MPLAB® Harmony
Integrated Software Framework
A Novel Approach to Embedded Software Development
Introduction
MPLAB Harmony is a flexible, abstracted, fully integrated firmware development environment for PIC32 microcontrollers. It enables robust development of interoperable, RTOS-friendly libraries with quick and extensive Microchip support for third party software integration. MPLAB Harmony includes a set of peripheral libraries, drivers and system services that are readily accessible for application development. The code development format allows for maximum re-use and reduces time-to-market. It features the MPLAB Harmony Configurator (MHC) plug-in that provides a graphical way to select and configure all MPLAB Harmony components, including middleware, system services and peripherals with ease.

Benefits
■ Faster time-to-market
■ Improved code interoperability
■ Simplified support
■ MPLAB Harmony Configurator (MHC) for enhanced user experience
■ Improved 32-bit scalability
■ Enhanced third-party software integration

MPLAB Harmony Configurator (MHC)
The MPLAB Harmony Configurator plug-in seamlessly integrates with MPLAB X Integrated Development Environment (IDE) to provide an easy setup and configuration experience with your chosen PIC32 microcontroller. It offers a simple graphical representation of the selected PIC32 MCU and allows you to quickly arrange the software modules that your application might need without a tedious hands-on setup of registers or configuration bits.

Highlights of MHC
■ Graphical Clock Configurator
■ Graphical Pin Manager
■ MPLAB Harmony Graphics Composer
■ Offers simple graphical representation of PIC32 MCUs
■ Eases configuration of middleware such as TCP/IP, USB, Graphics and Bluetooth® without the need to write source code
■ Enables seamless integration of third-party RTOS or libraries into your application with the click of a mouse
■ Dynamic help window provides relevant information instantly about the selected libraries
MPLAB® Harmony

PIC32 Software Development Tools Available with MPLAB Harmony

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<td>OSAL interface with “basic” and “none” implementation</td>
<td>Graphics, TCP/IP, USB, Cryptographic libraries, File systems, System services, Bluetooth, DSP/Math, Bootloader, Peripheral Libraries (PLIBs)</td>
<td>ADC, Audio Codec, Ethernet media access controller, Ethernet PHY interface, Controllerless graphics, Epson LCD controller, Non-volatile memory, SPI, UART, CAN2.0B, high-speed USB, Timer, Parallel master port</td>
<td>MPLAB® X IDE, MPLAB XC32++, MPLAB Harmony Configurator (MHC) Plug-In</td>
<td>Security, IoT, Graphics, RTOS</td>
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<td>CAN applications</td>
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Additional software components planned

MPLAB Harmony Block Diagram

**Application Layer**
- Implements desired overall behavior
- Abstracted hardware access
- Allows for easy port across PIC32 parts

**Common System Services**
- Provides common functionality to avoid duplication and conflicts
- Eliminates complex interactions and interdependencies between modules
- OSAL provides OS compatibility and interface
- Manages shared resources
- Supports low-level configuration and board support package

**Peripheral Libraries (PLIB) Layer**
- Provide functional interface for PIC32 scalability
- Implements part-specific features

**Middleware Layer**
- Implements complex libraries and protocols (USB, TCP/IP, file systems, graphics)
- Provides a highly-abstracted application program interface
- Libraries are thread-safe and RTOS-ready
- Built-on drivers, PLIBs, system services
- Supports third-party library integration

**Device Driver Layer**
- Provides highly abstracted interface to peripherals
- Controls access to the peripherals
- Manages multiple hardware instances and software clients with select drivers
- Manages peripheral state and multiple peripheral instances
- Accesses hardware via PLIB
- Supports blocking or non-blocking code
Connectivity

TCP/IP Network Stack and Wi-Fi® Support
The MPLAB Harmony TCP/IP Stack provides a foundation for embedded network applications by handling most of the interaction required between the physical network port and your application. It includes modules for several commonly used application layers, including HTTP for serving web pages, SMTP for sending e-mails, SNMP for providing status and control, Telnet, TFTP, Serial-to-Ethernet and much more.

