AN3456

Getting Started with tinyAVR 2 Family

Introduction

Author: Rupali Honrao, Microchip Technology Inc.

This application note outlines how to get started with the tinyAVR® 2 Family devices.

Refer to the data sheet for further information on the differences between the tinyAVR® 2 Family devices.

Features presented in this document

- Getting Started with tinyAVR® 2 Family Microcontrollers and Tools
- Getting Started with ATtiny1627 Curiosity Nano and Atmel Studio 7.0
- Getting Started with ATtiny1627 Curiosity Nano and MPLAB® X
- Code examples in Atmel START and Github

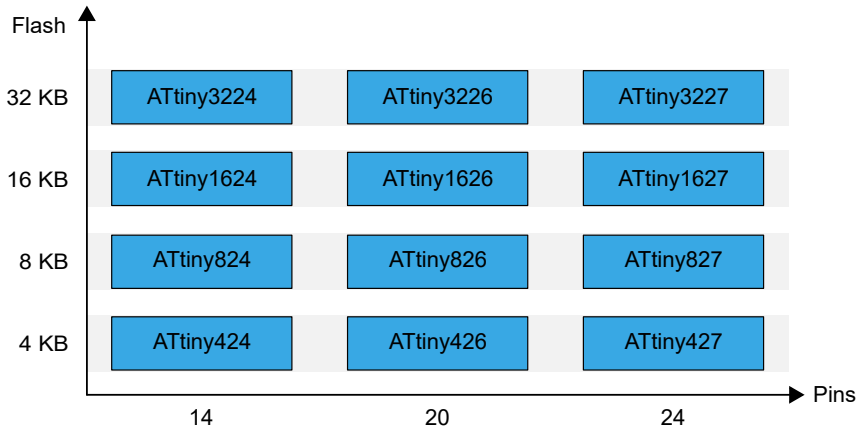
Table of Contents

1. Relevant Devices

This section lists the relevant devices for this document. The following figures show the different family devices, laying out pin count variants and memory sizes:

- Vertical migration upwards is possible without code modification, as these devices are pin-compatible and provide the same or more features
- Horizontal migration to the left reduces the pin count and, therefore, the available features
- Devices with different Flash memory sizes typically also have different SRAM and EEPROM

Figure 1-1. tinyAVR® 2 Family Overview



2. Get the Device Data Sheet

Product pages

- https://www.microchip.com/wwwproducts/en/ATtiny1624
- https://www.microchip.com/wwwproducts/en/ATtiny1626
- https://www.microchip.com/wwwproducts/en/ATtiny1627

Documents

- tinyAVR 2 Data Sheet (.pdf)
- tinyAVR 2 Errata (.pdf)

The documentation for the tinyAVR® 2 Family is split into two document types:

- Data sheet(1) (includes device description, number of peripherals, pinout and electrical characteristics)
- Errata (includes known errata for the device)

Note:

1. For devices that are future products, the product brief is available instead of the data sheet.

3. Relevant Documents

All relevant documents can be found under the documentation tab on the product page.

Below is list of documents relevant to tinyAVR® 2 Family Microcontrollers.

