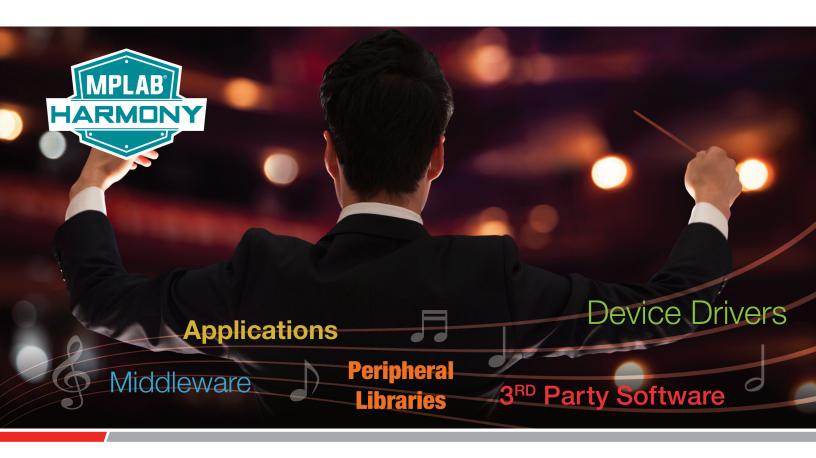


MPLAB® Harmony Integrated Software Framework

Industry's Most Advanced and Easy-to-Use Embedded Software Solution



MICROCHIP

MPLAB® Harmony

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

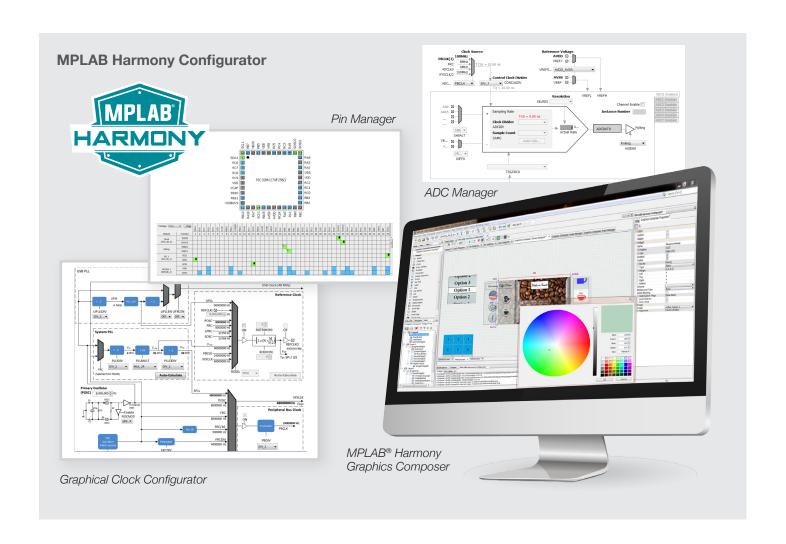
- Faster time-to-market
- Improved code interoperability
- Simplified support
- MPLAB Harmony Configurator (MHC) for enhanced user experience
- Improved 32-bit scalability
- Enhanced third-party software integration

MPLAB Harmony Configurator

The MPLAB Harmony Configurator (MHC) 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 initialize clock frequencies and IO pin settings and easily select and configure software modules without writing a single line of code yourself.

Highlights of MHC

- Graphical clock configurator
- Graphical pin manager
- Application templates for rapid configuration and quick code generation for up to 10 different user applications simultaneously
- MPLAB Harmony Display Manager
- MPLAB Harmony ADC Manager
- MPLAB Harmony Graphics Composer
- Enables seamless integration of third-party RTOS or libraries into your application with the click of a mouse



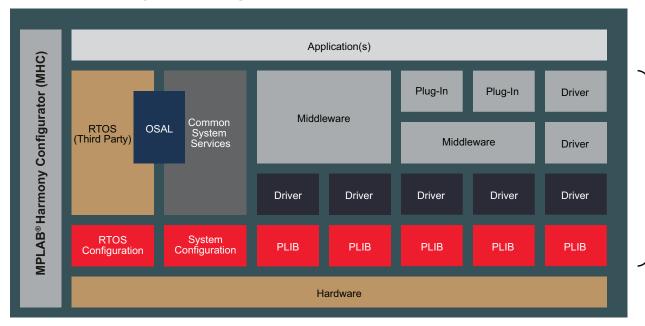
PIC32 Software Components Available with MPLAB Harmony