- Multiple interfaces (Ethernet and/or Wi-Fi)
- Dual stack with IPv4 and/or IPv6 support
- Fully dynamic
- Easy RTOS integration

The Wi-Fi software library, in conjunction with the MRF24WG0MA module, allows an application to:
- Join an existing secure 802.11 Wi-Fi network
- Create a secure 802.11 Wi-Fi network

USB Libraries
The USB Device Stack provides you with a framework to design and develop a wide variety of USB devices. A choice of full-speed only or full-speed and high-speed USB operations are available, depending on the selected PIC32 microcontroller.

The USB Device Stack features:
- Support for different USB device classes (CDC, audio, HID, MSD and generic)
- Support for multiple instances of the same class in a composite device
- Support for multiple configurations at different speeds
- Support for full-speed and high-speed operation

The USB Host Layer in the MPLAB Harmony USB Host Stack performs the tasks of enumerating an attached device and interfacing the HCD.

The USB Host Stack features:
- Support for multi-configuration and composite USB devices
- Support for VID PID and class, subclass and protocol devices
- Concise API simplifies application development
- Support for low-speed, full-speed, and high-speed USB devices

CAN Driver and CAN Peripheral Library
The CAN Static Driver provides a high-level interface to manage the CAN module on the Microchip microcontrollers. It features an API to initialize the CAN module and baud rate in addition to simple transmit and receive functionality.

The CAN Peripheral library provides a low-level abstraction of the CAN module on Microchip microcontrollers with a convenient C language interface. It can be used to simplify low-level access to the module without the necessity of interacting directly with the module’s registers, thus hiding differences from one microcontroller variant to another.

PIC32 Bluetooth Stack Library and Serial Port Profile (SPP)
The PIC32 Bluetooth Stack Library is provided in binary form and consists of a large number of routines that enable the interface of a PIC32 system to a Bluetooth radio via a Hardware Communication Interface (HCI) controller and a UART port. The communication is enabled by a Simple Secure Pairing (SSP) and data is transmitted through the Bluetooth Serial Port Profile (SPP). Bluetooth SPP—a wireless replacement to the serial port—is the basic data transfer profile that defines the necessary requirements for setting up emulated serial port connections between two peer Bluetooth devices.
MPLAB Harmony Solutions

Human Machine Interface (HMI)

Graphics Library and MPLAB Harmony Graphics Composer (MHGC) Tool

The Graphics Library is a free, modular library optimized for Microchip’s 32-bit microcontrollers. The library includes features such as alpha blending, gradient fills and anti-aliased fonts. Applications can take advantage of these features to enhance the user experience while delivering performance required by the application.

The Graphics Library features:
- Up to 16-bit or 65K colors
- 2D objects such as line, circle, text, rectangle, polygon or bar
- 3D objects such as buttons, panels, window, group box or sliders
- Image, animation
- Resistive touch screen, keypad
- Multiple fonts

The MPLAB Harmony Graphics Composer is a graphics user interface design tool that is integrated as part of the MPLAB Harmony Configurator (MHC). This tool allows you to easily configure and visually design for the MPLAB Harmony Graphics Primitive Library and the MPLAB Harmony Graphics Object Layer.

The MPLAB Harmony Graphics Composer features:
- What You See Is What You Get (WYSIWYG) design
- Integrated with MHC Configuration tool
- Multi-platform
  - Windows®, Linux® and Mac OS®
- Enhanced design tools
  - Drawing grids, auto widget alignment and other drawing shortcuts/productivity features
  - Cut, copy and paste properties

Digital Audio and Bluetooth

PIC32 Bluetooth Audio Package (SW320024-1HPM)

This complete software package enables audio playback with remote control in a Bluetooth application. It includes Bluetooth Audio SBC decoder and features Bluetooth audio protocols and profiles such as Serial Port Profile (SPP), Advanced Audio Distribution Profile (A2DP), Audio Video Remote Control Profile (AVRCP), Audio Video Distribution Transport Protocol (AVDTP) and Audio Video Control Transport Protocol (AVCTP).