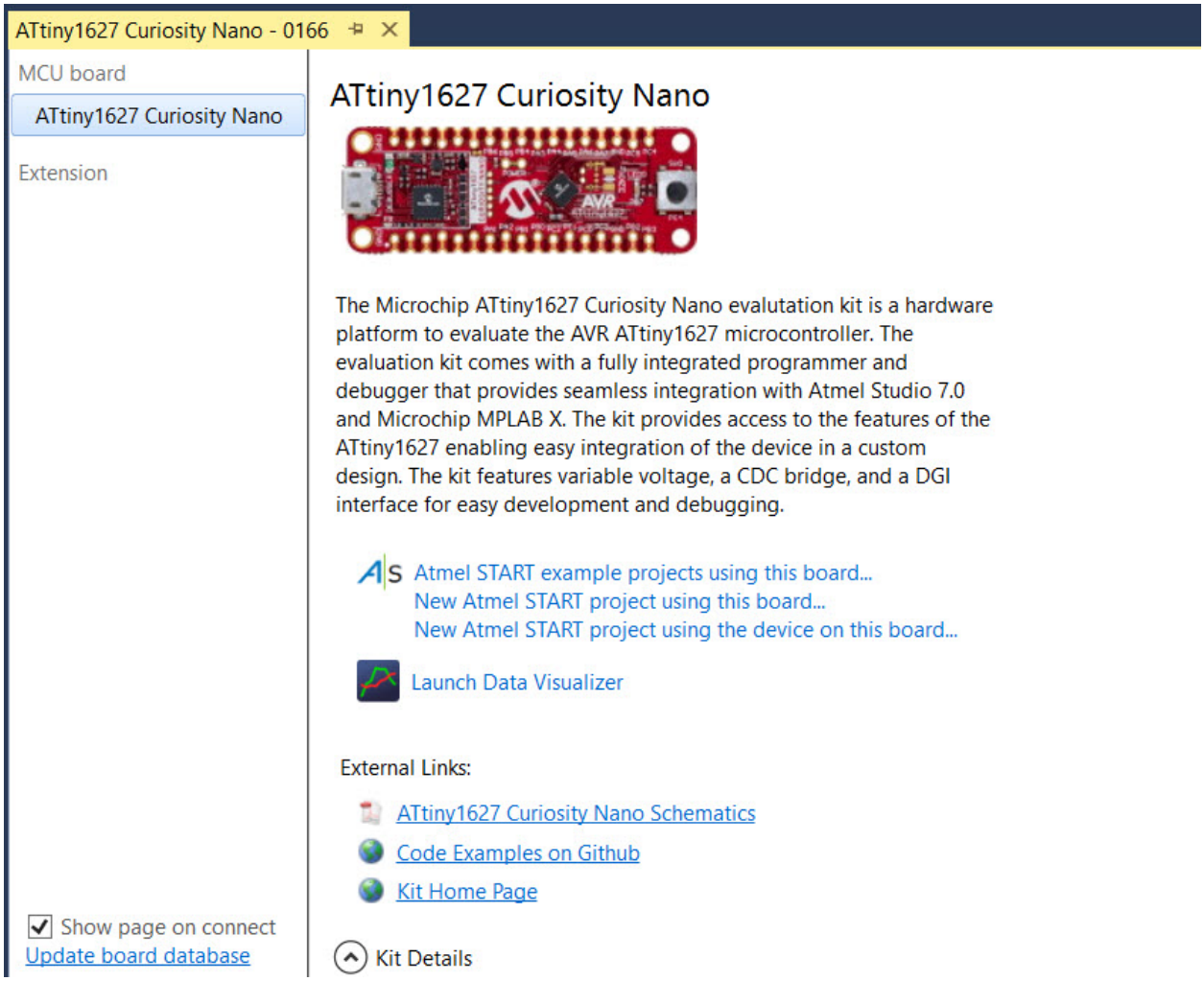
- Tech Briefs:
  - How to use the 12-Bit Differential ADC with PGA in Single Mode
  - How to use the 12-Bit Differential ADC with PGA in Series Accumulation Mode
  - How to use the 12-Bit Differential ADC with PGA in Burst Accumulation Mode
- Application Notes:
  - How to use Force Sensitive Resistor with 12-Bit ADC
  - How to use Sensor PIR with 12-bit ADC with PGA
  - Using Matrix Keypad With AVR® Devices
- Training Manual:
  - Getting Started with tinyAVR 2 Family ADC Hands-on

4. Get the Tools

Atmel Studio 7.0, which uses the GCC compiler, can be utilized as an IDE to get started with tinyAVR® 2 Family.

MPLAB® X, which uses the GCC or XC8 compiler, can be utilized as an IDE to get started with tinyAVR® 2 Family.

4.1 Get the ATtiny1627 Curiosity Nano Evaluation Kit



Web page: www.microchip.com/developmenttools/productdetails.aspx?partno=DM080104

Get the kit: www.microchipdirect.com/ProductSearch.aspx?Keywords=DM080104

Document/file:

- ATtiny1627 Curiosity Nano (.pdf)

Key Features

- ATtiny1627 Microcontroller
- One Yellow User LED
- One Mechanical User Switch
- Footprint for 32.768 kHz Crystal
- On-Board Debugger:
  - Board identification in Atmel Studio/Microchip MPLAB® X

  - One green power and status LED
  - Programming and debugging
  - Virtual COM port (CDC)
  - Two logic analyzer channels (DGI GPIO)
- USB Powered
- Adjustable Target Voltage:
  - MIC5353 LDO regulator controlled by the on-board debugger
  - 1.8-5.1 V output voltage (limited by USB input voltage)
  - 500 mA maximum output current (limited by ambient temperature and output voltage)

The ATtiny1627 Curiosity Nano user guide covers how to power the kit and the detailed information on board components, extension interface, and the hardware guide.

