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Adding Bluetooth® Low Energy to Your Application Just Got Easier
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Happy Birthday PIC10F!

It has been ten years since the debut of the PIC10F family of 8-bit MCUs. Back in 2004 we introduced the first four members of this family: PIC10F200, PIC10F202, PIC10F204 and PIC10F206. Over the years, we’ve significantly increased the capabilities of our 6-pin MCUs with subsequent product releases. Our newest devices in the PIC10F32x family feature our latest Core Independent Peripherals, which give them the ability to perform closed loop control tasks without CPU intervention.

We recently celebrated this milestone by sharing some PIC10F Fun Facts on our social media accounts. For example, did you know that we have shipped over 600 million PIC10F MCUs to customers all over the world in the past 10 years? We also found out that it would take 950 PIC10Fs to cover the 3” x 3” area of a sticky note, approximately 13.33 billion PIC10Fs to circle the earth and somewhere around 35,000 PIC10Fs to hit the one pound mark on a scale.

Often imitated but never duplicated, the PIC10F was the industry's first 6-pin MCU. It is a great problem solver that can be used to help fix issues or bugs created by a different device in an application, as well as for signal inversion, timing delays, feature upgrades and late-stage changes. Uses for PIC10F devices are limited only by your imagination. It ushered in the concept of disposable electronics for use in a variety of products, including fireworks. It can be found in a wide range of kitchen and household appliances. The PIC10F is also very smart. It is the only 6-pin device to feature High Resolution PWM (HRPWM), which is important to lighting as well as other applications.

As the PIC10F moves into its second decade, join us in wishing it many more years of success in a wide variety of designs, including yours!

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

Find us on these social channels:
The Smart Choice

Adding Bluetooth® Low Energy to Your Application Just Got Easier with the RN4020 Bluetooth Smart Module

Offers Integrated Bluetooth 4.1 Low Energy Stack for Use With or Without a Host MCU

Designers of cost-sensitive embedded applications are looking for turnkey solutions that make it easy to add the low power consumption and simplicity of Bluetooth Low Energy (LE) connectivity, which enables several years of operation from a single battery and has a large installed base of compliant smartphones, tablets and computers. They know that longer battery life means happier consumers. If you design low-power wireless command-and-control solutions for applications such as home automation and appliances; medical and wearable devices; toys, tags, fobs and remote controls; pulse and proximity sensor-based systems and even industrial use, the RN4020 Bluetooth Low Energy Module is the smart choice for you.

As our first Bluetooth 4.1 Low Energy module, the RN420 builds on our deep Bluetooth Classic experience.

As our first Bluetooth 4.1 Low Energy module, the RN420 builds on our deep Bluetooth Classic experience and carries both worldwide regulatory certifications and is Bluetooth Special Interest Group (SIG) certified. The integrated Bluetooth Low Energy (BTLE) stack and onboard support for the common SIG low-energy profiles will speed your time to market while ensuring Bluetooth compatibility, eliminating expensive certification costs and reducing development risks. The module is also pre-loaded with the Microchip Low-energy Data Profile (MLDP), which enables you to easily stream any type of data across the BTLE link.

Because the RN4020 is a stack-on-board module, it can connect to any microcontroller with a UART interface, including hundreds of PIC® MCUs, or it can operate stand-alone without an MCU for basic data collection and communication, such as a beacon or sensor. This stand-alone operation is facilitated by our unique no-compile scripting, which allows module configuration via a simple ASCII command interface—no tools or compiling are required.

The RN4020 Bluetooth LE Smart module includes all of the hardware, software and certifications that designers need to easily add this low-energy connectivity to any design, while easing End Product Listing (EPL) via QDID Bluetooth compatibility testing. All of the programmable profiles are stored and selectable on the module, including our flexible MLDP and the common Bluetooth SIG low-energy profiles. In addition to common public profiles, private services can be created via the ASCII command interface. The RN4020 also provides a built-in PCB antenna with 7 dBm transmit power and

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Need Bluetooth® Low Energy?
Get The Complete Solution

- Fully Certified Class 2 Bluetooth® 4.1 Module
- Complete Stack On-board
- Simple ASCII UART Interface
- Small Form Factor

The RN4020 combines our comprehensive experience in user-optimized, low-NRE Bluetooth Classic modules with our industry-leading manufacturing capabilities and support infrastructure to give you a convenient way to add the latest Bluetooth 4.1 wireless connectivity to your designs. The worldwide regulatory-agency and Bluetooth SIG-certified module measures 11.5 x 19.5 x 2.5 millimeters and includes a built-in PCB antenna. It is available today from Microchip’s worldwide distribution network or from microchipDIRECT.

Additionally, the onboard eXtreme Low Power (XLP) PIC18 microcontroller allows the PICtail board to run in stand-alone mode, powered by USB from the host, enabling portable demonstrations and proofs of concept.

Development Support
To assist with your product design, the flexible RN4020 Bluetooth Low Energy PICtail™/PICtail Plus Daughter Board (RN-4020-PICTAIL) enables code development via USB interface to a PC, and over the on-board In-Circuit Serial Programming™ interface for our PICkit™ In-Circuit Debugger or MPLAB® REAL ICE™ In-Circuit Emulator. It also leverages your investment in our existing development boards that have a PICtail interface, such as the Explorer 16, PIC18 Explorer and PIC32 I/O Expansion Board.

a receive sensitivity of −92.5 dBm, enabling operation over 100 meters in a compact form factor of only 11.5 x 19.5 x 2.5 millimeters.
With the Internet of Things growing at a rapid rate, so too are concerns about data security. Protecting embedded data as well as extending battery life are not an option, but a necessity for designers of the latest battery-operated and portable applications for the IoT.

We've recently expanded our line of eXtreme Low Power (XLP) PIC® microcontrollers (MCUs) to include a new family of devices which feature an integrated hardware crypto engine, a Random Number Generator (RNG) and One-Time-Programmable (OTP) key storage for protecting data in embedded applications. These PIC24F “GB2” devices offer up to 128 KB Flash and 8 KB RAM in small 28- or 44-pin packages, making them suitable for applications such as IoT sensor nodes, access control systems and door locks.

