control loop can regulate to a specified target current, or the voltage control loop can regulate to a target voltage. Each analog control loop has a separate feedback network for independent pole-zero placement and the ability to perform zero cross detection for quasi-resonant operation.
- The ability to dynamically switch from a voltage target to a current target, or vice-versa, by switching between the two control loops. The internal architecture ensures this transition is monotonic, without glitching or transient events. This control configuration even allows for prepositioning of the output voltage at open or no load conditions, greatly minimizing transients when a load is applied.

NEW PRODUCT

- A full suite of configurable, adjustable performance parameters. These parameters are set in the internal registers of the device (no external components required), and the settings are dynamically adjustable during operation.
- Integrated linear regulator, MOSFET drivers, 8-bit PIC MCU core, analog-to-digital converter, precision oscillator and analog control loops for a compact solution.

The MCP19124, which has nine GPIO pins, is available in a 24-lead 4×4 mm QFN package; the MCP19125 has 13 GPIO pins and is available in a 28-lead 5×5 mm QFN package. You can purchase them from **microchipDIRECT** or your nearest **Microchip sales office**.

NEW PRODUCT

Best in Class

Innovative 5V SAM C Family Features
Integrated Peripheral Touch Controller

Delivers Robust and High-Touch Performance for Home and Industrial Automation

Ready to power the next generation of industrial control and home appliance applications, the **SAM C** is the world's first full 5V ARM® Cortex®-M0+ based microcontroller (MCU) family with an integrated QTouch® Peripheral Touch Controller (PTC). In addition to offering 5V operation, a Direct Memory Access (DMA) controller and a PTC with excellent EMC robustness, these innovative devices also integrate advanced analog capability and offer EMI and ESD protection. With support for the IEC 60730 Class B Safety Library coming soon, SAM C MCUs are the perfect solution for the rapidly expanding smart appliance and industrial markets.

This series of MCUs incorporates a number of intelligent and flexible peripherals and an Event System for inter-peripheral signaling. An innovative Serial Communication Module (SERCOM) is fully software-configurable to handle I²C, USART/UART, SPI, RS485 and LIN communications. The multiple SERCOM modules enable you to tailor the peripheral mix precisely to suit your application.

SAM C MCUs are the perfect solution for the rapidly expanding smart appliance and industrial markets.

> To help develop user-friendly interfaces, the PTC offers built-in hardware support for buttons, sliders, wheels and proximity.

To help you develop robust and user-friendly interfaces, the PTC offers built-in hardware support for buttons, sliders, wheels and proximity. It supports both mutual- and self-capacitive touch without the need for external components and delivers superb sensitivity and noise tolerance, as well as self-calibration, making any user tuning unnecessary.

Devices in the SAM C20 and C21 family offer Flash memory densities ranging from 32 KB to 256 KB and packages ranging from 32- to 64-pin options. They are pin and code-compatible with the SAM D and SAM L series of MCUs. They are fully supported by the free Atmel® Studio integrated development environment, and program examples and drivers for all peripherals are available through the Atmel Software Framework.

(continued on page 12)

Key Features

- Expands the ARM Cortex-M0+ based MCU with hardware divide and square root accelerator at 48 MHz
- Large memories: SRAM up to 32 KB, and embedded Flash up to 256 KB
- Supports 2.7V to 5.5V operating voltage
- Industry-leading peripheral touch controller
- Incorporates proprietary DMA with SleepWalking, Event System and SERCOM
- Dual 12-bit ADCs and a 16-bit Delta-Sigma ADC
- Dual CAN 2.0 with FD support (SAM C21 series)

NEW PRODUCT

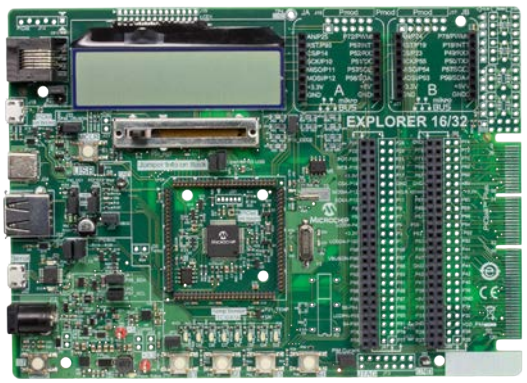
Development Tools

To help accelerate your product development, the SAM C21 Xplained Pro Evaluation Kit includes an on-board embedded debugger and programmer and supports a wide range of compatible extensions boards to help extend the features of the board and ease the development of custom designs.

Visit the **SAM C ARM Cortex-M0+ Microcontrollers page** to learn more and to get started developing your next design.

Explore the Possibilities

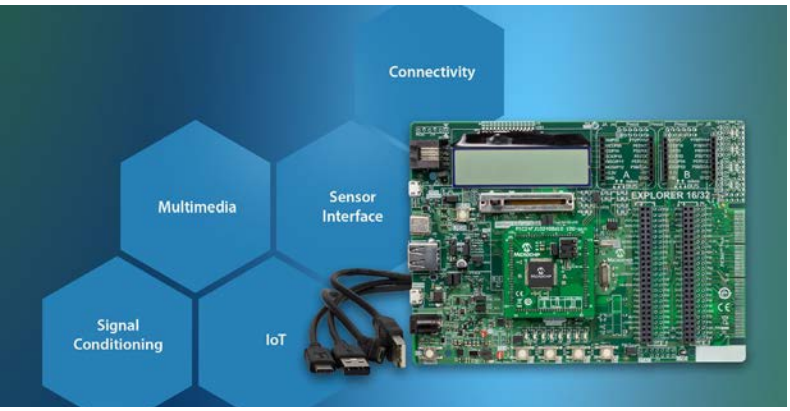
New Explorer 16/32 Development Board Targets 16- and 32-bit PIC® MCUs and dsPIC® DSCs



A Perfect Platform for Discovering the Full Capabilities of Latest Microchip Devices

Today's embedded systems are becoming increasingly complex. To meet the requirements of these challenging designs, Microchip is continually seeking to enhance the capabilities of its 16-bit and 32-bit PIC microcontrollers (MCUs) and dsPIC Digital Signal Controllers (DSCs). As a result, the latest PIC24, dsPIC33 and PIC32 families of devices come with increased performance, advanced Intelligent Analog peripherals and Core Independent Peripherals to take the load off of the CPU and extend functionalities. If you are ready to incorporate one of these 16- or 32-bit devices into your latest design, our new **Explorer 16/32 Development Board** (DM240001-2) is just the right tool to help you become familiar with new peripherals, take the advantage of sophisticated new features and explore new possibilities to succeed with your project.

Supported by a large ecosystem of Processor Plug-In Modules (PIMs), application daughter cards and other accessories, the Explorer 16/32 Development Board is the perfect platform for prototyping and adding new functionalities to a wide range of applications. It serves as an excellent starting point for 16- and 32-bit embedded projects by allowing you to quickly develop a proof of concept before migrating your project to the actual design phase.



The Explorer 16/32 Development Board offers a range of options for evaluating over 45 families of our 16- and 32-bit MCU and DSCs.

Highlights

- Flexible, convenient and ready to start
- Processor plug-in modules
- Integrated programmer/debugger
- USB for powering and communication
- Large ecosystem with hundreds of accessories

One-Stop Tool for All Your Prototypes

To meet the myriad of requirements of your embedded designs, the Explorer 16/32 Development Board offers a range of options for evaluating over 45 families of our 16- and 32-bit MCUs and DSCs that will help you select and easily add functions to your prototype. The many available **PIMs** enable easy swapping of devices and exploration of their innovative features. Expand your hardware and add new functionalities—like communications, graphics, audio, biometric scanning, Machine-to-Machine (M2M) capabilities, and much more—to your prototype by using the PICtail™ Plus and mikroBUS™ interfaces to add hundreds of plug-n-play **PICtail™ Plus daughter boards** from Microchip and **click boards™** from MikroElektronika. To reduce your design cycle time and eliminate hassles, the board comes with an extensive array of software libraries and code examples.

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More than Just a Board

The Explorer 16/32 Development Board provides a complete and cost-effective platform for all your embedded designs. Designed to expand its capabilities as your needs grow, it can be operated as an all-in-one development platform or it can be customized to suit your specific needs. It is developed to take full advantage of the **MPLAB® X Integrated Development Environment (IDE)**, **MPLAB Xpress cloud-based IDE** and **MPLAB Code Configurator**. The board also includes an integrated PICkit™ On-Board (PKOB) programmer/debugger and USB interface for powering the board and serial communications.

Updated and Backward Compatible

Over the years, the **Explorer 16 Development Board** (DM240001) has been one of Microchip's most popular development tools. Incorporating many new features and advanced capabilities at a reduced cost, the new Explorer 16/32 Development Board is poised to offer you endless possibilities for developing exciting and innovative projects. It is completely backwards compatible with the classic Explorer 16 Development Board by allowing you to use existing codes, libraries, prototypes, PIMs and PICtail Plus daughter cards interfaced via its side PICtail Plus connector. Migration is simple. You can reuse PICtail Plus daughter cards interfaced via the vertical PICtail Plus connector using the **PICtail Plus Expansion Board** (AC240100), which is sold separately.