4.2 Get the STK600 Starter Kit

Figure 4-1. STK600 Starter Kit

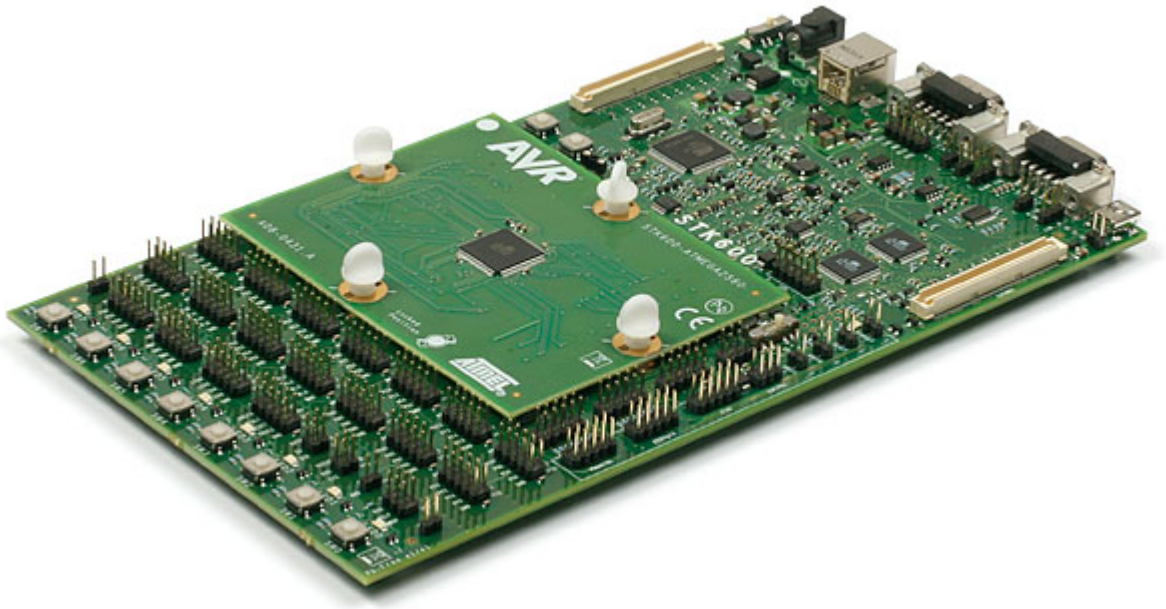


Table 4-1. STK600 Device Support for tinyAVR® 2 Family

Device	Routing Card	Socket Card
ATtiny1624	STK600-RC020T-104	STK600-SOIC
ATtiny1626	STK600-RC020T-104	STK600-SOIC
ATtiny1627	STK600-RC024T-103	STK600-QFN24

For device support for other devices, refer to: http://www.microchip.com/STK600_Starter_Kit-Users_Guide

Web page: http://www.microchip.com/ATSTK600

Get the kit: https://www.microchipdirect.com/product/ATSTK600

Document/file:

- STK600 User Guide (.pdf)

Key features

- Atmel Studio/AVR® Studio 5/AVR Studio 4/AVR32 Studio
- USB Interface to PC for Programming and Control
- Powered from the USB Bus or an External 10-15V DC Power Supply
- Adjustable Target V_{CC} (0-5.5V)
- Two Adjustable Reference Voltages with High Accuracy (0-5.0V, 10 mV res.)
- Clock Oscillator, Adjustable On-The-Fly from Atmel Studio (0-50 MHz, 0.1% res.)
- Serial In-System Programming (ISP) of tinyAVR and megaAVR® Devices
- PDI Programming of AVR XMEGA® Devices
- JTAG Programming of megaAVR, AVR XMEGA, and AVR UC3 Devices
- aWire Programming of AVR UC3 Devices
- ISP and JTAG Programming of AVR Devices in External Target Systems
- Flexible Routing and Socket Card System for Easy Mounting of all Supported Devices
- Eight Push Buttons for General Use
- Eight LEDs for General Use
- All AVR I/O Ports are Easily Accessible through Pin Header Connectors
- Expansion Connectors for Plug-In Modules and Prototyping Area
- On-Board 4 Mb DataFlash for Nonvolatile Data
- USB mini-AB (On-The-Go) Connector for AVR Devices with USB
- PHY and DSUB-9 Connector for RS-232 Interface
- PHY and DSUB-9 Connector for CAN Bus
- PHY and Header for LIN Bus
- Device Board with an ATmega2560 AVR Microcontroller Included

The STK600 User Guide describes how to power the kit and includes detailed information about board components, extension interface, and the hardware description.

4.3 Get Code Examples from Atmel START

The code examples are available through Atmel START, which is a web-based tool that enables the configuration of the application code through a Graphical User Interface (GUI). The code can be downloaded for Atmel Studio MPLAB X and IAR Embedded Workbench® via the direct example code link below or the **Browse Examples** button on the Atmel START front page.

The Atmel START webpage: Atmel START.

Code Examples

Finding code examples for devices in the tinyAVR 2 family can be done by searching for the device name (e.g., ATtiny1627), in the Atmel | START example browser.

Click **User Guide** in Atmel START for details and information about example projects. The **User Guide** button can be found in the example browser, and by clicking the project name in the dashboard view within the Atmel START project configurator.

Atmel Studio

Download the code as an `.atzip` file for Atmel Studio from the example browser in Atmel START by clicking **Download Selected example**. To download the file from within Atmel START, click **Export project** followed by **Download pack**.

Double click the downloaded `.atzip` file, and the project will be imported to Atmel Studio 7.0.

MPLAB X

Download the code as an `.atzip` file for MPLAB X IDE from within Atmel START by clicking **Export project** followed by **Download pack**.

To open the Atmel START example in MPLAB X, select from the menu in MPLAB X, *File > Import > START MPLAB Project* and navigate to the `.atzip` file.

IAR Embedded Workbench

For information on how to import the project in IAR Embedded Workbench, open the Atmel START User Guide, select **Using Atmel Start Output in External Tools**, and **IAR Embedded Workbench**. A link to the Atmel START User Guide can be found by clicking *Help* from the Atmel START front page or **Help And Support** within the project configurator, both located in the upper right corner of the page.