Applications	Operating System Abstraction Layer (OSAL)	Middleware/ Software Libraries	Device Drivers	Development Software	Third-Party Software
 Bluetooth® Low Energy, Bluetooth audio and SPP CAN applications Graphics applications TCP/IP applications and utilities USB applications Crypto 	 OSAL interface with "basic" and "none" implementation ThreadX embOS FreeRTOS OpenRTOS Micrium μC/OS-II Micrium μC/OS-III 	 Graphics TCP/IP USB Cryptographic libraries Class B File systems System services Bluetooth DSP/Math Bootloader Peripheral Libraries (PLIBs) 	 802.11 Wi-Fi® media access controller ADC Audio Codecs Ethernet media access controller Motor Control PWM Ethernet PHY interface Controllerless graphics Epson and Solomon LCD controller Non-volatile memory SPI, UART, CAN2.0B, high-speed USB Timer Parallel master port 	 MPLAB® X IDE MPLAB XC32++ MPLAB Harmony Configurator (MHC) Plug-In MPLAB Harmony Graphics Composer (MHGC) Board Support Packages (BSP) MPLAB Harmony Display Manager 	• Security • IoT • Graphics • RTOS

Additional software components planned



MPLAB Harmony Block Diagram



Software Framework

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
- 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
- Compliant with MISRA-C:2012 mandatory standards

Middleware Layer

- Eases implementation of libraries and protocols (USB, TCP/IP, digital audio, graphics)
- Provides a highly-abstracted application program interface
- Libraries are thread-safe and RTOS-ready
- Built-on drivers, PLIBS, system services

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 operation
- Accesses hardware directly or 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 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 MRF24WN and WINC1500, allows an application to:

- Join an existing secure 802.11b/g/n Wi-Fi network
- Create a secure 802.11b/g/n 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.

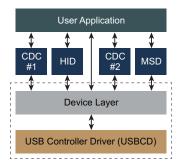
The USB Device Stack features:

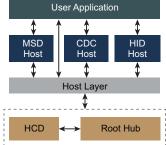
- Support for different USB device classes (CDC, audio, HID, MSD and generic)
- Support for multiple instances of the same class in a composite device
- Features thread safe operation when used in an RTOS based application
- Support for multiple configurations at different speeds
- Supports multiple USB peripherals

The USB Host Stack allows development of an embedded USB Host application that supports a variety of USB Device classes.

The USB Host Stack features:

- Supports CDC, MSD, HID, Hub and audio v1.0 device classes
- Support for Hub allows multiple USB devices to be supported in an application.
- Features thread safe operation when used in an RTOS based application
- 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





USB Device Library Architecture

USB Host Library Architecture

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 Basic Stack Library

MPLAB Harmony offers PIC32 Bluetooth® Basic stack supporting the data transfer and includes the Bluetooth Low Energy (BLE) and Serial Port Profile (SPP) Data demonstrations for free.



Human Machine Interface (HMI)

MPLAB Harmony Graphics Composer Suite

The MPLAB Harmony Graphics Composer Suite (MHGC) features a free, modular graphics stack, various tools and utilities for use with Microchip's PIC32 microcontrollers. The MHGC tool provides an easy to use GUI that works within the MPLAB X Integrated Development Environment (IDE). This is tightly coupled with MPLAB Harmony Configurator (MHC) for code development and other integrated debug features. The suite simplifies creation of advanced graphics content by facilitating automatic code generation to reduce the development time.

The Graphics Library features:

- 24-bit color (32-bit with alpha channel) and multi-layer support
- Display Manager for automatic generation of display drivers
- MHGC Design Tool
- Aria Graphics Library
- Nano2D driver support for Graphics Processing Unit (GPU)
- Multiple modern widgets with support for touch gestures
- Multi-lingual font package
- Run-time graphic widget motion
- Run-Length Encoding (RLE) image compression

Aria Graphics Library

The library provides the building blocks to ease the development of aesthetically pleasing user interfaces and is responsible for managing the interface once created.

Key Features

- Provides a simple but powerful user experience
- Customizable to the needs of the application
- Light and flexible with regards to resource consumption
- Easily extensible to meet future design needs

Display Manager

A rapid prototyping tool that automatically generates drivers for your chosen display. It offers simulation of display controller timing and active area management. The tool supports both Low Cost Controller-less graphics (LCC) and display controllers that include GLCD, S1D13517, SSD1926, and OTM2201A. It can also be easily configured to incorporate a custom display driver.