Getting Started

We have made it easy for you to get started with your embedded application using the Explorer 16/32 Development platform. For an out-of-the box evaluation and quick prototyping experience, choose the **Explorer 16/32 Development Kit** (DM-240001-3). This kit comes with all the necessary components to get started: the main development board, a 16-bit **PIC24FJ1024GB610 PIM** (MA240023), a USB A to micro-B cable and a USB A to USB Type-C™ cable. If you want to customize your development platform based on the PIC MCU or dsPIC DSC of your choice, the **Explorer 16/32 Development Board** (DM-240001-2) provides just the main board and you can then select and purchase the PIM you need separately.

Explorer 16/32 Development Board with PIC24F1024GB610 Plug-In Module (DM240001-3)

Explorer 16/32 Development Board (DM240001-2)

Visit **microchipDIRECT** to purchase the Explorer 16/32 Development Board and many other related products.

USB Type-C and USB-C are trademarks of the USB Implementers Forum.

Feature	Classic Explorer 16 Board	New Explorer 16/32 Board
Device Families Supported via PMS	PIC24, dsPIC® DSC, PIC32	PIC24, dsPIC DSC, PIC32
9–15V DC Power Supply Support	✓	✓
PICkit™, MPLAB® ICD and MPLAB REAL ICE™ Programmer/Debugger Support	✓	✓
LCD, User LEDs, Push Buttons	✓	✓
PICtail™ Plus Expansion Board and Daughter Cards	✓	✓ (Using optional PICtail Plus Expansion Board)
USB Power Support	✓	✓
Integrated Debugger: PKOB	–	✓
On-Board USB for Application	–	✓
USB-to-Serial Communication Bridge	–	✓
Current Measurement Capability	–	✓
mikroBUS™ Interface and Pmod™ Footprint	–	✓

Table 1: Features Available in the Classic Explorer 16 Board Compared to the New Explorer 16/32 Board

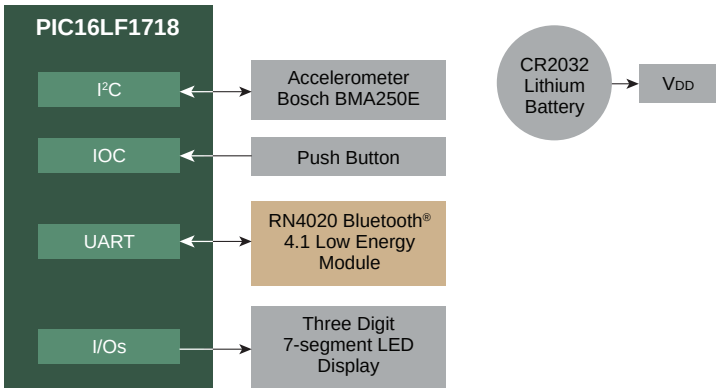
Steps to Success

Design a Low-Cost, Low-Power, Wearable Pedometer with Bluetooth® Low Energy Connectivity

Reference Design Can Be Expanded for Developing More Advanced Activity Tracker Functions

In an era when connectivity is rapidly spreading throughout everyday life in many areas of the world, one of the points of convergence is in the health and fitness market. Consumers who want to increase their physical activity and improve their health are using wearable devices to help them set and meet their fitness goals and boost their motivation. While a simple pedometer can track the number of steps taken, the latest devices provide advanced features that offer users additional ways to monitor their health and collect more data during their activities.

Our **Pedometer Demonstration/Wearable Activity Tracker Development Board** can help you get started with developing a low-cost, low-power digital device that incorporates Bluetooth Low Energy to enable communication with a smartphone or tablet. This device can be worn on the wrist like a bracelet or watch and can count the number of steps a person takes and show this number on its LED display. This reference design can also be used as a development platform for creating products with more advanced activity tracker functions. Additional biometric measurement capabilities can be incorporated using other reference designs that are available from Microchip.



System Diagram for the Pedometer Demonstration/Wearable Activity Monitor Development Board

Powered by a single, 3V Lithium coin cell, the design uses an 8-bit **PIC16LF1718** microcontroller (MCU) which is a cost-effective device with eXtreme Low Power (XLP) technology. This MCU also features capacitive touch channels, a 10-bit Analog-to-Digital Converter (ADC), an 8-bit Digital-to-Analog Converter (DAC), high-speed comparators, an internal voltage reference module and Core Independent Peripherals to offload tasks from the MCU core. The motion sensing capability is provided by Bosch Sensortec's BMA250E Digital Triaxial Accelerometer. When no motion is detected, the MCU goes into Sleep mode and the accelerometer goes into low-power mode to save power. Both devices wake up when motion is resumed. The on-board **RN4020** Bluetooth 4.1 Low Energy Module allows the pedometer to communicate with a smartphone or tablet app to track and display the user's exercise data and any other metrics that are collected.

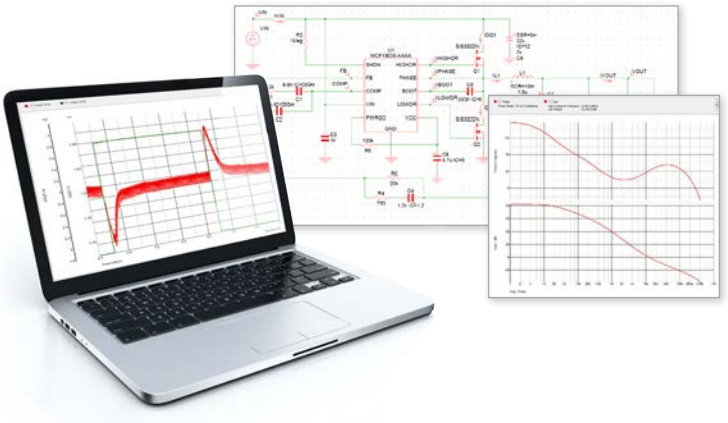
It's easy to get started with your wearable pedometer/activity tracker using the resources you'll find on our **Pedometer Demonstration/Wearable Activity Tracker Development Board page**. From there, you can download the related application note, schematics and C source code that can be modified to meet the needs of your application. Contact your local **Microchip sales office** if you would like to see a working demonstration of this development board.

Fast, Accurate Analog Circuit Simulations

New Downloadable Analog Simulation Tool Reduces Circuit Design Time and Design Risk

As a design engineer, you need as many resources as possible to help you meet your project schedules, reduce design risk and speed your company's product to market. Before you move on to building actual hardware, it is important to ensure that you have identified any potential circuit design problems that might result in lost time or additional cost. To make this process easier, Microchip has recently launched **MPLAB® Mindi™ Analog Simulator**.

This downloadable analog simulation tool reduces your circuit design time and design risk by enabling you to simulate analog circuits prior to hardware prototyping. It uses a SIMetrix/SIMPLIS simulation environment, with options to use SPICE or piecewise linear modeling to cover a very wide set of possible simulation needs. This capable simulation interface is paired with proprietary libraries from Microchip to model specific Microchip analog components, as well as a significant portfolio of generic circuit components. Available for free, this tool can simulate up to 140 circuit nodes, not including the nodes internal to Microchip model files.



This downloadable analog simulation tool reduces your circuit design time and design risk.

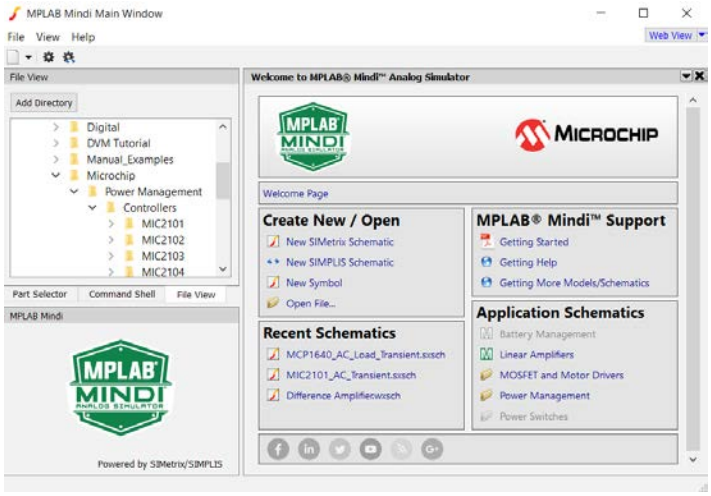


Figure 1: MPLAB® Mindi™ Analog Simulator Launch Window

MPLAB Mindi Analog Simulator has two simulation modes—one for SPICE simulation and one for SIMPLIS simulation—each of which uses different model files. SPICE can precisely track complex nonlinear circuit elements, appropriate for modeling continuous systems and transient behaviors such as analog filters or nonswitching subcircuits. SIMPLIS is appropriate for modeling switching power supplies, with better convergence and faster run times when compared to SPICE. Using these two simulation modes allows you to cover a wide variety of systems or subsystems. MPLAB Mindi Analog Simulator can be used to show steady state, transient or frequency domain responses of analog signal conditioning, motor drive, power supply, sensor

(continued on page 17)

interface, battery management or output drive subsystems. It is a perfect companion to the **MPLAB X Integrated Development Environment (IDE)** and **MPLAB XC Compilers**. You can use these software tools to compile and simulate the firmware for your selected PIC® microcontroller (MCU) and use MPLAB Mindi Analog Simulator to investigate the interface between that firmware and the world outside the MCU, with all its parasitic behaviors, temperature dependencies and tolerances. This can greatly shorten your design cycle, minimize your development risk and/or help confirm hardware behavior for debugging purposes. In addition, Microchip models can be used to create simulations for Core Independent Peripheral behavior to better support our evolving line of PIC MCUs.