Several security features are integrated into the PIC24F “GB2” family to protect embedded data. The fully featured hardware crypto engine, supporting the AES, DES and 3DES standards, reduces software overhead, lowers power consumption and enables faster throughput. This is another example of our

**Core Independent Peripherals**, which can run with no CPU supervision. Also, a Random Number Generator creates random keys for data encryption, decryption and authentication to provide a higher level of security. For additional protection, the One-Time-Programmable (OTP) key storage prevents the encryption key from being read or overwritten. These security features increase the integrity of embedded data without sacrificing power consumption. With its XLP technology, the “GB2” family achieves 180 µA/MHz Run currents and 18 nA Sleep currents, delivering very long battery life for portable applications.

For connectivity, the “GB2” family integrates USB for device or host connections, as well as a UART with ISO7816 support, which is helpful for smart card applications. With these features, the PIC24F “GB2” devices protect embedded data while conserving power and maximizing battery life, all in packages as small as 28-pin QFN for medical/fitness applications (e.g., pedometers, wearable fitness, handheld devices), computer applications (e.g., PC peripherals, printers, portable accessories) and industrial applications (e.g., security door locks, access control systems, security cameras, access control systems and door locks.

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These new MCUs can help you achieve faster throughput, lower BOM cost, secure data and very long battery life in your design. PIC24FJXXXGB2XX variants support USB and PIC24FJXXXGA2XX have no USB support. Visit their respective product pages for details on packages and pricing. All of these devices are available today for sampling and volume production from Microchip’s worldwide distribution network or they can be ordered from microchipDIRECT.

POS terminals, smart card readers, heat/gas meters, IOT sensor nodes).

Development Support

We offer a flexible range of certified wireless modules for Wi-Fi®, ZigBee®, Bluetooth® and Bluetooth Low Energy, making it easy for you to add low-power wireless connections to your PIC24 “GB2” application.

The PIC24F “GB2” family is also supported by our standard suite of world-class development tools, including the Explorer 16 Development Board (DM240002), the PIC24FJ128GB204 Plug In Module for USB (MA240037), the PIC24FJ128GA204 Plug In Module for Non-USB (MA240036) and the USB PICtail™ Plus Daughter Board (AC164131). In addition, wireless connections can be added using one of our Wireless PICtail Daughter Boards, including the Wi-Fi PICtail Development Board (RN-171-PICTAIL), and the Bluetooth Low Energy PICtail/PICtail Plus (RN-4020-PICTAIL).

These new MCUs can help you achieve faster throughput, lower BOM cost, secure data and very long battery life in your design. PIC24FJXXXGB2XX variants support USB and PIC24FJXXXGA2XX have no USB support. Visit their respective product pages for details on packages and pricing. All of these devices are available today for sampling and volume production from Microchip’s worldwide distribution network or they can be ordered from microchipDIRECT.
Memory Boost

PIC32MX1/2 Family Offers the Performance, Memory and Peripheral Mix to Support the Latest Applications

Low-Cost PIC32MX1/2 Series of Devices Offers Larger Flash and RAM

Do you need a flexible 32-bit microcontroller (MCU) solution which allows you to integrate more functionality into applications that need large complex code? If so, our new family of PIC32MX1/2 MCUs now offer 256/64 KB Flash/RAM configurations, along with a feature-rich peripheral set, all at a low cost. These new MCUs are coupled with comprehensive software and tools for designs in digital audio with Bluetooth®, USB audio, graphics, touch sensing and general-purpose embedded control.

These new MCUs are an expansion to the popular PIC32MX1/2 series of low-cost small-footprint 32-bit devices. The PIC32MX1/2 boasts a wide variety of features including I²S™ for digital audio, large memory configuration and 83 DMIPS performance for executing Bluetooth audio and advanced control applications, CTMU for capacitive touch sensing, 8-bit PMP for graphics or external memory, a 10-bit 1-Msps 13-channel ADC and serial communications peripherals with the PIC32MX2 series supporting USB-device/host/OTG functionality.

In addition to these hardware peripheral features, our MPLAB® Harmony software development framework supports these devices to simplify the development cycle by integrating the license, resale and support of Microchip and third party middleware, drivers, libraries and RTOSs. Our readily available software packages—such as Bluetooth audio development suites, audio equalizer filter libraries, various Decoders including AAC, MP3, SBC, sample rate conversion libraries, USB stacks, graphics and touch libraries—will rapidly reduce the development time of your applications.

The PIC32MX1/2 MCUs are targeted for low-cost applications in the consumer markets, such as Bluetooth speakers, consumer music-player docks, noise-cancelling headsets, infotainment systems, clock radios, and entertainment-system sound bars, as well as touch screens with buttons and sliders, and USB device/host/OTG applications. In the medical and industrial markets, applications include industrial-grade noise-cancelling headsets and medical/industrial displays with touch-sensing capabilities.

Development Support

The PIC32MX1/MX2 series of devices is supported by our free MPLAB X Integrated Development Environment (IDE) and the

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These new PIC32MX1/2 MCUs are offered in 28-pin QFN, SOIC, SPDIP and SSOP packages and 44-pin QFN, TQFP and VTLA packages. They are available now for purchase from Microchip’s worldwide distribution network or they can be ordered from microchipDIRECT.

MPLAB XC32 Compiler for PIC32. The application-specific development tools that support the PIC32MX1/MX2 series include the PIC32MX270F256D Plug-in-Module for Explorer 16 Development Board (MA320014) and the PIC32MX270F256D Plug-in-Module for Bluetooth Audio Development Kit (MA320013).

**NEW PRODUCT**

**Fat-Free GRAPHICS**

**Great-Looking GUI For Less**

- Direct Connect to Display
- No Extra Graphics Controller
- Full-Featured Libraries
- Lower Cost, Power, Complexity
If you develop embedded applications that require low power in very compact designs, the SST25WF020A, SST25WF040B and SST25WF080B SPI Flash memory devices are economical and innovative solutions that will help reduce the overall power consumption in your products. These products offer 2-, 4- and 8-Mbit of memory and are manufactured with our high-performance SuperFlash® technology and NOR Flash cell architecture for superior quality and reliability.

With a low-operating voltage range from 1.65 to 1.95V, extremely low-power consumption, small-footprint, and low-profile packaging, these SPI Flash memory devices excel in a variety of applications. The memory is partitioned into uniform 4 Kbyte sectors and 64 Kbyte blocks, offering flexible erase capabilities and seamless partitioning for program and data code in the same memory block. These devices enable you to improve your product's performance and lower your system's cost during the design cycles and manufacturing.