Nano2D Driver Library

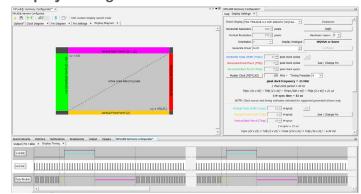
The Nano2D Library provides full functionality for the PIC32MZ 2D Graphics Processing Unit (GPU), which includes lines, rectangles, bit block transfers (blits), transparency, and binary Raster OPerations (ROP2). The library provides the APIs for drawing accelerated raster graphics onto memory buffers with the aid of the GPU and uses little to no CPU resources.

maXTouch® Driver and Touch System Services Library

The MPLAB Harmony maXTouch Driver provides a high-level interface to the MXT336T 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. The MPLAB Harmony Graphics Composer is designed to automatically configure the Touch System Service and the Message System Service based on your request for touch screen input. 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.

Display Manager



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.

BM64 Bluetooth Application

MPLAB Harmony offers free audio applications built using the BM64 Bluetooth driver. The application makes use of the A2DP and HFP profiles to demonstrate hands-free voice call.

Free Audio Decoder Libraries

Microchip also offers decoder libraries that are available with the free download of MPLAB Harmony Framework. These include FLAC, OPUS, SPEEX, WAVE and ADPCM.

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.

USB Audio Host Client Driver Library

It allows USB Host applications to support and interact with USB Audio Class 1.0 devices with the following features:

- Supports USB Audio Class 1.0 device with multiple streaming interfaces
- Designed to support multi-client operation
- RTOS ready
- · Features an event driver non-clocking application interaction model
- · Supports queuing of read and write data transfers

Universal Audio Decoder:

The Universal Audio Decoder application runs in USB Host mode and supports the FAT32 file system to play audio files from the mass storage device. The application supports WAVE, MP3, AAC, WMA, ADPCM and Speex formats.

emWin Media Player:

This application demonstrates the creation of an audio player that plays WAVE files from an SD Card and from a USB Flash-drive. The Graphical User Interface (GUI) with touch screen support is designed using the SEGGER emWin Graphics Library. The GUI provides options to select media type (SD Card/Flash-drive), volume controls, random selection/shuffling of tracks and playlist view with progress bar/seek bar.



Basic Libraries, System Services and OSAL

Peripheral Libraries (PLIBs)

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. PLIBs comply to MISRA-C:2012 mandatory standards.

Class B Library

This library provides Class B safety software routines which can detect the occurrence of faults in a single channel CPU. These routines have been developed in accordance with the IEC 60730 standard to support the Class B certification process. Each routine can be directly integrated with the your application to test and verify the critical functionalities of a controller and can be called periodically at start-up or run time.

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. The C code implementation of of LibQ Fixed-Point Math library is also available that provides functions written in C for portability between MCUs.

Cryptographic Library

Microchip offers 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 underlying file systems and multiple media in the same application. Supported file systems are FAT12, FAT16, FAT32 and MPFS. A common interface provides easy access to any supported file system format on any supported storage medium.

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

The Bootloader can be used to upgrade firmware on a target device without the need for an external programmer or debugger. MPLAB Harmony offers multiple bootloader configurations that include UART, USB, Ethernet and SD card.

Operating System Abstraction Layer (OSAL)

The OSAL provides the interface to commonly available Real-Time Operating Systems (RTOS) such that MPLAB Harmony libraries may be written using a single interface to a minimal set of OS features needed to provide thread safety.

The Operation System Abstraction Layer supports:

- FreeRTOS
- OpenRTOS
- Micrium µC/OS-II
- Micrium µC/OS-III
- ThreadX
- embOS

MPLAB Harmony Third-Party Partners

Microchip offers solutions from industry-leading RTOS, Internet of Things (IoT), security and graphics third parties 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 opensource RTOS.

Micrium

Micrium is a leading provider of high-quality embedded software and is known for clean code, throrough 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.

iREASONING Networks

The iREASONING Networks MIB Browser is used to run the MPLAB Harmony TCP/IP SNMP demonstration. It is a powerful and easy-to-use tool powered by iReasoning SNMP API. It allows you to load standard, proprietary MIB, and even some mal-formed MIBs.

SEGGER

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

emWin 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 FreeR-TOS, the highly successful, small, efficient embedded RTOS. It removes the FreeRTOS modified GPL conditions, provides commercial indemnification, confidentiality and professional support.

wolfSSL

The wolfSSL, 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.