Featuring an advanced graphical user interface, the MPLAB Mindi Analog Simulator runs on SIMetrix/SIMPLIS version 8.0. It currently offers model files for approximately 200 circuits and devices that will allow you to simulate projects using:

- Operational amplifiers
- Instrumentation amplifiers
- Active filter circuits
- Half-bridge motor drivers
- PWM and non-PWM power controllers
- Power modules
- LED drivers
- Switching regulators
- Generic switch and passive components included with SIMPLIS/SIMetrix

MPLAB Mindi Analog Simulator is available as a free download and installs and runs locally on your PC. Once downloaded, it can be used without requiring an Internet connection. Since the simulation run time is not dependent on a remotely located server, you get fast, accurate analog circuit simulations that save you time and effort.

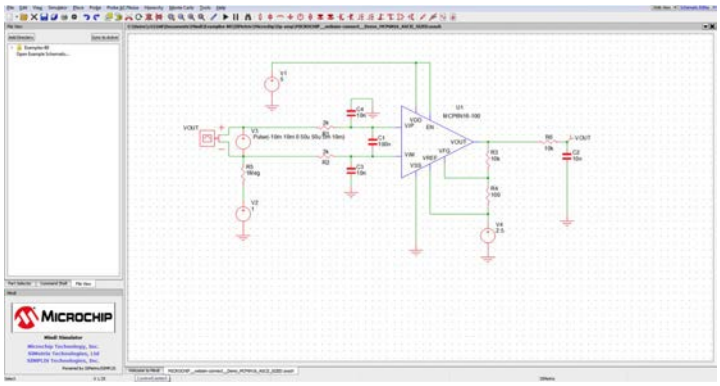


Figure 2: Instrumentation Amplifier Model

Benefits

- Run the simulation tool directly on your own PC; once installed, no Internet connection is required
- Choose from SPICE or piecewise linear SIMPLIS models for accurate results in fast simulations
- Model a wide variety of analog systems using standard or Microchip-proprietary component models
- Generate time or frequency domain responses for open- and closed-loop systems
- Perform AC, DC and transient analysis
- Use sweep modes to identify circuit sensitivities to device behaviors, load variations or tolerances
- Validate system response, control and stability
- Identify problems before building hardware

If you are ready to get started with this time-saving simulation tool, visit the **MPLAB Mindi Analog Simulator page** to download the software, application schematics and device models.

Rolling Along

MOST® Continues to Extend Worldwide Adoption as the High-Speed Networking Technology Developed by Carmakers for Carmakers

Media Oriented Systems Transport (MOST) is the de facto standard for high-bandwidth automotive multimedia networking currently being used in over 200 car models that are manufactured worldwide. Since a MOST network can support multiple data types simultaneously, it enables the car manufacturers to offer system and feature set flexibility for current and future automotive infotainment applications. This also helps reduce the wiring harness weight for easier compliance with environmental regulations.

MOST continues to extend its worldwide adoption as, over the past several months, two major car makers have launched MOST50 implementations in their new car platforms.

General Motors (GM) is using Microchip's MOST50 Intelligent Network Interface Controllers (INICs) to manage the infotainment system networking functions in their global compact car platform. This includes the Chevy Cruze, Chevy Volt, Opel Astra, Buick Excelle and Buick Verano. In addition to these GM compact cars, the synchronous, flexible, and cost-effective MOST networking technology has also been implemented in GM mid-size, full-size, performance, cross-over and SUV, truck and luxury platforms across all vehicle brands. **(More information.)**

Our MOST50 INICs are also powering the infotainment systems of Toyota Motor Corporation's new Lexus GS line of luxury sedans. The new GS line is the latest Toyota brand to use MOST50 in their infotainment system, implemented via our OS81092 INIC. The carmaker is one of more than 30 manufacturers to rely on Media Oriented Systems Transport (MOST) technology to transport video, audio, packet and control data throughout the vehicle. **(More information.)**

In April 2016, the **MOST Cooperation**—the organization through which the technology is standardized and refined—**announced** a procedure to begin the transfer of the MOST specifications to the International Organization for Standardization (ISO). This is being done to make the specifications more accessible through an internationally recognized and accredited standards organization, and establish an international standard that meets the OEM requirements of long-term stability, maintenance and reliability. This action follows international norms for continued development and supports involvement of worldwide stakeholders.

Microchip is the one-stop shop for approved solutions that support all three speed grades of MOST: 25, 50 and 150 Mbps. Our combination of highly integrated mixed-signal integrated circuits and real-time, object-oriented network management software provide the resources needed to implement a complete MOST system design. Visit our **MOST Design Center** to learn more about our MOST networking products.

Defensive Driving

While Automotive Industry Awaits Long-Term Resolution, Solutions Currently Exist to Implement Security in Today's Connected Cars

The automotive industry has a substantial challenge on its hands. Carmakers are incorporating more electronics into automobiles and, at the same time, they are increasingly connecting their cars to the Internet. This opens up the vehicle to a number of security threats—and security is not yet a part of the traditionally closed automotive architecture.

Changes are coming in the long term, but it will probably be several years before new standards materialize. During this time of transition, cars and drivers could be at risk. Therefore, developers need an automotive security solution they can implement today. Secure microcontrollers, Trust Anchor Devices (TAD) and border security devices can provide an intermediate solution. They are straightforward to implement and dramatically strengthen a car's ability to reject any unauthorized or malicious activity.

An Insecure Legacy

Automobiles have been going electronic for many years. Because a failure can result in the loss of life, automobiles are designed differently from other vehicles in the interest of safety. Each electronic function gets its own independent computing resources, bundled into what's called an Electronic Control Unit, or ECU. These ECUs are interconnected by the CAN bus, which was developed for this specific purpose.

Originally, only drive-oriented functions were built and attached to the CAN bus. But new electronic automobile content—specifically, Advanced Driver Assistance Systems (ADAS) and the infotainment "center stack"—has requirements that go far beyond just making sure the car runs efficiently. While some components are more safety critical than others, they're all connected to the same CAN bus.

The addition of infotainment systems to today's automotive designs, in particular, has created a demand to include an Internet connection. Through that connection, a hacker or other individual can attempt to access the CAN bus, opening up a pathway to all of the electronic modules—critical and not—in the car. This potential threat makes security an important consideration for designers. While it might be tempting to place all of the blame on this pathway to a non-mission-critical set of modules, a cellular Internet connection isn't the only possible entry point. Cars will also offer Wi-Fi® and Bluetooth® connectivity as alternate ways to gain entry, and even keyless lock systems and on-board diagnostic systems provide possible access points into the core of the vehicle.

Meanwhile, ADAS software creates complex relationships between various sensors in the car and other actuators. If the car detects a possible collision with the car ahead, it may apply the brakes automatically to slow down faster than the driver can react, avoiding a disaster. The ADAS system must, therefore,

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have access to critical parts of the drive and safety systems. Because the Internet connection exposes all of these systems, this presents another security challenge.

The problem is that the CAN bus architecture has no inherent security. CAN bus performance is also too slow to support adding security on an ad-hoc basis. So, at this point, automobile manufacturers and their suppliers have no guiding principles on how to implement system-wide security without either inventing a massive system themselves or just plugging security leaks one by one as they're found.

While the development of basic ECU software may be moving at a leisurely pace, the amount of ADAS and infotainment code that is currently being developed is exploding. This presents an ongoing challenge to software developers: how can they be sure that they're not creating opportunities for someone to break in and begin toying with the vehicle's critical components?

This is not just a concern within the individual vehicle. Car-to-car communication is critical for ADAS systems to sort out what else is happening on the road and how to appropriately respond to urgent situations. This technically means that all cars within listening range of each other are on the same network, potentially putting each other at risk.

Help Is Coming—Eventually

Change is difficult in an industry where it can take five years for a new concept to go from idea to the dealership floor. Even the very need for implementing security has seen pushback, since it represents a fair amount of work to retool operations to incorporate security features. However, dramatic, real-life instances of vehicles being hacked—as reported in the media—have successfully demonstrated that automotive security really does matter.

Fortunately, the recently approved next generation of the CAN bus standard—CAN FD—offers the performance required to support automotive security. It is four times faster than CAN 2.0 and has a 64-byte payload instead of the 8 bytes that CAN 2.0 provides. CAN FD will support movement away from the highly distributed nature of functions towards a more centralized, controllable structure. ECUs can be merged within domains, with domain controllers acting as firewalls protecting their domain. Ultimately, these domain controllers themselves can be merged, providing a centralized locus for authentication and access authorization. Carefully selected secure microprocessors can manage a secure boot process and enforce isolation and trusted zones to protect against rogue software gaining access to critical resources.