4.4 Get Code Examples from GitHub

The code examples are available through GitHub, which is a web-based server that provides the application codes through a Graphical User Interface (GUI). The code examples can be opened in both Atmel Studio and MPLAB X. To open the Atmel Studio project in MPLAB X, select from the menu in MPLAB X, *File > Import > Atmel Studio Project* and navigate to `.cproj` file.

The GitHub webpage: GitHub.

Code Examples

Finding code examples for devices in the tinyAVR 2 Family can be done by searching for the device name (e.g., ATtiny1627), in the GitHub example browser.

Download the code as a `.zip` file from the example page on GitHub by clicking the **Clone** or **download** button.

4.5 Get Atmel Studio 7.0

Webpage: www.microchip.com/development-tools/atmel-studio-7

Document/file:

- Atmel Studio 7.0 Installer (.exe)

Atmel Studio 7.0 or later is the preferred IDE for developing and debugging firmware for the tinyAVR® 2 Family.

For device support, refer to 4.8 Get Device Support for Atmel Studio.

4.6 Get MPLAB® X

Webpage: MPLAB® X IDE

Document/file:

- MPLAB X

MPLAB X can be utilized as an IDE for developing and debugging firmware for the tinyAVR® 2 Family.

For device support, refer to 4.9 Get Device Support for MPLAB X.

4.7 Get IAR Embedded Workbench® for AVR®

Webpage: https://www.iar.com/iar-embedded-workbench/#!?architecture=AVR

Document/file: IAR Embedded Workbench installer for AVR®.

4.8 Get Device Support for Atmel Studio

Atmel Studio: Support for new devices in Atmel Studio can be added by using the *Device Pack Manager*, which is found under *Tools → Device Pack Manager*.

For tinyAVR® 2 Family, update to the latest version by performing the following steps:

1. Click **Check for Updates**.
2. For tinyAVR® 2 Family, select the latest available version of *ATtiny_DFP*.
3. Click **Install**.

For offline installers, go to packs.download.atmel.com/. To install a package, double click on the installer file and follow the instructions. Any open Atmel Studio window will have to be closed for the installation to take effect.

IAR™: Support for new devices in IAR Embedded Workbench can be added by installing the latest service package. The service package is available at *My Pages* on https://iar.com.

4.9 Get Device Support for MPLAB® X

MPLAB X: Support for new devices in MPLAB X can be added by using the *MPLAB Pack Manager*, which is found under *Tools → Packs*.

For the tinyAVR® 2 Family, update to the latest version by performing the following steps:

1. Click **Check for Updates**.
2. For the tinyAVR® 2 Family, select the latest available version of *ATtiny_DFP*.
3. Click **Install**.

For offline installers, go to packs.download.microchip.com/. To install a package, double click on the installer file and follow the instructions. Any open MPLAB X window will have to be closed for the installation to take effect.