The wolfMQTT library is a client implementation of the Message Queuing Telemetry Transport (MQTT) written in C for embedded use. It supports SSL/TLS via the wolfSSL library. It was built from the ground up to be multi-platform, space conscience and extensible. It supports all packet types and all Quality of Service (QoS) levels 0-2. This implementation is based on the MQTT v3.1.1 specification.



MPLAB Harmony Board Support Packages (BSP)

A Board Support Package provides code and configuration items necessary to support board-specific hardware. A BSP may contain custom library code supporting on-board LEDs and switches as well as appropriate configuration settings to configure drivers and libraries that support available hardware on the selected board. Everything that is contained within a BSP can be either used or replaced by application-specific items if desired.

Application	Development Tool	Part Number	
	PIC32MX1/2/5 Starter Kit	DM320100	
	PIC32 Bluetooth Starter Kit	DM320018	
	PIC32 Ethernet Starter Kit	DM320004	
	PIC32MK GP Development Kit	DM320106	
	PIC32 Ethernet Starter Kit II	DM320004-2	
	PIC32 XLP Starter Kit	DM320105	
	PIC32 USB Starter Kit II	DM320003-2	
	PIC32 USB Starter Kit III	DM320003-3	
	PIC32MZ Curiosity Development Board	DM320104	
Connectivity: USB, Ethernet, CAN,	PIC32MZ with FPU, Embedded Connectivity Starter Kit	DM320007	
Wi-Fi®, Bluetooth® SPP and	PIC32MZ with FPU and Crypto, Embedded Connectivity Starter Kit	DM320007-C	
Bluetooth® Low Energy	PIC32 I/O Expansion Board	DM320002	
	Explorer 16 Development Board	DM240001	
	PIC32MX460 Plug-In Module (PIM)	MA320002	
	PIC32MX450/470 PIM	MA320002-2	
	PIC32MX795F PIM	MA320003	
	PIC32MZ with FPU PIM	MA320019	
	chipKIT® WF32 Wi-Fi Development Board	TDGL021	
	WINC1500 Wi-Fi PlCtail/PlCtail Plus Daughter Board	AC164156	
	chipKIT Wi-FIRE Development Board	TDGL021-2	
	Multimedia Expansion Board II (MEB II)	DM320005-5	
	Graphics Controller PlCtail™ Plus Epson S1D13517	AC164127-7	
	Graphics LCD Controller PICtail Plus SSD1926	AC164127-5	
	Low-Cost Controllerless (LCC) Graphics Board	AC164144	
	PIC32 GUI Development Board	DM320015	
	Graphics Display Truly 3.2" 320 × 240 Board	AC164127-4	
Graphics and Touch	Graphics Display Truly 5.7" 640 × 480 Board	AC164127-8	
	Graphics Display Powertip 4.3" 480 × 272 Board	AC164127-6	
	Graphics Display 5" WVGA PCAP Board	AC320005	
	PIC32MZ Embedded Graphics with Stacked DRAM (DA) Starter Kit	DM320010	
	PIC32MZ Embedded Graphics with Stacked DRAM (DA) Starter Kit (Crypto)	DM320010-C	
	PIC32MZ Embedded Graphics with External DRAM (DA) Starter Kit	DM320008	
	PIC32MZ Embedded Graphics with External DRAM (DA) Starter Kit (Crypto)	DM320008-C	
	PIC32MX470 Curiosity Development Board	DM320103	
	PIC32 Bluetooth Audio Development Kit	DV320032	
	PIC32 Audio DAC Daughter Board	AC320032-2	
Digital Audio and Bluetooth	Audio codec daughter card-AK4642	AC320100	
Digital Addio and Didetootil	PIC32MX270F512L Bluetooth PIM	MA320017	
	PIC32MZ with FPU Bluetooth PIM	MA320018	
	Audio codec daughter card-AK7755	AC327755	
	BM64 Bluetooth Radio Daughter Board	AC320032-3	

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"



Self-Paced Training

www.microchip.com/developerhelp



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. For more information, please visit www.microchip.com:

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Training

If additional training interests you, Microchip offers several resources including in-depth technical training and reference material, self-paced tutorials and significant online resources.

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- MASTERs Conferences: www.microchip.com/masters
- Developer Help Website: www.microchip.com/developerhelp
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China - Hong Kong SAR Tel: 852-2943-5100

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China - Shanghai Tel: 86-21-3326-8000

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