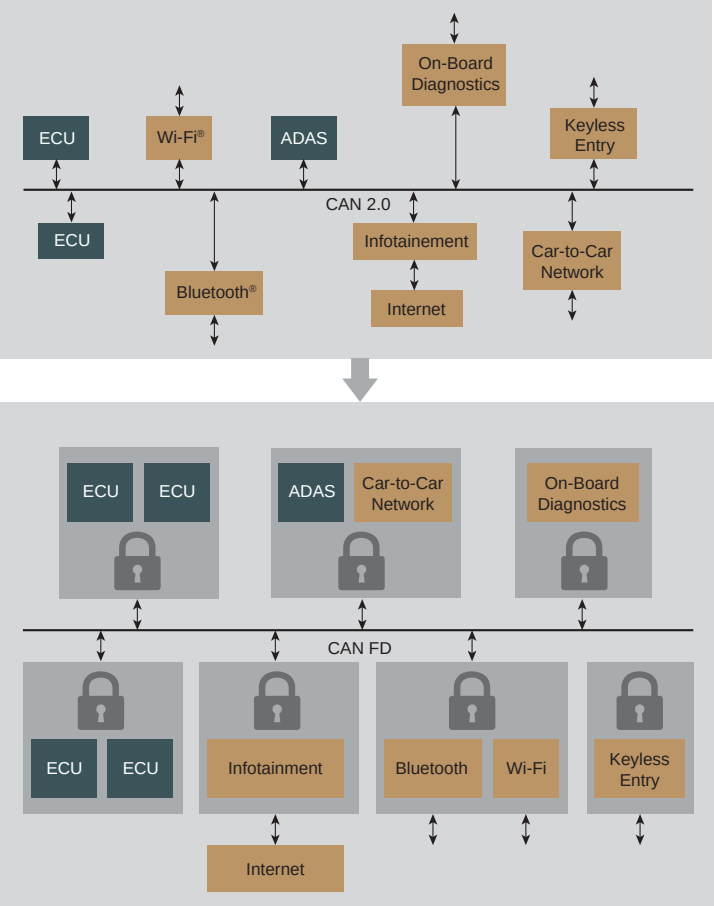

Figure 1: Since security is not available in CAN 2.0, mission-critical ECUs share the same unprotected bus with infotainment and other functions. CAN FD will allow domains, with domain controllers acting as firewalls, to restrict access. Shown above is one way to group the different functions into domains.

Since CAN FD represents a major change to the current CAN architecture, its rollout will involve five to eight years of inspection and evaluation (and possibly resistance), followed by eventual adoption. This is good news for implementing automotive security in the long term. In the meantime, something must be done to protect the cars that will be rolled out before CAN FD becomes the new standard in the industry.

Holding Down the Fort

As CAN FD transceivers are already available today, this provides an opportunity to add security now. This can be done in a number of ways. While secure microcontrollers exist, they are typically higher-end processors that might be out of the price range to meet an ECU's cost constraints. Alternative

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devices that can be used to ensure that each ECU is protected include TADs, which provide crypto functionality, or border security devices, which combine a TAD with a CAN FD transceiver. They can be placed between a processor with a CAN 2.0 transceiver and a CAN FD bus, providing added security while requiring a minimal amount of design change to ECU hardware and software.

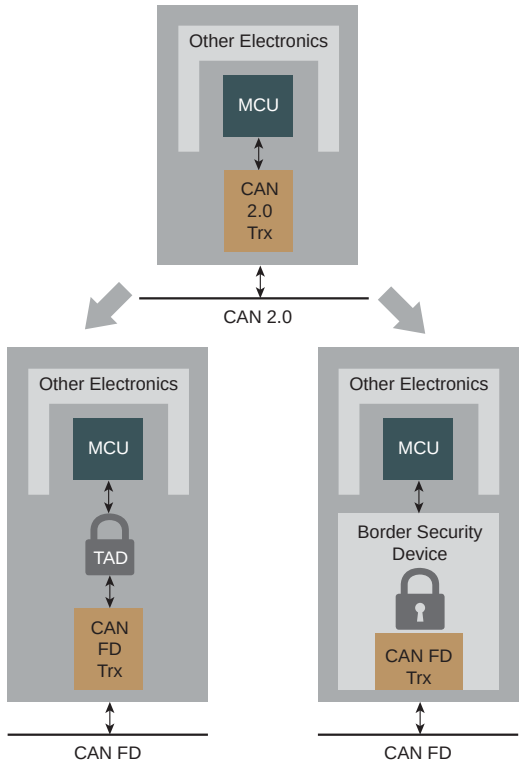


Figure 2: Replacing the CAN transceiver chip with a TAD or a border security device will fortify an existing electronic module even if no other changes are made to the module.

The crypto functionality supports strong authentication to protect access to the ECU. It can also be used to encrypt communication if needed, although most applications only require authentication. For existing modules that use RSA encryption as part of their ad-hoc security scheme, TADs and border security devices will support this functionality. However, newer devices support elliptical curve cryptography, which gives stronger protection and/or allows shorter keys than the older RSA encryption system.

All of the cryptographic functions are executed in hardware, making it impossible to examine cryptography code as it's running. This critical feature also improves performance, reducing any additional overhead needed for security. In addition, a border security device will protect all keys in a manner that makes it impossible for anyone—authorized or not—to see any of the keys. Its tamper-proof features prevent a determined snooper from cracking open the device in an attempt to extract its secrets by brute force or through side-channel attacks.

Security is Available Today

Automobile modules that incorporate TADs or border security devices can help prevent the serious vulnerabilities that are potentially lurking on our roads. Microchip offers a range of CAN FD transceivers, TADs and border security devices so you can add security to your automotive design with minimal software design changes and without significant impact on the cost of the ECU. Please contact your local **Microchip sales office** to learn more about our cryptosecurity solutions for the automotive industry.

Connected HAT

PiJack is the Easiest Way to Add Ethernet to Your Raspberry Pi® Zero

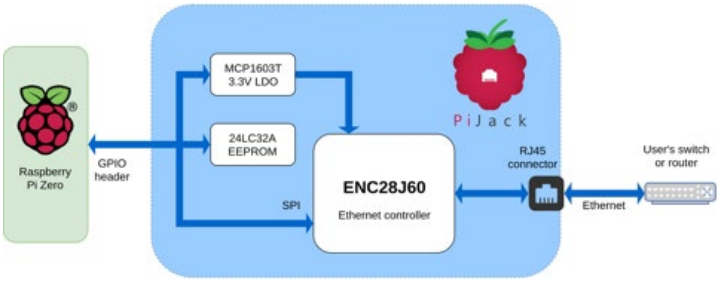
Contributed by Hot Glue Technologies

Get online quickly with your Raspberry Pi Zero. Developed by Hot Glue Technologies, **PiJack** is an add-on board that delivers Ethernet capability to this tiny $5 computer. As a Raspberry Pi Hardware Attached on Top (HAT) device, it fits neatly over the Raspberry Pi Zero or Model A and works right out of the box. Simply attach the PiJack, power it up and the Ethernet controller is automatically detected and configured. Connect the Raspberry Pi to an Ethernet network and, voila, it's online!

Inside the PiJack

At the heart of PiJack is Microchip's **ENC28J60**, a stand-alone Ethernet controller with on-board MAC and PHY. The Raspberry Pi drives the PiJack over SPI and the ENC28J60 connects to Ethernet via a standard RJ45 connector and magnetics.

An on-board 3.3V regulator ensures sufficient current is available to the ENC28J60 without stressing the Raspberry Pi's own 3.3V rail. The HAT-compliant configuration EEPROM completes the board. This I²C ERPROM stores GPIO configuration and Device Tree data, allowing the Raspberry Pi to automatically detect the PiJack, map the GPIO and load the correct drivers for the ENC28J60. The EEPROM also contains the PiJack's unique MAC address, which is passed to the driver as it is loaded.



Although it's a simple and elegant design, a significant amount of design effort was needed to enable the PiJack to work out of the box and make the product a reality. What's even more amazing, this was all done for a product we created by accident.

The Germ of an Idea

Hot Glue Technologies is a small start-up company, focused primarily on building Internet of Things (IoT) devices. Working from our offices in Edinburgh, Scotland, and Bratislava, Slovakia, we had been looking for the perfect device to be a hub in our IoT sensor network, serving to gather data from our low-power, 868 MHz wireless sensor nodes. The Raspberry Pi Zero is that perfect device. It's a tiny, low-cost Linux® computer with enough I/O, processing power and RAM to handle our data. The only feature that we found missing to meet our requirements was good, solid Ethernet connectivity. While we have experience building and using meshing Wi-Fi® networks, Ethernet still cannot be beaten for simple and reliable connectivity.

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After doing some research, we came across the ENC28J60. Because it is an SPI device, it is well suited for use with the Raspberry Pi Zero's GPIO and fits perfectly with the GPIO pins that we planned to use for our RF module and other I/O. Even better, there's already a driver for the ENC28J60 available in the mainline Linux kernel.

To test the ENC28J60 with the Raspberry Pi Zero, we followed the documentation and reference layouts and quickly designed a rough HAT PCB to try out the controller and the driver. We built one prototype, and it worked the first time. Spurred on by this success, we started to integrate the device into our IoT products. At that point, we realized that adding Ethernet to a Raspberry Pi Zero would appeal to others too. We decided to launch a Kickstarter campaign to allow us to build our simple HAT board, calling it PiJack.