5. Atmel Studio Users Getting Started

5.1 Atmel Studio with ATtiny1627 Curiosity Nano

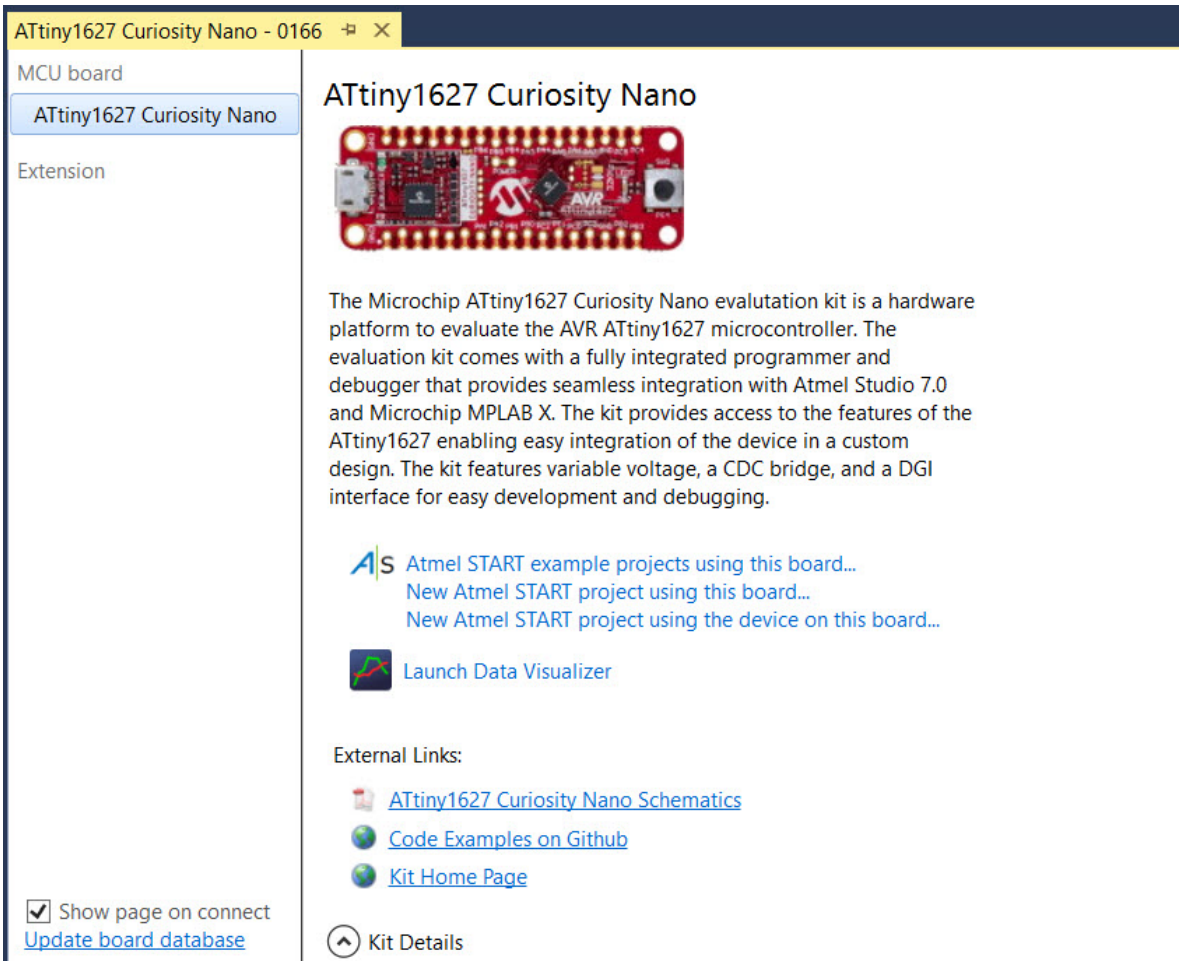
Prerequisites

- Atmel Studio 7.0.2397 or later installed
- The ATtiny1627 Curiosity Nano Board connected to Atmel Studio 7.0 via the on-board USB connector, which is connected to the embedded debugger. The kit will be powered by the USB, and the embedded debugger will enable debugging and programming via the USB.

Workflow

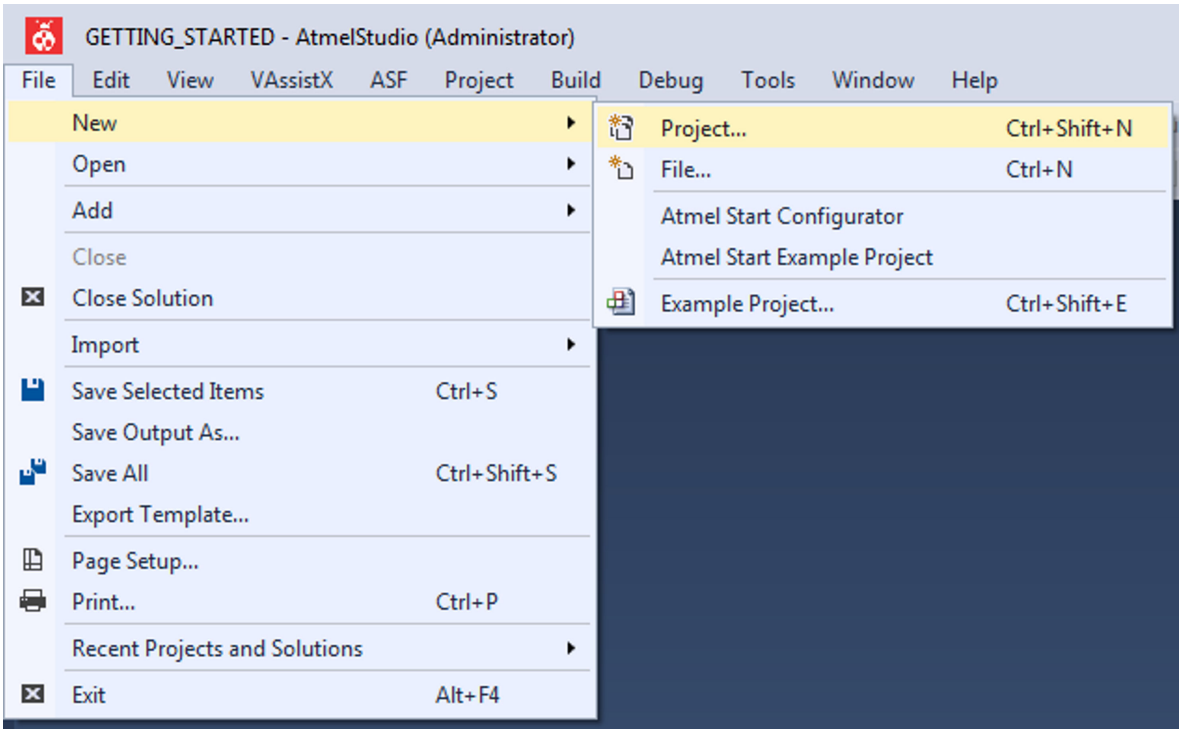
1. Launch Atmel Studio 7.0.
2. The page shown below will appear when ATtiny1627 Curiosity Nano is connected to Atmel Studio 7.0.