Microchip offers MP3 (SW320022-1HPM), AAC (SW320023-1HPM) and WMA (SW320025-1HPM) decoder libraries that are designed and optimized for all PIC32 devices and seamlessly integrates with MPLAB Harmony Software Framework.

Note: The PIC32 Bluetooth Audio Package, MP3, AAC and WMA libraries are not included in the free download of MPLAB Harmony Framework and must be purchased. For information on purchasing please visit www.microchip.com/harmony.

Touch Controller Driver and Touch System Services Library

The MPLAB Harmony Touch Controller Driver provides a high-level interface to the MTCH6301 touch controller device. This driver provides application routines to read the touch input data from the touch screen.

The Touch System Service provides a simple interface to manage the touchscreen drivers. It implements the core interface routines for the Touch System Service by utilizing the Microchip Graphics Library. This library provides a low-level abstraction of the Device Control System Service Library that is available on the Microchip family of PIC32 microcontrollers with a convenient C language interface.

USB Audio Device Libraries

The MPLAB Harmony USB Audio Device Libraries feature routines to implement a USB Audio Class 1.0 and USB Audio Class 2.0. The libraries offer various services to the USB audio device to communicate with the host by abstracting USB specification details and simplifying the implementation.
MPLAB Harmony Solutions

Basic Libraries, System Services and OSAL

Peripheral Libraries
Peripheral libraries provide a set of C language functions for setting up and controlling PIC32 MCU peripherals. The function implementations are provided as “in-line” headers and pre-built binaries. Their implementations may change from one PIC32 MCU family to another, but the function names and data types remain the same to make it easy to port code from one PIC32 MCU to another.

Math Libraries
The DSP Fixed-Point Math Library contains building block functions for developing digital signal processing algorithms. The library supports the Q15 and Q31 fractional data formats. Functions included in the DSP Fixed-Point Math Library include complex math, vector math, matrix math, digital filters and transforms. The LibQ Fixed-Point Math Library simplifies writing fixed-point algorithms, supporting Q15, Q31 and other 16-bit and 32-bit data formats. Functions in the LibQ library include capabilities for trigonometric, power and logarithms and data conversion.

Cryptographic Library
Microchip offers a reliable security solution for embedded applications built on the 32-bit MCU platform. The Cryptographic Library features encryption, decryption, authentication, hashing, compression and random number generation routines with a convenient C language interface.

File System
The File System service is a framework designed to support multiple file systems (native file system) and multiple media in the same application. Supported file systems are FAT12, FAT16, FAT32 and MPFS. Each of these native file systems have a common set of APIs that can be used to access the files of that particular native file system.

MPLAB Harmony Third-Party Partners
Microchip offers solutions from industry-leading OS, Internet of Things (IoT), Security and Networking specialists that are compatible with the MPLAB Harmony Framework.

Express Logic
ThreadX is a small, fast RTOS that provides preemptive, hard real-time scheduling, intuitive API and pre-build example programs.

FreeRTOS
FreeRTOS is a small-footprint, portable, preemptive and open-source RTOS.

Micrium
Micrium is a leading provider of high-quality embedded software and is known for clean code, thorough documentation and top-notch technical support. Micrium offers a complete RTOS including kernel, file system, GUI and protocol stacks.

PubNub
PubNub provides secure, real-time IoT solutions using their Global Data Stream Network.

System Services
MPLAB Harmony System Services are responsible for managing shared resources so that other modules, such as drivers, middleware and applications, do not conflict on shared resources. Some of the system services provided by MPLAB Harmony include clock, console, debug, device control, DMA, interrupt, messaging, ports, random number generator, reset, timer and watch-dog timer.

Bootloader Library
The Bootloader Library can be used to upgrade firmware on a target device without the need for an external programmer or debugger. A demonstration application, which can be downloaded into the target PIC32 device using the bootloader is included. It provides a personal computer host application to communicate with the bootloader firmware running inside the PIC32 device. The personal computer application is used to perform erase/programming operations.

Operating System Abstraction Layer (OSAL)
The OSAL provides the interface to commonly available Real-Time Operating Systems (RTOS) such that drivers and middleware (and optionally, applications) may be written using a single interface to a minimal set of OS-specific features needed to provide thread safety.