Making it Happen

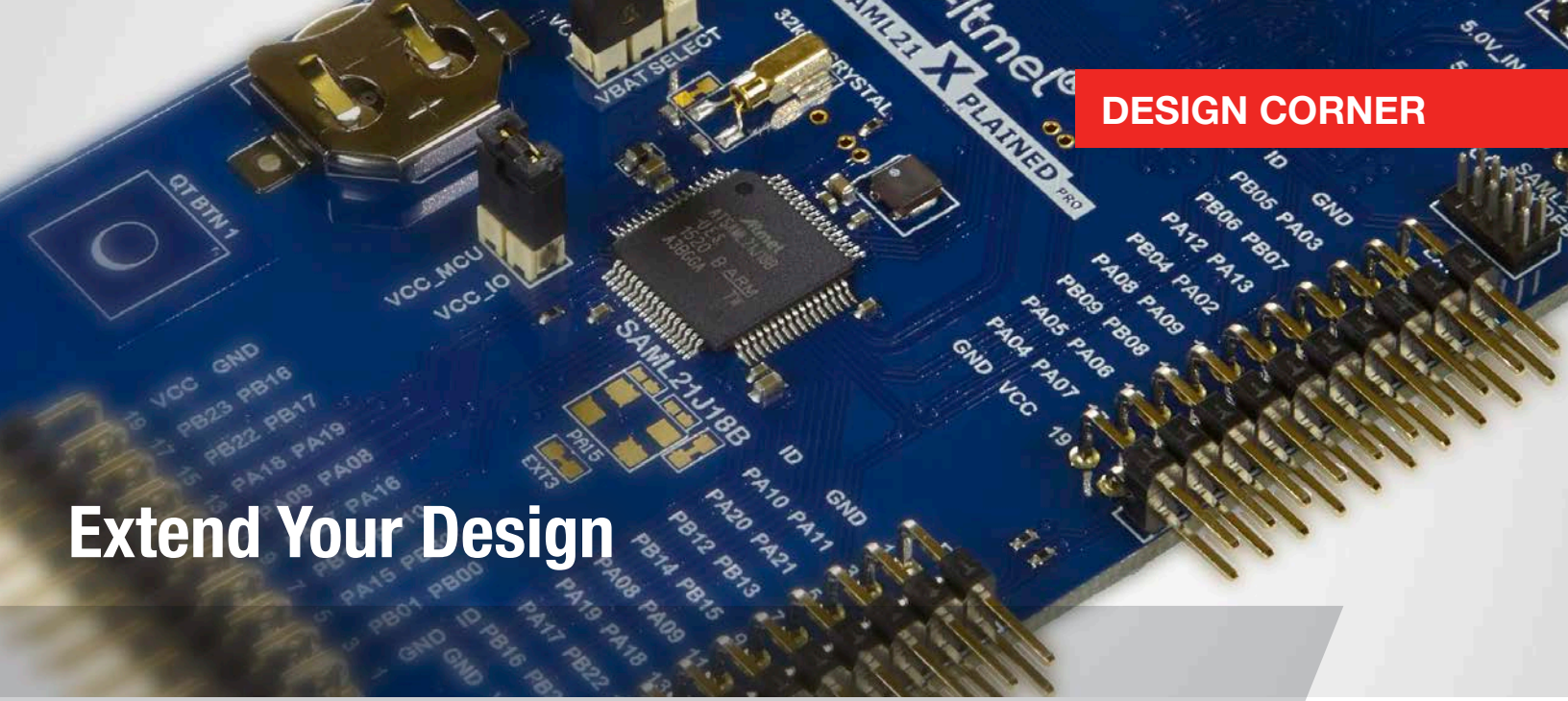
Interest in our Kickstarter campaign was strong. However, while 96 backers signed up, we didn't quite manage to make our target. At that point, we assumed we'd be heading back to our other projects, until we received an interesting message from Ian Saturley at Microchip. Ian looks after the company's USB and networking products and was intrigued by our design. He wondered if he could help us bring PiJack to reality.

Working with Ian and Microchip's technical support team, we were able to move forward and refine our design to improve its usability and reduce the cost, making the product viable. Microchip's LANCheck online design review service helped us by checking over our board's Gerber files to make sure we had complied with the recommended layout for the device, giving us confidence our board would work. With Ian's help, we tested PiJack for compliance with IEEE Ethernet standards and have now moved into full production.

We also invested time in understanding the Raspberry Pi HAT auto-configuration system. Based on that work, we were able to ensure that the Raspbian Linux can autoload the correct driver on boot without any user interaction. We've also loaded each PiJack with a unique MAC address, making for reliable networking across reboots.

To guarantee performance and reliability, we've sourced components from microchipDIRECT, specified quality connectors and built PiJack in Europe. We've overseen our boards being assembled at a Slovak factory that is more used to manufacturing automotive and telecommunication components.

All of this adventure began because PiJack scratches our own itch to add Ethernet connectivity to one of today's cheapest computers. If you'd like to connect your Raspberry Pi Zero-based project to the Internet, visit **pijack.net** for more information and to buy your own PiJack. We'll see you and your Raspberry Pi online!



Extend Your Design

Xplained Pro Development Environment Makes It Easy to Customize Applications Using AVR® and SMART ARM®-based MCUs

The **Xplained Pro** is one of the most successful families of development tools for Microchip's AVR and SMART ARM-based microcontrollers. Featuring up to three generic, platform-specific, 20-pin connector interfaces, these low-cost and easy-to-use evaluation kits support a number of extension boards that have been developed over the past two years. These extension boards are a great way to add vertical, domain-specific development tools to the Xplained Pro family.

Using the CMSIS-DAP-compliant Embedded Debugger (EDBG), the Xplained Pro board will automatically be detected and identified by the **Atmel® Studio Integrated Development Platform** (IDP), when connected to the PC. Once the board is connected, the EDBG gets enumerated in one of two modes: EDBG Data Gateway Interface (DGI) device and EDBG Mass Storage device. (Note: EDBG Mass Storage mode is not supported on all Xplained Pro boards.)

While the DGI is used for debug and data visualization functions, the mass storage mode works as an intuitive programming tool. Copying a hex file or a binary into the mass storage device is all that is required to program it to the Flash memory of the host MCU.

Atmel Studio's Data Visualizer plug-in helps plot the debug data stream from the host MCU through the EDBG's DGI. The Data Visualizer can be set to render multiple streams of data in real time, keeping the most recent data on screen, with an option to save captured data to a file. It is an extremely useful tool for quickly analyzing and debugging your embedded application. The Data Visualizer is also able to graphically visualize the power consumption of the application running on Xplained Pro boards equipped with the Xplained Pro Analog Module (XAM).

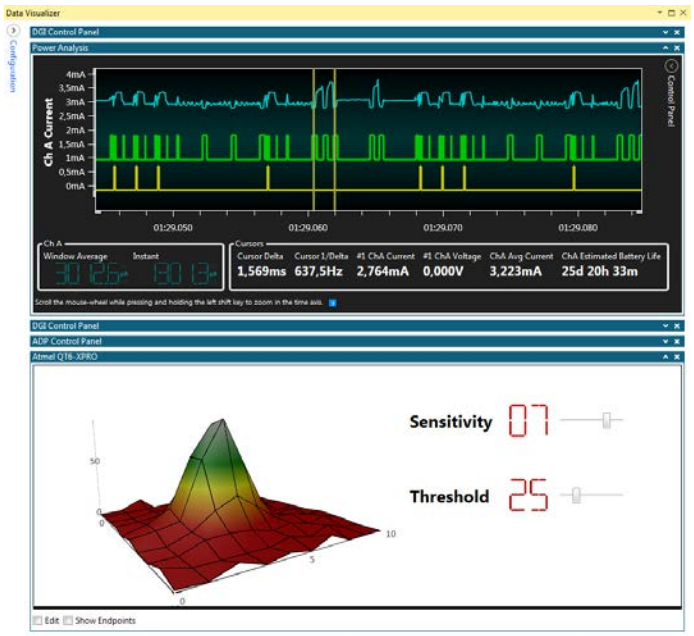


Figure 1 - Sample Data Visualizer Screen

If you are the "I want to do stuff on my own" type, then the Xplained Pro family has some cool extensions like the

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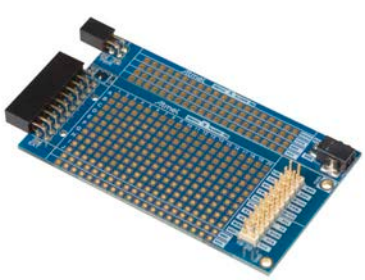
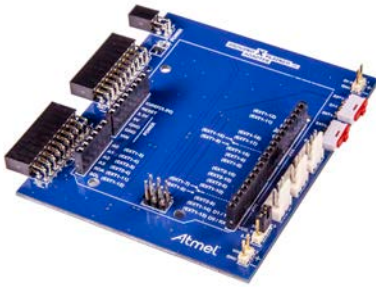
ATI/O1-XPRO with a light sensor, the **ATBNO055-XPRO** with a 9-axis absolute orientation sensor and RGB LED and the **ATPROTO1-XPRO** breadboard that connects to Xplained Pro. For more fun, there is the **ATOLED1-XPRO** with a display, LEDs and buttons.

For Arduino® fans, the **ATARDADPT-XPRO** is an Arduino adapter board for Xplained Pro. It has a shield socket to connect Arduino shields with the Xplained Pro. The latest Xplained Pro boards even have the Arduino shield footprint available on board. More complex functions like current measurement and application code power profiling are supported in select Xplained Pro boards to develop for and take advantage of industry leading ultra-low power MCUs like the SAM L22 series.