Figure 5-1. ATtiny1627 Curiosity Nano Page in Atmel Studio



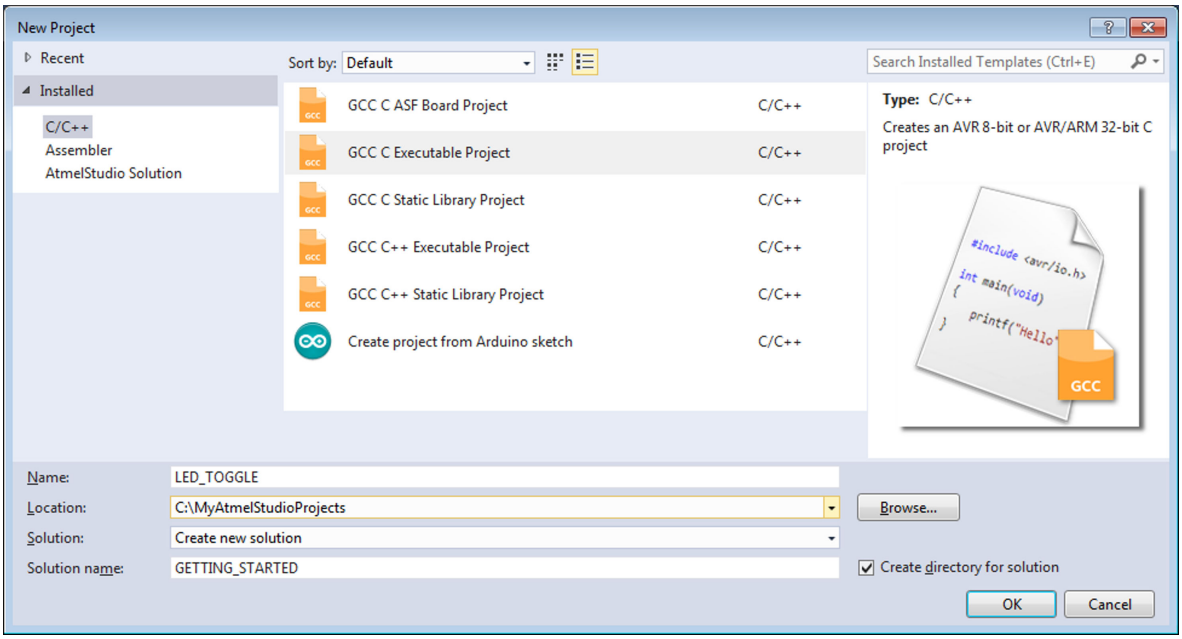
3. Start creating a new project by clicking **New** → **Project...** or by using **Ctrl+Shift+N** shortcut, as shown in Figure 5-2.

Figure 5-2. Create New Project in Atmel Studio



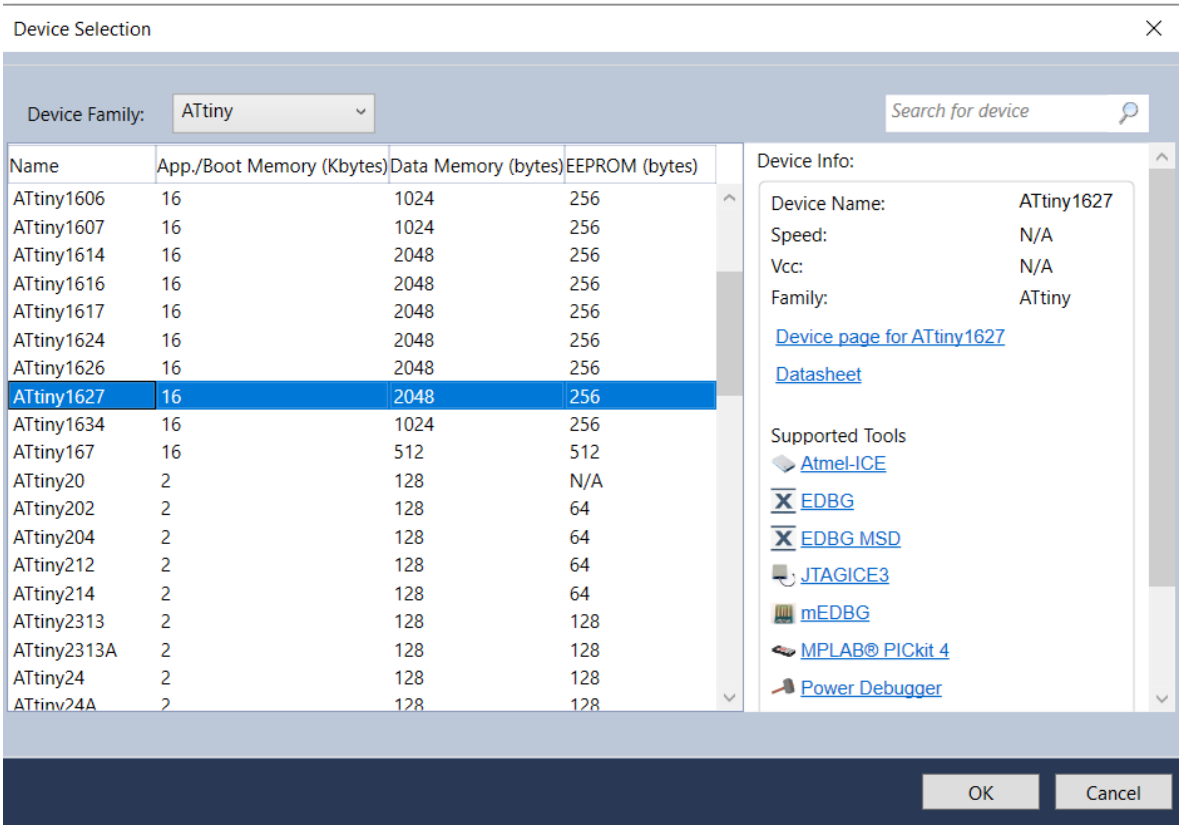
4. Select the **GCC C Executable Project** template, as shown in Figure 5-3, type in the name of the solution and project (e.g., *GETTING_STARTED* and *LED_TOGGLE*), and click **OK**.