The SST25WF020A, SST25WF040B and SST25WF080B SPI Flash memory devices offer flexible erase and program performance, including erasing 4 Kbyte sectors as fast as 40 ms, erasing 64 Kbyte blocks as fast as 80 ms, erasing the entire Flash memory chip in 300 ms, and a programming time of 3 ms for a 256-byte page using Page Program. The devices also offer Fast-Read Dual I/O and the superior reliability of 100,000 endurance cycles, typical, and greater than 20 years of data retention. The active read current is only 4 mA, typical, at 40 MHz, and standby current is only 4 µA, typical. Package offerings include 8-pin USON (2 x 3 mm) that uses one-fifth the board space of the traditional 8-pin SOIC. For even more space-constrained designs, a chip scale package is expected to be available in October.

All three devices excel in a broad range of applications, including those in the consumer electronics, medical and industrial markets. Examples of end applications include wireless products for sports, fitness, health, monitoring and networking; digital radios; Bluetooth® wireless audio accessories; low-power Wi-Fi®; ZigBee®; GPS and a wide array of battery-operated products.

The SST25WF020A, SST25WF040B and SST25WF080B devices are available today from Microchip’s worldwide distribution network or from microchipDIRECT.
Wide operating voltages and extended temperature ranges are common in industrial and automotive power supplies. The two latest additions to our 36V digital potentiometer (digipot) portfolio can meet the requirements of any applications that need to operate on higher system voltages.

The MCP45HV31 and MCP45HV51 are volatile I2C™ devices which are the industry’s first digipots to offer a 5 kΩ resistance with a specified operating voltage of 36V. Additionally, they provide 10V to 36V analog operation and 1.8V to 5.5V digital operation for systems requiring wide signal swings or high power-supply voltages.

These digipots support both 7-bit and 8-bit resistor configurations.

The MCP45HV31-51 digipots support both 7-bit and 8-bit resistor configurations and a high terminal/wiper current, including the ability to sink/source up to 25 mA on all terminal pins for driving larger loads. These features—combined with an extended temperature range of −40°C to +125°C—make the MCP45HV31-51 well suited for a broad range of high-voltage and high-temperature applications, including those in the industrial, automotive and audio markets.

The MCP45HV31’s 7-bit resistor network resolution enables 127 resistors and 128 taps, while the MCP45HV51’s 8-bit configuration supports 255 resistors and 256 taps. These devices also provide RAB resistance options of 5, 10, 50 and 100 kΩ. They also feature a 1 µA typical serial-interface inactive current and a 2 MHz typical bandwidth operation (−3 dB) at the 5 kΩ resistance level.

Development Support

Our 20-Pin TSSOP and SSOP Evaluation Board (TSSOP20EV) allows you to quickly evaluate the operation of these new MCP45HV31-51 digipots in their 14-pin TSSOP package option.

Both digital potentiometers are available today for samples and volume production, in 14-pin TSSOP and 20-pin, 5 x 5 mm QFN packages. They can be ordered from Microchip’s worldwide distribution network or from microchipDIRECT.
Supporting a wide variety of applications, our instrumentation amplifier portfolio has just been expanded to include the new zero-drift MCP6N16. This self-correcting architecture maximizes DC performance by enabling ultra-low offset, low-offset drift, and superior common-mode and power-supply rejection, while eliminating the adverse effects of 1/f noise. The result is very high accuracy across both time and temperature.

The MCP6N16’s low-power CMOS process technology enables low power consumption while still providing 500 kHz bandwidth, and it features a hardware-enable pin for even more power savings. This low-power operation and shutdown capability requires less current for the given speed and performance, which extends battery life and leads to less self heating. Additionally, the amplifier’s low, 1.8V operation allows two dry-cell, 1.5V batteries to be drained well beyond typical use, and its rail-to-rail input and output operation enables full-range use, even in low-supply conditions. This provides better performance across the entire operating-voltage range.

The MCP6N16 instrumentation amp is ideal for applications that require a combination of high performance and precision, low power consumption, and low-voltage operation. Examples include sensor interfaces, signal conditioning, and stationary and portable instrumentation for the medical, consumer and industrial markets.

The Zero-Drift MCP6N16 Instrumentation Amplifier is available in 8-pin MSOP and 3 x 3 mm DFN packages. It can be ordered today for samples and volume production from Microchip’s worldwide distribution network or from microchipDIRECT.
Currently deployed in 160 car models worldwide, MOST® technology is the de-facto industry standard used by carmakers to create a high-speed networking backbone within their vehicles. As one of the earliest adopters of this technology, Daimler AG helped to establish the MOST Cooperation. Daimler is also the latest automotive company to adopt the latest-generation MOST150 standard, using our Intelligent Network Interface Controllers (INICs).

At the 2014 MOST Forum this past May, Daimler’s Dr. Jan Bauer explained why Daimler chose MOST150 for its flagship Mercedes-Benz S-Class sedan’s next-generation infotainment system. He also provided insights on how they easily moved from a legacy MOST25 system to gain performance improvements of 150 Mbit/s, while utilizing MOST150’s many new features, including isochronous video streaming and the new MOST Ethernet Protocol (MEP), which is a dedicated channel that was added to the many transport mechanisms already supported by MOST technology.

Dr. Bauer explained how Daimler was able to take advantage of the high streaming-data transfer speeds to achieve the simultaneous playback of four HD videos, due to MOST150’s elimination of addressing control or overhead. He also cited the standard’s ability to efficiently route data to the appropriate interfaces, such as I²S™ for audio and I²C™ for control, which eliminates interrupts to the host processor for streaming, freeing it to perform other tasks or enabling the use of a less expensive MPU.

Regarding MOST150’s new MEP, Dr. Bauer said in his accompanying paper, “The MOST Ethernet channel can transport unmodified Ethernet frames, according to IEEE 802.3. This permits software stacks and applications from the consumer and IT domain to be seamlessly migrated into the car. TCP/IP stacks, or protocols utilizing TCP/IP, can communicate via the MOST bus without any modification. Thus the new generation of MOST technology provides the automotive-ready physical layer for Ethernet in the car.”