Visit the **Atmel Xplained web page** to learn more about this prototyping and evaluation platform and its many add-on boards.



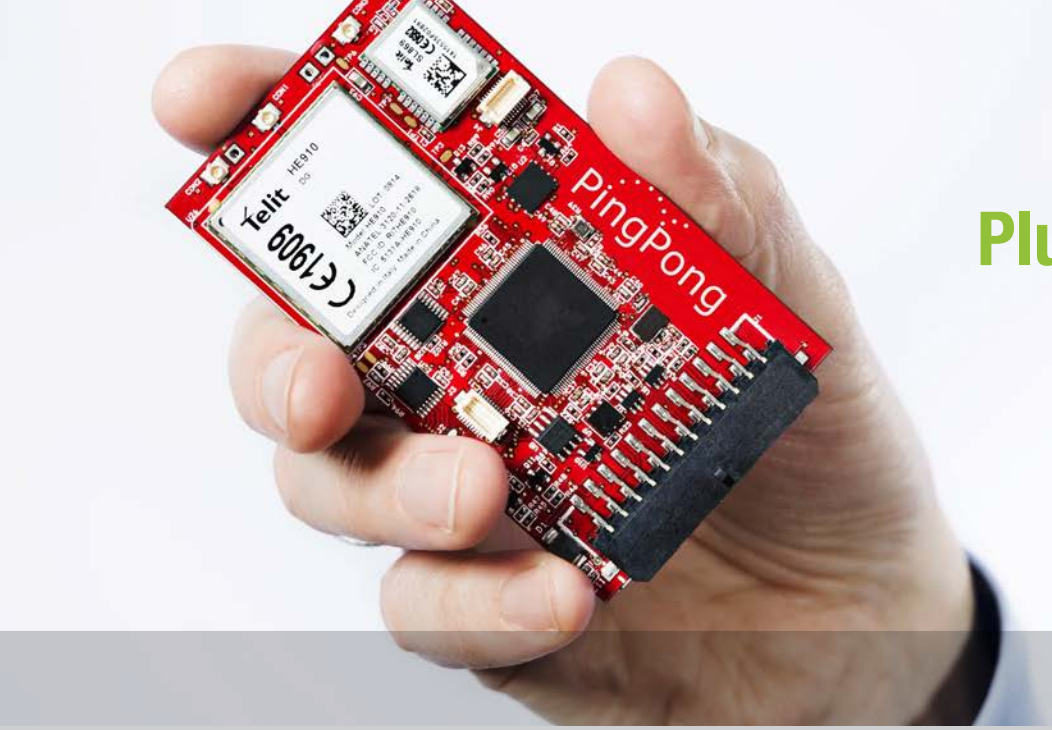
ATPROTO1-XPRO



ATARDADPT-XPRO

ATI/O1-XPRO

ATBNO055-XPRO



Plug, Push and Play

Open-Source and Modular IoT/M2M Hardware Platform Features High-Performance PIC32 Microcontroller

Contributed by Round Solutions

In the fast-paced world of the Internet of Things (IoT), time is money. Getting your design to market quickly is extremely important, but many times, overcoming the development challenges can slow you down. Round Solutions—a Microchip Authorized Design Partner—is a leading supplier of products and services for the industrial market, with expertise in a wide range of wired and wireless technologies. The company's **PingPong IoT Development Board** is an open-source and modular IoT/M2M hardware platform based on the high-performance PIC32MZ Embedded Connectivity family of microcontrollers (MCUs). It supports the addition of a range of extension boards to provide professional firmware/software developers with the ability to quickly and easily design Internet-enabled and mobile communications devices for industrial applications. For ultimate flexibility, the board features both wired and wireless connectivity as well as UART, SPI, CAN and I²C communication buses, making it truly a plug, push and play solution.

A PIC32MZ Microcontroller On Board

The world's fastest 32-bit MCU powers both versions (RTOS and Linux) of the PingPong board. Round Solutions chose the PIC32MZ because it provides industry-leading performance of 330 DMIPS and 3.28 CoreMarks®/MHz, plus up to 2 MB dual-panel Flash for live-update support and large RAM (512 KB). Its connectivity peripherals—which include a 10/100 Ethernet MAC, Hi-Speed USB MAC/PHY and CAN ports—enable the development of connected industrial applications. It also incorporates an SQI™ interface and the most serial channels available on a PIC32 MCU. The PIC32MZ also has class-leading code density that is 30% better than competitive products. Rounding out the PIC32MZ's high level of integration is a full-featured hardware crypto engine with a random number generator for high-throughput data encryption/decryption and authentication such as AES, 3DES, SHA, MD5 and HMAC.

Develop innovative IoT applications using this modular IoT hardware platform.

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Modular and Customizable

In addition to the PIC32MZ MCU, the PingPong base circuit board also includes a high-speed Telit cellular module and a high-accuracy positioning component for the Global Navigation Satellite System (GNSS). It also includes Ethernet, USB and CANBus interfaces. The Evaluation Kit comes with a dedicated M2M/IoT SIM card to enable connectivity to a cloud platform. Using one or more of the available extension boards, you can add Wi-Fi®, Bluetooth®, I/O, Iridium satellite communication, Radio Frequency (RF), and NFC/RFID to your design. This connectivity format provides a plug-and-play solution that works as soon as the extension board is plugged onto the base board. You can instantly begin developing applications for sensor reading, asset tracking, routing, metering/telemetry and security surveillance, just to name a few. Round Solutions can also develop specific firmware applications for the PingPong board or produce special, cost-reduced versions that eliminate unused components to meet your design's specific requirements.

Firmware and Software

The PingPong's open-source firmware and software enable quick customization to speed up a project's time to market. The board is available in two open-source software versions. The RTOS version running in C/C++ is intended for professional C-firmware developers and features a very fast boot time. It is compatible with Microchip's **MPLAB® Harmony** integrated software framework. The Linux® version is intended for applications that require an OS to run to deliver additional performance and functionality. This version offers additional options, such as Open VPN and IPSEC tunnels for router functionality.

Microchip's **MPLAB X IDE** and **MPLAB XC32 complier** are recommended for developing applications and modifying the firmware. Also, Microchip's MPLAB Harmony integrated software framework allows you to easily configure peripherals and use different stacks in your project. MPLAB Harmony comes with a set of examples that demonstrates the use of all the peripherals integrated into the PIC32MZ2048ECM144 MCU.

Round Solutions also offers the following ready-made software packages and libraries for use with both PingPong boards:

- Remote metering
- Asset tracking
- Wi-Fi/Bluetooth gateway
- MODbus over TCP
- MODbus over RS485

Cloud Connectivity

Complete and ready-to-use access to the cloud is provided by the Telit IoT Portal and the Cumulocity IoT Cloud Platform. A graphical user interface—accessible through any web browser or via mobile devices like smartphones and tablets—allows a range of sensor data to be easily collected and sent to the cloud, providing a number of different ways to monitor, visualize, remotely maintain and control the PingPong board. The included IoT connectivity SIM card ensures stable data transfer between the PingPong board and the cloud, enabling "always on" connectivity for remote applications.

A Sample Application

Versatile and flexible, the PingPong platform offers a wide range of features to meet the demands of many industrial designs. It can be used in applications that target a single function or for applications that combine several technologies within one instrument. For example, a PingPong-based system can be used to monitor the temperature in a refrigerated truck. A temperature sensor can be connected to the PingPong board via the I/Os and the temperature data can be sent to the cloud. This application can be extended by adding GPS monitoring to track the truck's movements. The PingPong board can also be connected to the CAN interface to monitor the driving time or the vehicle's output data. Adding the Wi-Fi or Bluetooth expansion card enables alerts to be sent to the driver via smartphone.

If you are ready to get started with developing your cloud-connected industrial application, you can purchase the PingPong IoT Development Board (THW1007) and the PingPong IoT Wi-Fi/Bluetooth Expansion Board (THW1008) from **microchipDIRECT**. Visit the **Round Solutions website** for more information about the PingPong platform.

Tiny and Mighty

Micromite and Micromite Plus Bring a Full-Featured BASIC Interpreter to PIC32MX Microcontrollers for Easy Programming

Sometimes appearances can be deceiving. At first glance, the Micromite and Micromite Plus look like your standard PIC32MX microcontrollers. But, they have a hidden superpower. They have been pre-programmed with a free and open BASIC interpreter for 32-bit microcontrollers known as MMBasic. This makes the Micromite and Micromite Plus easy to program while providing access to the many features and capabilities of the PIC32MX MCU. These tiny and mighty devices, the brainchildren of Geoff Graham, can be great starting points for beginners, hobbyists and professionals alike in developing a wide range of innovative projects.

In the Beginning

There's a fascinating back story to the development of the Micromite and Micromite Plus, which you can read about in much more detail in **"The Maximite Story"** article published on the ***Geoff's Projects* blog**. However, here is the very condensed version.