The Operation System Abstraction Layer supports:
- FreeRTOS
- OpenRTOS
- Micrium μC/OS-II
- Micrium μC/OS-III
- ThreadX
- embOS

SEGGER
embOS is a priority-controlled RTOS. It boasts a zero interrupt latency, extremely-fast context switching time and industry-proven reliability.

evWin is a graphics library that provides efficient GUI building blocks for applications that operate with a graphical LCD. It features robust graphics widget and shape drawing library and is RTOS independent.

WITTENSTEIN high integrity systems
OpenRTOS is the only available commercial license for FreeRTOS, the highly successful, small, efficient embedded RTOS. It removes the FreeRTOS modified GPL conditions, provides commercial indemnification, confidentiality and professional support.

wolfSSL
CyaSSL, Embedded SSL Library, is a light weight SSL/TLS library written in ANSI C and targeted for embedded, RTOS and resource-constrained environments. This is primarily because of its small size, speed and feature set.

For latest updates on MPLAB Harmony solutions and third-party partners, please refer to the MPLAB Harmony Help File/Release Notes under the “Documentation” section at www.microchip.com/harmony.
A Board Support Package provides code and configuration items necessary to support board-specific hardware. A BSP may contain a board-specific configuration header, a board-specific system initialization file, a file containing board-specific ISR implementations. Everything that is contained within a BSP can be either used or replaced by application-specific items if desired.

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<tr>
<th>Application</th>
<th>Development Tool</th>
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<td>Connectivity: USB, Ethernet, CAN, Wi-Fi® and Bluetooth® SPP</td>
<td>PIC32MX1/2/5 Starter Kit</td>
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<td>PIC32MZ with FPU, Embedded Connectivity (EC) Starter Kit</td>
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<td>PIC32MX460 Plug-In Module (PIM)</td>
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<td>Graphics Controller PICtail™ Plus Epson S1D13517</td>
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<td>Graphics LCD Controller PICtail Plus SSD1926</td>
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<td>Low-Cost Controllerless (LCC) Graphics Board</td>
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<td>PIC32 GUI Development Board</td>
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Board Support Packages (BSPs) for one or more combinations of the development tools listed above are offered with the MPLAB Harmony Software Framework. For a specific combination of BSPs and updates, please refer to the Board Support Packages document under the “Documentation” section at www.microchip.com/harmony.

**MPLAB Harmony Resources**

**Download**
Download MPLAB Harmony at www.microchip.com/harmony.

**Support**
User support is provided by forums at www.microchip.com/forums keyword: “harmony”.

**Pricing**
The basic framework is free. Select libraries may need to be purchased.

**One-Stop Shop**
License, resale and support (including select third-party solutions) all via www.microchip.com/harmony.
Support
Microchip is committed to supporting its customers in developing products faster and more efficiently. We maintain a worldwide network of field applications engineers and technical support ready to provide product and system assistance. In addition, the following service areas are available at www.microchip.com:
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- **Sample** link offers evaluation samples of any Microchip device: [http://sample.microchip.com](http://sample.microchip.com)
- **Forum** link provides access to knowledge base and peer help: [http://forum.microchip.com](http://forum.microchip.com)
- **Buy** link provides locations of Microchip Sales Channel Partners: [www.microchip.com/sales](http://www.microchip.com/sales)

Training
If additional training interests you, then Microchip can help. We continue to expand our technical training options, offering a growing list of courses and in-depth curriculum locally, as well as significant online resources – whenever you want to use them.
- Technical Training Centers and Other Resources: [www.microchip.com/training](http://www.microchip.com/training)
- MASTERS Conferences: [www.microchip.com/masters](http://www.microchip.com/masters)
- Worldwide Seminars: [www.microchip.com/seminars](http://www.microchip.com/seminars)
- eLearning: [www.microchip.com/webseminars](http://www.microchip.com/webseminars)

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<td>Thailand - Bangkok</td>
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<td>Tel: 86-29-8833-7252</td>
<td>Tel: 66-2-694-1351</td>
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