Dr. Bauer concluded his MOST Forum paper by saying, “The development of this latest MOST generation has been accompanied by a cost/benefit analysis that led to several innovations on the one hand, and to a high level of

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backward compatibility on the other. Existing applications can easily be reused in the new network by simply modifying their network interfaces. Therefore, it offers a smooth adoption, with the majority of features being continued. Daimler is able to reuse and adopt many components out of the proven system architectures, such as, for example, main parts of topologies, network management and application structures. MOST150 is able to cope with the challenges of a modern infotainment system, as shown in the Mercedes-Benz S-Class. Again, as with MOST25 in the past, MOST150 technology will be rolled out onto all other Mercedes-Benz car lines, step by step.”

**MOST® ToGo Reference Designs Support Development of MOST150 and MOST50 Systems**

Our new MOST ToGo Reference Designs make it easy for you to learn and implement MOST technology in your automotive infotainment systems and help you get your MOST designs to market quicker than ever. They enable you to leverage our extensive experience, allowing you to focus on your application software development rather than spend your valuable time on studying the vast MOST specifications.

Two MOST ToGo options are currently available. The **MOST150 cPhy MOST ToGo Evaluation Kit** (B20001) includes everything needed to implement a MOST150 coax network. This kit is based on the **OS81110 cPhy Evaluation Board**, which is also available separately (B20002). The **MOST50 ePhy MOST ToGo Evaluation Kit** (B20004) includes everything needed to implement a MOST50 electrical network. This kit is based on the **OS81092 ePhy Evaluation Board**, which is also available separately (B20003). Included in both reference designs are three MOST network-compliant hardware nodes with full schematics, code and function catalogs—everything needed to train, learn or develop a full MOST system design, from concept, to implementation to testing. The kits can be used as a complete blueprint for critical circuits to create quick demonstrations and significantly speed overall development and testing times.

Both kits provide a MOST technology hardware reference design and fully implemented software stack, which helps you pass compliance testing on the first try. The boards include a daughter-card connector, enabling the addition of expansion boards for more audio, video, wireless or a host of other functions. These kits and board can be purchased from Microchip’s worldwide distribution network or from microchipDIRECT.
Music on Demand

Microchip Extends Spotify® Connect Support in New JukeBlox® Platform Release

Media Module Provides Easiest and Most Cost-Effective Platform to Support Spotify Connect

Spotify Connect is an award-winning digital music service that provides on-demand access to more than 20 million tracks. Spotify makes it easier than ever to discover, manage and share music. Spotify Premium users can control and play their music through their phone, tablet and audio devices simply and effortlessly, at the touch of a button. Spotify Connect is available in 28 markets worldwide with more than 24 million active users and over 6 million paying subscribers.

We recently announced a new release of Spotify Connect in our standard JukeBlox® Platform.

With the addition of this leading music streaming service, audio devices powered by the JukeBlox platform—such as wireless speakers, AV receivers, Internet radios, home theater systems, wireless speakers and portable music player docking stations—will now be part of the Spotify Connect experience.

This release extends support to more than 8 million audio products based on our network audio processors and includes a number of key improvements on the initial release. Audio brands can easily add Spotify Connect to previously sold products with just a firmware upgrade and to new designs based on all of our CX870 Wi-Fi® modules and DM860 Ethernet processor. To speed product and firmware availability to consumers, our APT Lab is the first to offer pre-certification services to customers using Spotify Connect.

Spotify Connect does not require the mobile device to continuously stream content to a wireless speaker or AV receiver. The key benefit of Spotify Connect is that once a track has been selected, the audio stream is delivered directly from Spotify’s servers to the wireless speaker using the local network. This frees the mobile device for use during music playback which greatly reduces battery depletion and allows the mobile device to move anywhere in the network without interrupting music playback.

Spotify Connect is available today, via a free download from Spotify’s website. Spotify offers a 30-day free trial period and thereafter there is a $9.99 monthly fee for Premium Service. For additional information on the Jukeblox Platform or our network audio processors, contact any Microchip sales representative.
Catch A Savings Wave

Summer means sun, sand and savings with our latest Development Tools Deals. These special sale prices will be available on microchipdirect.com for the whole month of August. Simply add the item to your cart and apply the coupon code during checkout. These are limited time offers so act quickly to get your savings while the deals are still available and supplies last.

**dsPIC33E USB Starter Kit**

**microchipDIRECT Coupon Code: TP1432**

The dsPIC33E USB Starter Kit (DM330012) comes preloaded with basic Communication Device Class (CDC) demonstration software and provides a low-cost method for developing and testing USB Host and Device applications with the dsPIC33E DSC family. Save 35% off regular price and get yours for $42.00.

**Microstick for 5V PIC24F K-Series**

**microchipDIRECT Coupon Code: TP1433**

TheMicrostick for 5V PIC24F K-Series (DM240013-2) is a flexible, USB-powered development platform for the low-cost PIC24F KM and KA microcontroller families. Smaller than a stick of gum, this easy-to-use tool is on sale for just $22.00.

**MPLAB® XC PRO HPA (Workstation License)**

**microchipDIRECT Coupon Code: TP1434**

The MPLAB XC Compiler supports all PIC® MCUs and dsPIC® DSCs and integrates with the MPLAB X IDE. The PRO version provides powerful code optimization at better than 50% when compared to the free edition, giving the most efficient memory usage. This month, you can save $50.00 on the High Priority Access (HPA) workstation license (SW006021-2H), which is a 12-month maintenance subscription providing priority technical support, new architecture support and new compiler versions for MPLAB XC PRO workstation. The sale price is $149.99 per license.

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PIC18F4XK22 Development Kit
microchipDIRECT Coupon Code: TP1435

The PIC18F4XK22 Development Board (DM164134) highlights the PIC18F4X/2XK22 series of eXtreme Low Power, high-performance 8-bit microcontrollers. Suitable for prototyping many low power applications, it includes the development board, programming lessons and demos. It’s on sale for $60.00, a 25% savings off the regular price.

Are Longer Leadtimes Giving You a Headache?

Get instant relief with microchipDIRECT
As your go-to source for Microchip products, we have the widest and highest levels of Microchip stock worldwide. We can help your production run smoothly. Visit www.microchipDIRECT.com to choose from our extensive inventory.
Did you know that you do not need to use an external graphics controller when it comes to adding professional-looking graphics to 32-bit embedded designs? Microchip has developed a way for you to implement Graphical User Interfaces, or GUIs, in your design using only the peripherals that are already available on any device in the PIC32 catalog.