Introduced originally in 2014, the Micromite has its roots an earlier project Geoff created, called the **Maximite**. He had been experimenting with the PIC32 MCU when it was first launched and wanted to come up with an example project that he could share in an article for *Silicon Chip* magazine. Thinking back to the days of the Tandy TRS-80 and Commodore 64, he decided to design a simple, self-contained computer running BASIC. For that, he needed to create an open-source and fully functional BASIC interpreter that could work with a console for text input/output. After a number of weeks trying to work with an existing and rather ancient program called Bywater BASIC, Geoff ended up creating his own interpreter, **MMBasic**, which offers over 200 commands and functions to run with the Maximite. On the hardware side, a PIC32MX MCU running MMBasic managed all the features including 20 external I/O pins, USB 2.0 interface, PS2 keyboard, VGA video (monochrome), sound, SD card, communication protocols and more. After being introduced in *Silicon Chip* magazine, the Maximite became an instant hit, and Geoff introduced a **color version** to give users even more opportunities to come up with some exciting projects. You'll find details on how you can build or purchase your own Maximite on Geoff's blog.

The original Maximite

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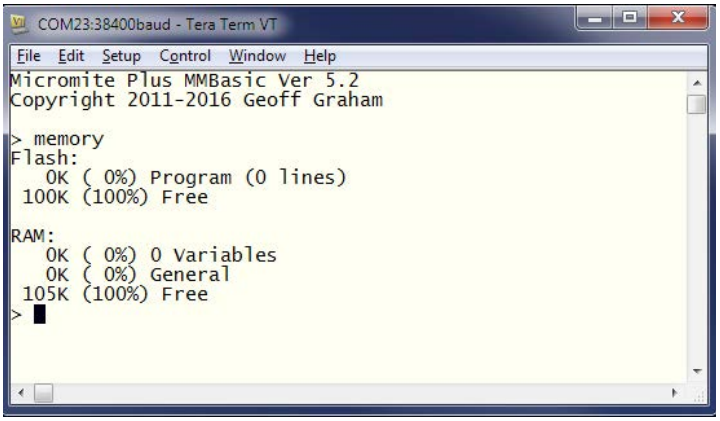
A Free and Open BASIC Interpreter

After its genesis for use with the Maximite, MMBasic found a home in other platforms and has collected a fairly large following of its own. Written in ANSI C, it requires a 32-bit MCU and uses about 94 KB of Flash memory and as little as 16 KB of RAM. The primary emphasis is on ease of use and rapid software development rather than on speed. As an interpreter, it decodes each statement as the program is running, so it is not as fast as a compiled language. On the other hand, this means that you do not need a compiler, operating system or host computer. You just enter your program and run it. It features floating point, integer and string variables; arrays; long variable names; a built-in program editor and much more. It also supports graphics and color and provides commands for loading and saving programs using an SD card. A downloadable MMBasic library, which is a collection of user-written programs that include games, snippets of code and other interesting resources, is also available. A separate **MMBasic website** has been created where you can download the latest version of MMBasic and get other information.

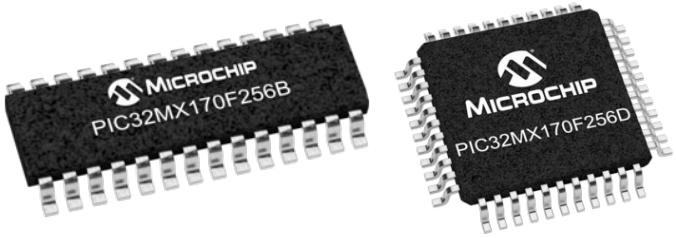


MMBasic Command Prompt

Enter the Powerful Micromite

The next step for Geoff was taking a PIC32 MCU programmed with MMBasic to function on its own outside of the Maximite. He knew that many users were intimidated by the thought of programming a high-performance microcontroller because of the challenges of learning languages like C and assembly and using tools like compilers and other software. MMBasic opens the door for non-programmers to feel more comfortable with customizing their projects. The Micromite and Micromite Plus are simple enough for beginners but offer advanced functionality to make them powerful solutions for professional designs.

The standard **Micromite** is intended as a low-cost way for those just starting to get familiar with 32-bit MCUs. It comes in two options. The PIC32MX170F256B-based Micromite has 19 I/O pins and comes in a 28-pin DIP package which can be easily plugged into a breadboard or an IC socket or easily soldered onto a prototyping board. The PIC32MX170F256D has 33 I/O pins in a 44-pin surface mount package. You'll need to solder it onto a printed circuit board to use it, or you can purchase the Micromite Module—which is available in a variety of forms to meet your needs—from **micromite.org**.



Both devices have 256 KB of Flash memory and 64K of SRAM memory, which are sufficient for fairly large BASIC programs. They are programmed and controlled via a serial console, and a full screen emulator is built in. The Micromite can support TFT LCD panels and their resistive touch controllers, allowing you to use them as sophisticated input devices. The Micromite supports a comprehensive range of communications protocols and offer built-in commands to directly interface to sensors and other special devices for creating innovative projects. There are also up to five PWM or SERVO outputs. Special embedded controller features in MMBasic allow you to vary the clock speed to balance power consumption and speed and put the CPU to sleep. A watchdog feature monitors the running program and can be used to restart the processor if the program fails or gets stuck in a loop. All of these features are internal and the only extra external component you need to get started is a 47 µF capacitor.

The **Micromite Plus** offers all the features and capabilities of the Micromite, but it is up to three times faster, has double the memory and supports more peripherals, including a PS2 keyboard and an SD card for storing programs and data. But its most compelling feature is its support for large (up to 8 inch) LCD panels and advanced graphics and screen controls. This allows you to use the Micromite Plus for even more challenging applications, like industrial controllers. The Micromite Plus uses a PIC32MX470F512 MCU in a 64-pin or 100-pin TQFP, so you will also need to solder it to a board to use it.

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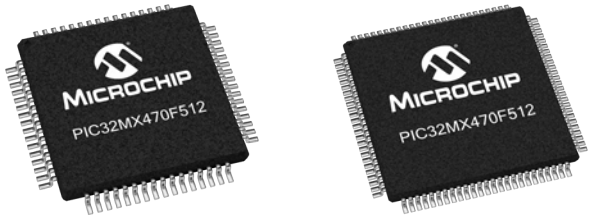
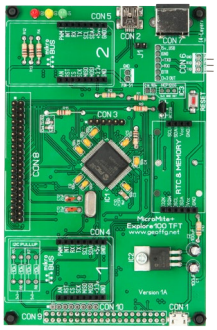


If soldering sounds daunting, there are three development boards that are currently available to help you get started with the Micromite Plus.

The **CGMICROBOARD2 module** by CircuitGizmos features the 64-pin Micromite Plus, an Arduino® compatible socket and supporting circuitry. A company called **Rictech Ltd.** offers the Explore 64 and Explore 100 for trying out the 64-pin and 100-pin Micromite Plus. While the Explore 64 is designed to be plugged into a standard solderless breadboard, the Explore 100 is intended to fit onto the back of a 5 inch LCD panel. It also includes two miKroBUS™ sockets so that you can select from the many click boards™ available from MikroElektronika and add them to your Micromite Plus project.

Explore 64



Explore 100

Micromite Super Clock

The best way to get started with the Micromite and the Micromite Plus is to download the user manuals and firmware. Since they are intended for hobbyists, they are completely free. There is also a wealth of information and resources about the Micromite and Micromite Plus available on the Geoff's Projects blog, including some interesting articles about projects he has created using these little devices. Maybe you'll be inspired to design your own PIC32MX-based project using the Micromite.

Geoff Graham's Introduction to the Micromite Plus

Prioritizing Tasks

RTOS 101: Semaphores and Queues

Contributed by Percepio AB

In the **first article** of our "RTOS 101" series, we described how using a Real-Time Operating System (RTOS) in your embedded software designs makes it easy to divide your code into smaller blocks known as *tasks*. While these tasks can appear to run in parallel and independently from each other, fully independent tasks are rarely possible in practice.

In many cases, tasks need to be triggered by a specific event, for example by an interrupt service routine or by another task requesting a service. Moreover, tasks often need to share hardware resources such as communication interfaces, which can only be used by one task at a time. This is known as *mutual exclusion*, a type of synchronization. Inexperienced developers may try to use global variables, but implementing thread-safe communication is tricky, and a poorly designed solution may fail if a context-switch strikes at a critical point. For instance, consider this situation:

```
1: while (COM1_busy);
   // if busy, wait until free
2: COM1_busy = 1;
3: SendBytes(COM1, data);
4: COM1_busy = 0;
```

The initial loop (line 1) may seem to give exclusive access to the COM1 interface (line 3), but this is not guaranteed. It probably works most times, perhaps often enough to pass all testing. However, if an interrupt strikes after the initial loop on line 1 and before the assignment at line 2, a task-switch might occur. This might enable a second task to get into the critical section before the first task is finished. Implementing a thread-safe critical section requires that you either disable the interrupts or use special instructions for atomic "test-and-set." Taking all this into consideration, it is typically easier and safer to use the synchronization services intended for this purpose. These services, detailed below, provide for safe communication and synchronization not only in between tasks, but also between interrupt routines and tasks.

Common RTOS Synchronization Services

- A **semaphore** is a signal between tasks/interrupts that does not carry any additional data. The meaning of the signal is implied by the semaphore object, so you need one semaphore for each purpose. The most common type of semaphore is a binary semaphore that triggers activation of a task. The typical design pattern is that a task contains a main loop with an RTOS call to "take" the semaphore. If the semaphore is not yet signaled, the RTOS blocks the task from executing further until some task or interrupt routine "gives" (signals) the semaphore.
- A **mutex** is a binary semaphore for **mut**ual **ex**clusion between tasks, to protect a critical section. Internally it works much the same way as a binary semaphore does, but it is used in a different way. It is "taken" before the critical section and "given" right after, remaining in the same task. A mutex

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typically stores the current "owner" task and may boost its scheduling priority to avoid a problem called "priority inversion", discussed below.