Figure 5-3. New Project Wizard



5. Select ATtiny1627 from Figure 5-4, and click **OK**.

Figure 5-4. Device Selection Wizard



A new project with a `main.c` file associated with it will be generated in Atmel Studio.

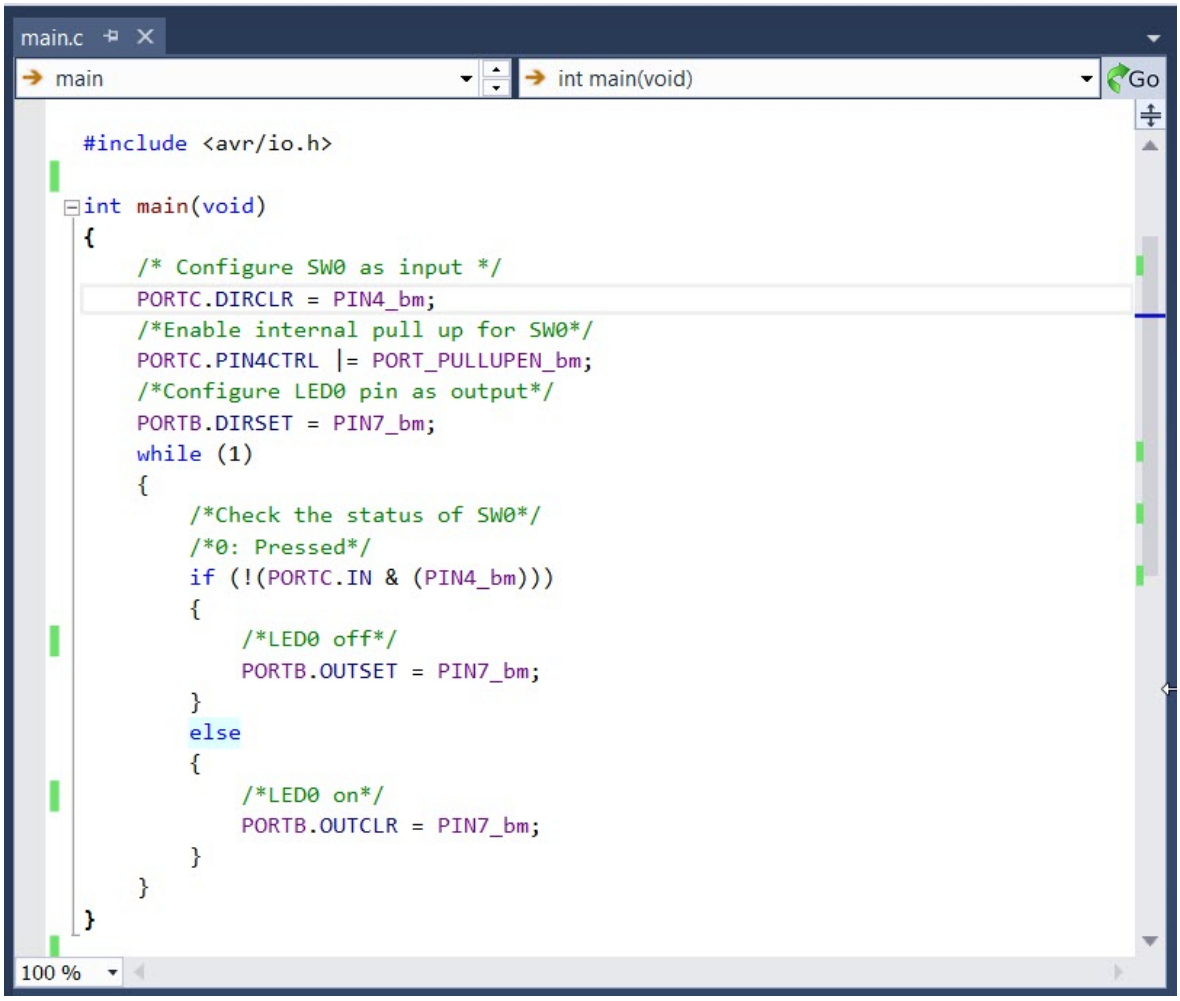
6. Replace the `main.c` file with the following code snippet:

```
int main (void)
{
  /* Configure SW0 as input */
  PORTC.DIRCLR = PIN4_bm;
  /*Enable internal pull up for SW0*/
  PORTC.PIN4CTRL  = PORT_PULLUPEN_bm;
  /* Configure LED0 pin as output */
  PORTB.DIRSET = PIN7_bm;

  while (1)
  {
    /* Check the status of SW0 */
    /* 0: Pressed */
    if (!(PORTC.IN & (PIN4_bm)))
    {
      /* LED0  off */
      PORTB.OUTSET = PIN7_bm;
    }
    /* 1: Released */
    else
    {
      /* LED0 on */
      PORTB.OUTCLR = PIN7_bm;
    }
  }
}
```