Microchip’s PIC32 line of 32-bit microcontrollers clocks in at up to 200 MHz and incorporates high-performance Direct Memory Access (DMA) to render graphics directly to displays. This Low-Cost Controllerless Graphics (LCCG) implementation enables PIC32 devices to drive a display without an external graphics controller, helping reduce the cost and complexity of your design. Some features of an LCCG solution include:

- Uses < 5 MIPS (with DMA) to render graphics
- Direct interfaces to STN, TFT displays
- Flexible frame buffer
  - Supports WQVGA 24 bpp with internal frame buffer
  - Supports VGA 24 bpp with external frame buffer using PMP (Parallel Master Port)
- Works with any PIC32 32-bit microcontroller

With devices offering up to 2 MB Flash and 512 KB RAM, the PIC32 family of MCUs gives you plenty of space for application code, communications stacks and data buffering. In addition to their graphics capabilities, PIC32 MCUs also have integrated peripherals for USB, CAN, Ethernet, capacitive touch sensing, EBI, SQI and crypto engine.

In general, graphics display controllers must send a frame of pixel information to a display glass at a certain rate. This rate—called the refresh rate—is usually around 50-60 Hz. Currently, systems
employ an external controller to transfer this frame data from memory to the display. Other overly complex and expensive processors will incorporate this controller.

LCCG allows you to drive graphics with a controller that has the appropriate size and performance for your needs without requiring any additional external components. While it may seem that the task of driving pixel data to the display would take up most of the CPU time in an MCU, the PIC32 device’s DMA peripheral can transfer data from one location to another without CPU intervention. Therefore, with the DMA transferring the pixel data, less than 5% of CPU time can be used to achieve a professional-looking graphics display. The PIC32 MCU’s 200 MHz performance allows you to implement advanced graphical capabilities such as double buffering, alpha blending, animation and video support.

Microchip provides free tools and libraries to enhance design and speed production. The Microchip Graphics Library is highly modular and fully compatible with MPLAB® Harmony for PIC32 MCUs. The library consists of pre-made graphics objects, support for multiple fonts and languages, and code for implementing user interface solutions using mTouch® sensing technology. Microchip’s Graphics Display Designer (GDD X) is a GUI plug-in for the MPLAB X IDE. It utilizes the Microchip Graphics Library to enable development of interactive GUIs on Microchip PIC32 MCUs. The output source files can be compiled with the Graphics Library using Microchip C compilers. Ultimately GDD X reduces the need to memorize graphics object information, improves the edit-compile-execute cycle and allows developers to work in the same space as users. LCCG also has support from a growing set of ecosystem partners, such as SEGGER’s emWin graphics offerings.

Visit the Low-Cost Controllerless Graphics page on the Microchip website to learn more about how the PIC32 portfolio provides the performance, flexibility and integration you need for your graphics display application.

Figure 1 - Controllerless Graphics System Diagram
Requirements for embedded systems are growing as the feature set of many new end products is increasing at an exponential rate. Wireless communications, advanced control techniques and new human interfaces are becoming common across all embedded markets. This change is driven by evolving consumer demand and enabled by massive advances in semiconductor technology. Each new feature or function added to an end product requires a corresponding increase in system complexity and more sophistication from its control elements.

These increasingly complex control elements place an immense burden on product designers, as each new function requires additional code and debugging time. For highly integrated systems, the bulk of an engineer’s design budget is often spent eliminating timing concerns caused by the feature integration. Because of this, managing the cost of software development has become a top priority for many companies.

Microchip’s PIC microcontrollers are designed to support increasing levels of functional integration without concern for timing issues or increased power consumption. By integrating flexible, intelligent hardware peripherals, PIC MCUs enable designers to create functional building blocks that operate efficiently with and autonomously of the CPU. These intelligent hardware peripherals can now be easily configured to perform desired functions using the MPLAB Code Configurator, which ultimately accelerates code development.

MPLAB Code Configurator is a free, user-friendly plug-in that seamlessly integrates with your existing MPLAB X Integrated Development Environment (IDE) to provide an easy setup and

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configuration experience with your chosen PIC microcontroller. It offers a simple graphical representation of the selected PIC MCU and its on-chip peripherals and allows you to quickly arrange hardware peripherals into functional building blocks without an in-depth setup of registers or flags. The tool also displays package pins in both a graphical and tabular format, which makes pin and I/O configuration as easy as a mouse click.

Key Features

- **Flexible:** You can use MPLAB Code Configurator for simple configuration of your microcontroller in-system or to create complex functions with groups of integrated peripherals. Many PIC MCUs and their peripherals are supported, with new ones added regularly.

- **Intelligent:** MPLAB Code Configurator can alert you of a potential pin or function conflict. It creates efficient code with a small memory footprint.

- **Easy to Use:** Intuitive Graphical User Interface provides a visual representation of your selected PIC MCU, with an “aerial view” of the package. Pin selection and configuration is done via mouse click.

- **Saves Time:** MPLAB Code Configurator generates simple, clearly documented APIs without the hassle of register-level setup. Its C code output can be easily modified for quick platform-level development.

MPLAB Code Configurator generates function and peripheral drivers in seamless, easy-to-understand C code for ultimate flexibility and portability. Its ease of use will help significantly reduce your software development time and get your product to market quicker.

If you already have the MPLAB X IDE installed, there’s no need to download MPLAB Code Configurator. It is already available to you as a plug-in. However, if you’d like to download MPLAB Code Configurator separately, it is available from the MPLAB Code Configurator area on Microchip’s website, where you’ll also find additional information and resources to help you get started using this flexible and powerful code development tool.

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**Zero-Drift INA**

**Superior Performance**

**Small Size**

- Ultra Low Offset Voltage
- No 1/f Noise
- Enhanced EMI Rejection
- Superior CMRR/PSRR
Assessing the Benefits of Zero-Drift Amplifiers
Maximizing Dynamic Range for Small Sensor Signals Using Zero-Drift Amplifiers

The noise of an operational amplifier and its quiescent current ($I_{q}$) typically follow a fixed relationship—the lower the noise the higher the $I_{q}$ number. For designers of battery-powered systems this creates a problem, especially since operating hours is an important design objective requiring the system to draw the lowest possible operating current while achieving the targeted performance levels, such as the number of bits of resolution. To the designer, power efficiency often means that the system has to operate on a single +5V or even a +3.3V supply rail. This sets the limit for the maximum signal amplitude for which the system can be designed, i.e. the full-scale input range of the ADC. The situation only gets worse as the low-power requirement seems to limit the choices of selecting the best op amp.