- A **counting semaphore** is a semaphore that contains a counter with an upper bound. This allows for keeping track of limited shared resources. Whenever a resource is to be allocated, an attempt to "take" the semaphore is made and the counter is incremented if it is below the specified upper bound. Otherwise, the attempted allocation blocks the task (possibly with a timeout) or fails directly, depending on the RTOS semaphore service's parameters. When the resource is ready to be released, a "give" operation is made, which decrements the counter.
- A **queue** is a FIFO buffer that allows for passing arbitrary messages to tasks. Typically, each queue has just one specific receiver task and one or several sender tasks. Queues are often used as input for server-style tasks that provide multiple services/commands. In this case, the usual design pattern is to provide a common data structure for messages, consisting of a command code and parameters, and use a switch statement in the receiver task to handle the different message codes. If you are using a union structure for the parameters, the parameters can be defined separately for each command code.

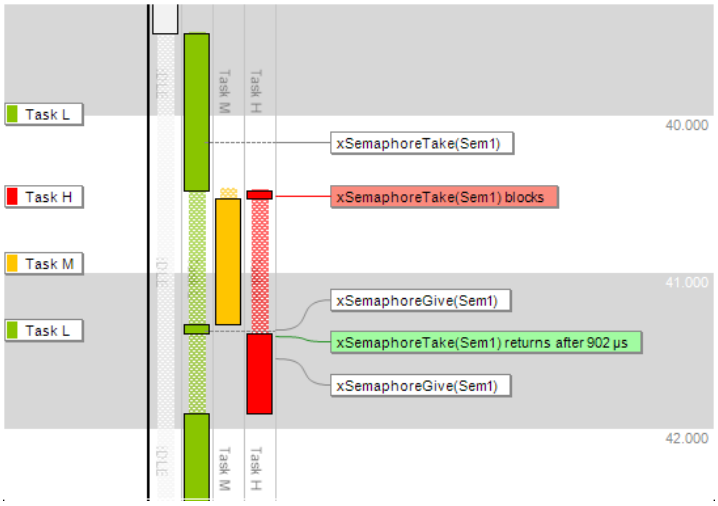

Figure 1: Illustration of a Priority Inversion

Priority inversion was responsible for problems that occurred during the **Mars Pathfinder mission**. This occurs when a higher-priority task is accidentally delayed by a lower-priority task, which is not usually possible in an RTOS that uses fixed-priority scheduling. However, this could potentially happen if a high-priority task ("Task H") needs to take a mutex that is currently held by a lower-priority task ("Task L"). This blocks Task H until the mutex is available. Since a mutex is typically only held for brief durations during a critical section, this is often not a problem in itself.

However, as illustrated in Figure 1, priority inversion occurs when an unrelated medium-priority task ("Task M") comes in and preempts Task L, thereby delaying the release of the mutex that Task H is waiting for. Most RTOSes provide mutexes with "priorty inheritance" or similar protocols, which raise the scheduling priority for the owner task if other, higher-priority tasks become blocked by the mutex. This prevents medium-priority tasks from interfering in the process. Priority inversion can also occur with queues and other similar primitives, as described in **Customer Case 2: The mysterious watchdog reset**.

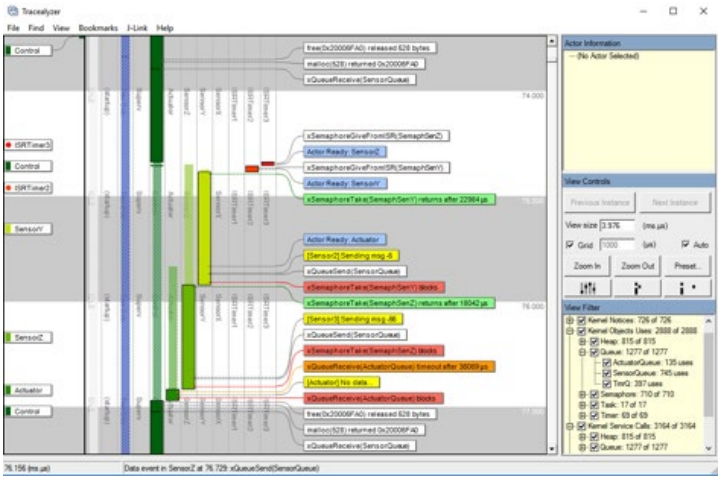

Figure 2: Tracealyzer Main Trace View

Percepio Tracealyzer allows you to see most RTOS calls made by the application—including operations on queues, semaphores and mutexes—in the vertical timeline of the main trace view, in parallel with the task scheduling, interrupts and logged application events.

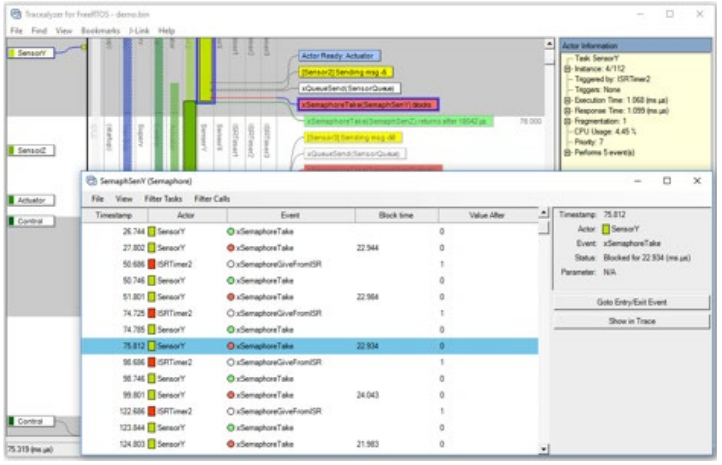

Figure 3: Tracealyzer Kernel Object History View

If you click on any semaphore, queue or mutex operation in the main trace view, the Kernel Object History view opens for the

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selected object, as illustrated in Figure 3, showing a separate timeline with all operations and states of this specific object. You can double-click in this view to find the corresponding event in the main trace view.

For queue objects, you also get a visual display of the number of messages in the buffer at any point, and you can even track messages from send to receive or vice versa. For mutex objects, you see the names of the tasks that currently own them.

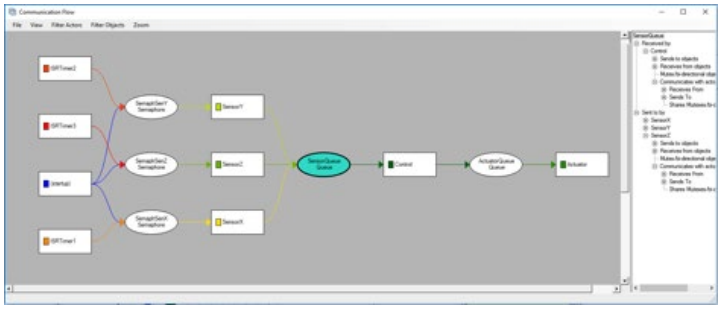

Figure 4: Tracealyzer View of Kernel Objects

Tracealyzer also provides an overview of the interactions between tasks and interrupts via kernel objects such as queues, semaphores and mutexes. This gives a high-level illustration of the runtime architecture based on the trace. You can even generate this view for specified intervals in the trace. An example is shown in Figure 4. Rectangles indicate tasks and interrupts, while ovals indicate queues or semaphores. Mutexes are shown as hexagons. Since binary semaphores are sometimes used as mutexes (when they are taken and given by the same task), the classification of mutexes is made based on their usage pattern. Therefore, semaphore objects may also be displayed with hexagons if they are used like a mutex.

As a superb solution for debugging, validation and performance analysis of RTOS-based embedded software, Tracealyzer provides you with an accurate picture of how the RTOS is executing your application. This includes showing you the interactions between tasks via semaphores, mutexes and queues, as well as blocking and timeouts. It is available for several common RTOSes, including FreeRTOS™, SAFERTOS®, Linux®, VxWorks® and Micrium µC/OS-III®. A version for ThreadX® will be released during 2017.

Download a free trial version of Tracealyzer from **Percepio's website** and visit the "Getting Started" page for additional information. A version of Tracealyzer specific to PIC32 MCUs is available on **microchipDIRECT** at some very attractive price points.

Adding BLE to Your IoT Application Just Got Easier

Energy-efficient and economical Bluetooth® Low Energy (BLE), also known as Bluetooth Smart, was created for the Internet of Things (IoT). This wireless technology is poised to power a wide range of connected applications, from wearable fitness devices to smart homes to the latest entertainment products to in-store advertising using beacons, and more. Now you can build better end applications with lower power consumption using two next-generation BLE solutions. The RN4870 and RN4871 support the latest Bluetooth 4.2 specification and have a Bluetooth stack on board with an easy-to-use ASCII command interface making the devices easy to configure and greatly reducing development time.

Highlights

- User-friendly ASCII Command Interface
- Fully certified to save you additional time and money
- On-board Bluetooth 4.2 Low Energy stack for drop-in connectivity

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Bluetooth 4.2 Module with Shield and Built-In Antenna (RN4870)

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