Using a simple example, let’s assume the system design requires the amplification of a small sensor signal that has a maximum signal of 2 mVp-p. With the ADC’s full-scale range of 2 Vp-p a gain of 1000 V/V (60 dB) needs to be realized. The sensor signal is slow moving and the signal path bandwidth is defined from 0.1 Hz to 10 Hz. Based on the system’s low-power requirements, the current consumption of the op amp should not exceed 50 µA. A quick check on the gain-bandwidth requirements shows that the op amp should have a minimum GBW of 100 kHz (this includes a factor of 10x $f_{\text{max}}$ to ensure sufficient loop gain). With this set of specifications two low-power amplifier models seem suitable: the MCP6051 and the MCP6V31, as shown in Table 1.

While the MCP6051 with 45 µA has a higher quiescent current as compared to the MCP6V31’s 34 µA, with 35 nV/√Hz it offers a lower noise number, which is in line with the point made initially.

<table>
<thead>
<tr>
<th>Op Amp Model</th>
<th>$I_{\text{q/Ch Max (µA)}}$</th>
<th>Gain-BW (kHz)</th>
<th>$V_{\text{os Max (µV)}}$</th>
<th>$V_{\text{os Drift Max (µV/°C)}}$</th>
<th>$E_{\text{nI}}$ (nV/Hz @1kHz)</th>
<th>$E_{\text{nI 0.1 Hz to 10 Hz (µVp-p)}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP6051, Precision RRI/O</td>
<td>45</td>
<td>385</td>
<td>150</td>
<td>4</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>MCP6V31, Zero-Drift, RRI/O</td>
<td>34</td>
<td>300</td>
<td>8</td>
<td>0.05</td>
<td>50</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1 - Performance Specifications of MCP6051 and MCP6V31
However, it should be noted that this is the noise density at 1 kHz, which is outside the signal bandwidth of our example here. In order to find the noise relevant for the signal bandwidth (0.1 Hz to 10 Hz) we can look up the datasheet specification for the integrated input noise voltage ($E_{n,i}$). Here, the MCP6V31 comes out ahead with 1 $\mu$Vp-p compared to 5 $\mu$Vp-p for the MCP6051.

Taking all these noise numbers into account and comparing them reveals an interesting result. Table 2 shows the contribution of the 1/f-noise and the white noise for each op amp model, the resulting total noise (referred-to-input, RTI, and total output noise), and the Signal-to-Noise ratio (SNR).

For the signal bandwidth of 0.1 Hz to 10 Hz, almost all of the noise contribution (97%) for the MCP6051 comes from 1/f noise. In zero-drift amplifiers, the 1/f-noise contribution is virtually eliminated by the use of a self-correcting architecture that primarily results in ultra-low offset voltage and drift. In addition, the self-correcting function inherently delivers a noise-shaping effect by which the low frequency noise content, i.e. the 1/f noise, is shifted up in frequency. Details and a description of the internal architecture can be found in the MCP6V3x series datasheet. The 1/f noise, also known as Flicker noise, increases 3 dB for every octave decrease in frequency. While its 1/f noise is different for different silicon processes, it is intrinsic in semiconductor devices and practically impossible to filter out without affecting any signal in that bandwidth as well. Figure 1 (on the next page) clearly illustrates this advantage of zero-drift amplifiers.

In the case of our design example, the noise performance of the MCP6V31 is four times better when compared to the MCP6051, leading to a 12 dB improvement in Signal-to-Noise ratio (Table 2). Using the simple equation $ENOB = (SNR - 1.76 \text{ dB}) / 6.02$, we see that this effectively results in two additional bits of resolution. This example does not take the actual noise bandwidth of the system into account, but it would apply to both devices equally and would not change the relative improvement that is achievable with the MCP6V31. It also neglects additional noise coming from other components such as resistors necessary for a functional circuit. But it highlights the importance of matching the amplifier’s noise characteristics to the signal bandwidth of the sensor. If the bandwidth of interest is less than 1000 Hz, zero-drift op amps will often have a significant advantage over standard precision (time-continuous) op amps simply because of the absence of 1/f noise. If the application requires the highest accuracy and precision, then other aspects of zero-drift amplifiers such as ultra-low offset voltage drift, or high Common-Mode (CMRR) and Power-Supply Rejection (PSRR) tilt the needle even further in favor of zero-drift amplifiers. Here, the MCP6V31 features a low 50 nV/°C

<table>
<thead>
<tr>
<th>Device</th>
<th>1/f-noise Contribution (RTI)</th>
<th>White Noise Contribution (RTI)</th>
<th>Total Noise (RTI)</th>
<th>Total Output Noise (RTO)</th>
<th>SNR (2 Vpp ADC Full-Scale Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP6051</td>
<td>97% (622 nVrms)</td>
<td>3% (110 nVrms)</td>
<td>632 nVrms (4.17 uVp-p)</td>
<td>632 uVrms (4.17 mVp-p)</td>
<td>61 dB (ENOB = 9.8 Bit)</td>
</tr>
<tr>
<td>MCP6V31</td>
<td>0% (152 nVrms)</td>
<td>100% (152 nVrms)</td>
<td>152 nVrms (1 uVp-p)</td>
<td>152 uVrms (1 mVp-p)</td>
<td>73 dB (ENOB = 11.8 Bit)</td>
</tr>
</tbody>
</table>

Table 2 - Noise Contribution and Resulting SNR of the MCP6051 and MCP6V31

(continued on page 23)
offset voltage drift (max.) over the extended temperature range (−40°C to +125°C), as well as a minimum of 120 dB for CMRR and PSRR. While the MCP6V31 is a single amplifier, it is also available in dual (MCP6V32) and quad (MCP6V34) versions. For applications with even more stringent low power requirements, the MCP6V11/12/14 series of zero-drift amplifiers might offer a solution: at a mere 7.5 µA of quiescent current (typical), the noise remains at a low level of only 2.1 µVp-p for the 0.1 Hz to 10 Hz range.

Visit our Operational Amplifiers product page for additional details on these and other devices in our product portfolio.

Figure 1 - Comparison of the Input Noise Voltage Density of the MCP6051 and the MCP6V31 Zero-Drift Amplifiers
Battery Back-Up Utilizing Low Threshold MOSFETs

 Frequently, circuit designs require a combination of low on-resistance to prolong battery life, low gate drive to meet battery voltage limitations and small packages to accommodate board space limitations. MOSFETs offer performance advantages due to their low voltage drop, as compared to the voltage drop of bipolar transistors and diodes in these applications. Bipolar transistor performance is limited by $V_{CE(sat)}$ and diodes by $V_f$, depending upon the semiconductor material used. The simple battery backup circuit described in this article illustrates how the Supertex N-channel low gate threshold MOSFETs offer a number of benefits which make them well-suited for a variety of battery-powered applications. This circuit utilizes the following features of MOSFETs:

- Low drain to source voltage drop.
- Complete turn-on/off of bidirectional currents.
- Turn-on with low biasing voltages.
- No biasing power compared to base current loss in bipolar transistors.
- Utilization of the intrinsic drain to source diode for limiting charging currents to efficient and safe levels.

![Battery Backup Circuit Diagram](image)

*Figure 1 - Battery Backup Circuit*
The battery backup circuit shown in Figure 1 has two different modes: battery charging and battery backup.

**Battery charging mode:** The 120V AC is stepped down via transformer and full-wave rectified by D₁, D₂, and C₁ to 7.5V DC. This 7.5V DC supplies power to RL and provides the charging current to the batteries. R₁, D₃, and D₄ generate a 1.2V reference for U₁a and U₁b. D₅, R₂, R₃, C₂ and COMP2 keep Q₁ and Q₂ off when switch S is closed. The battery, consisting of five nickel cadmium cells in series, is charged with a current set by R₈ and the intrinsic drain to the source diode of Q₂. For fully discharged batteries, there will be a high charge current for a few seconds, rapidly decaying to a slow charge. As the battery becomes almost fully charged to 6.8V, the current is reduced to a trickle charge current of a few mA. The trickle charge current is further reduced to μA when Vᵦᵣᵦ exceeds 7.0V. This is because the voltage across the diode of Q₂ is 0.5V and will allow only a small amount of current flow. This maintains the full charge of the battery when it is not in use over an extended period of operation.

**Battery backup mode:** When switch S is opened—simulating a power outage, unplugged equipment or a blown fuse—the circuit goes into battery backup mode. U₁b turns on Q₁ and Q₂. As Vᵦᵦᵦ supplies the 60Ω load, U₁a monitors the Vᵦᵦᵦ voltage to keep it from fully discharging, as complete discharge and subsequent cell voltage reversal can degrade the performance of the NiCd battery. The circuit is designed for the U₁a to turn Q₁ and Q₂ off if Vᵦᵦᵦ is less than 5.5V and to turn them on if Vᵦᵦᵦ is greater than 6.5V. The hysteresis is designed to avoid oscillation and is set by R₆, R₅, R₄ and R₃.

**Design Considerations and Component Selection**

The design of this circuit utilizes standard, readily available components. The number and different types of components are minimized. Diodes D₁ to D₅ are 1N4001. All resistors are standard 1/4 watt, 5% tolerance. National Semiconductor’s LM393N dual comparator is used for its low biasing current for U₁. The battery consists of five Eveready nickel cadmium cells in series. The cells are AA size, CH15 with a C rating of 500 mAH.

The most important factor to be considered in the design is the selection of the MOSFETs Q₁ and Q₂, which are configured as an analog switch. In the battery backup mode, the voltage drop across the MOSFETs must be low to minimize resistive voltage drop and power loss, consequently enhancing battery life. Supertex TN0604N3 low threshold N-channel DMOS transistors were selected for their guaranteed low on-resistance at low gate drive and their cost-effective TO-92 package, which saves board space.

<table>
<thead>
<tr>
<th>Typical Ros(on)</th>
<th>Maximum Ros(on)</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9Ω</td>
<td>1.5Ω</td>
<td>Vgs = 5.0V, ID = 750 mA</td>
</tr>
<tr>
<td>0.6Ω</td>
<td>0.75Ω</td>
<td>Vgs = 10V, ID = 1.5A</td>
</tr>
</tbody>
</table>

Table 1 - TN0604N3 Resistance Data

Q₁ and Q₂ are easily turned on with a simple pull-up resistor, R₇. For a “worst case” design, Ros(on) = 1.5Ω and a load current of 125 mA are used. The maximum voltage drop across Q₁ and Q₂ works out to only 375 mV. In actual operation, this voltage drop is substantially lower because the typical value of Ros(on) is 0.8Ω. The voltage drop across Q₁ and Q₂ was measured to be 200 mV.

(continued on page 27)
Figure 2 is a discharge curve of $V_{\text{batt}}$ vs Time showing battery backup operation of approximately four hours. Figure 3 is a charge curve of the battery. The component selection ensured that basic charging current guidelines for NiCad cells were not violated. Assuming the worst case, using fully discharged batteries, the maximum charging current will be 227 mA. The charge rate will be from $10 \text{ mA} / 500 \text{ mAH} = 0.02\text{C}$ to $3.3 \text{ mA} / 500 \text{ mAH} = 0.007\text{C}$, which is very safe for the NiCad cells.

**Optional Features**

When space is at a premium, the TN2504N8 provides performance almost identical to that of the TN0604N3, but it comes in a SOT-89 (TO-243AA) surface mount package.

Added features such as battery backup mode indicator, low battery voltage early warning, or battery shutdown indicator can be incorporated by using one or more of the optional circuits shown in Figure 4A through 4C. These can be easily modified to interface with a microprocessor in more complex systems.

NiCad batteries are quite rugged, however, they are prone to damage due to cell voltage reversal if fully discharged. Other kinds of batteries are more sensitive and may be damaged below a certain voltage per cell, e.g. 1.75V for lead acid.

The circuits shown can be modified to suit other kinds of rechargeable batteries, such as lead acid, lead calcium (gel), lithium, etc. For lead acid, the threshold voltage to disconnect the load from the battery can be adjusted to 1.75V per cell.

---

**Figure 2 - $V_{\text{batt}}$ Discharge Curve**

**Figure 3 - $V_{\text{batt}}$ Charge Curve**

**Figure 4 - Optional Circuitry**
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In-Circuit Serial Programming and Debugging

For use as an In-Circuit Serial Programmer, simply connect LOAD-n-GO to a PC. Then, using the provided CCSLOAD Programmer Control Software, select “ICSP” from the main menu. Programming is effortless. Select the program to be placed in the selected memory bank, verify the file (and that the target device is shown) and click ‘Burn Chip’.

LOAD-n-GO can also function as an In-Circuit Debugger when used with the CCS C-Aware IDE Compiler with Real-time Advanced Debugging. LOAD-n-GO debug support covers all targets that have debug mode, not to mention all 8-bit, 16-bit, or 32-bit PIC MCU or Flash Devices.

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Power Options

Power the LOAD-n-GO with four AA batteries or with the provided 9V DC adapter. Under battery power, the unit will conserve battery life using an auto-shutoff feature after five minutes of idle time. Your programs are safely stored even after power-down or auto-shutoff. Note also that the LOAD-n-GO can be used to provide 5V, 3.3V or 2.5V to the target board, but this involves inserting a shunt jumper on the LOAD-n-GO circuit board. To access these jumpers, open the enclosure by removing the four screws on the back, and find the marked locations of the jumpers on the circuit board.

Specifications

• 2 MB internal flash for up to four programs
• Free CCSLOAD Software for ease of programming
• ICSP cable terminated with RJ-12 connector for target programming
• USB cable for plug-and-play PC connections
• Drivers for Linux® and Windows® (32- or 64-bit)
• RoHS compliant
• Dimensions: 3¼" x 5½" x 1¼"

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In the late 1960s the Programmable Logic Controller, or PLC, was created to speed up the changeover of automotive production lines. It has long been the computational work horse of industrial automation. PLCs are often programmed graphically, using ladder-logic symbols which were originally devised to represent control systems based on mechanical relays. Most PLCs are proprietary systems.

Meanwhile, the open-source software movement began in the 1980s. Software engineers started using their free time to create useful programs that were distributed at low or no cost to the user. An important aspect of this distribution model is that the source code is available for anyone to view and improve. Over time the quality of open-source software tends to improve organically, as engineers learn from each other and improve the software according to their own needs and interests. The result is sophisticated software at no cost to the user. (Note: Some effort is generally required to configure and install open-source software.) The poster child of this movement is the web server. Today more than 80% of the world’s web servers are based on open-source software.

In the late 1990s the concepts established and proven by the open-source software movement started to be applied to hardware. Hardware, in this case, is typically an electronic circuit or mechanical device. Unlike open-source software, the utility of open-source hardware requires an investment to manufacture the electronic circuit or mechanical device. Even so, access to open-source designs can greatly reduce the resources and time required to create new or modified circuits and devices.

Today, new software and devices are starting to appear that have a PLC form factor but utilize the ideas of open-source software and open-source hardware. This in turn enables the creation of industrial processes based on open solutions. An example is the Quick240™ from PONTECH, based on the open-source chipKIT™ platform with a PIC32MX795F512L MCU. The Quick240 is a rugged and versatile controller that can be easily configured and expanded using Quick Kards™. 

(continued on page 32)
Utilizing open technologies for industrial processes provides both short and long term benefits as follows:

Immediate Benefits

• Lower equipment costs: Since organizations selling open hardware have participated in a larger group of volunteers, the cost to create a new product is lower and savings are passed on.
• No hidden features or bugs: If a problem is found with the equipment and the manufacturer does not wish to fix the issue, the organization is not locked in to a flawed solution.
• Second sourcing: No need for second sourcing since the designs are open.
• Community support: A community of corporations and users provide extended support beyond what traditional closed systems can offer.
• Larger talent pool: A community of individuals focused on a common set of open standards means there is a larger pool of possible talent familiar with the technology. This makes it easier for managers to find the talent capable of building equipment today and repairing or maintaining equipment in the future.
• Flexibility: Open systems are flexible and can be easily expanded in ways that closed systems are not, such as by the end user or by third parties. Both hardware and software can grow with business needs. In contrast it is usually difficult to extend capability or add new, highly customized features to a closed proprietary system.

Long Term Benefits

• Extended Life: When a proprietary PLC is discontinued by the manufacturer, it usually means that old equipment cannot be maintained. Open systems, when discontinued by a specific manufacturer, have all documentation open, so that it can be maintained or even reproduced by a third party.
• Reuse: When equipment is decommissioned, usable hardware that may have previously been discarded can be more easily re-used, due to a reduction in the barrier of finding adequate documentation.

For additional information contact Jacob Christ, a product designer and the proprietor of PONTECH, at Jacob@pontech.com.
The Right Information, Right Now

Whether you’ve got a single question or are so new to a topic that you’re not even sure what questions to ask, getting the right information when you need it is critical. We believe that embedded systems development knowledge should be freely available, always reachable, quickly accessible, and most importantly, usable. To help you get answers to your questions, we are pleased to bring you Microchip’s new Developer Help site.

The Developer Help site has been developed by experienced engineers from our Technical Training and Applications Engineering Groups. We strive to go beyond the help files, data sheets, and user’s manuals to provide practical information, in context and in depth. Although it is still in its infancy with plenty more content to be added, on the Developer Help site you’ll find technical how-to information organized by product, application and development tools. You’ll find plenty of information on our MPLAB® X IDE and MPLAB XC compilers. You can also look up a single topic or take self-paced versions of many of our popular Regional Training Center classes that include access to the same content and lab exercises.

The site also serves as the portal to our Live Online classes, offered every Tuesday at noon EDT. You can now attend live versions of many of our Self Paced Training Modules—using the same training materials—from the convenience of your home or office. These Live Online classes are taught over the Internet by our Technical Training Engineers. There’s no more need to pre-register for classes. Just log-in up to 15 minutes before class time and be sure to download and install the necessary materials prior to the start of the class. Free evaluation versions of all software tools—including C compilers and the Proteus VSM simulator—are provided for you to install in advance using the links in the calendar. All you need is a computer running Microsoft® Windows® and a high-speed Internet connection. The list of available classes is updated regularly, so check it often to see what new learning opportunities are available.

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