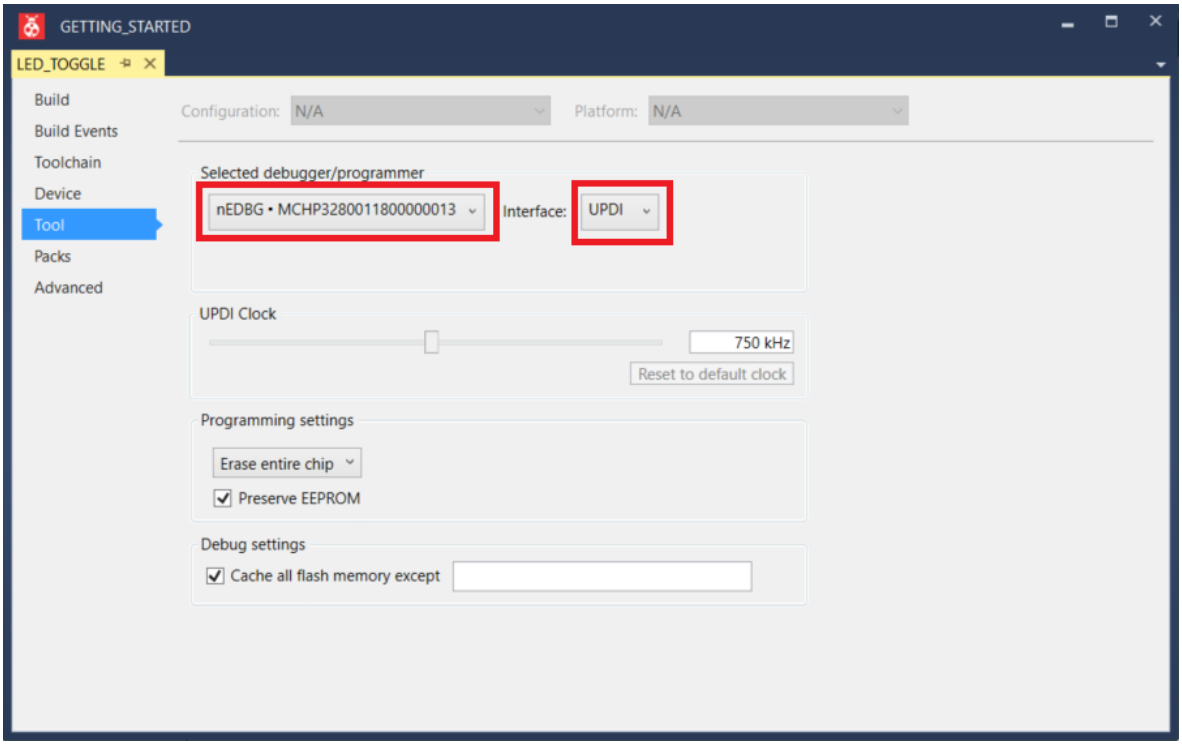
In the code editor, the code will appear, as shown in Figure 5-5.

Figure 5-5. Code Editor Window



7. Open project properties by clicking **Project** → **Properties** or by using **ALT+F7** shortcut.
8. In the **Tool** view (see Figure 5-6), set *Selected debugger/programmer* to nEDBG and *Interface* to UPDI.

Figure 5-6. Debugger and Interface for ATtiny1627



9. Build the project by clicking **Build** → **Build Solution** or by using **F7** shortcut.
10. Program ATtiny1627 with the project code and start debugging by clicking **Debug** → **Start debugging and break** or by using **ALT+F5** shortcut . The application is programmed onto the device, and program execution will break in `main()` function.
11. Run the code by clicking **Debug** → **Continue** or by using **F5** shortcut .
12. Verify that LED0 is lit when SW0 is pushed on the ATtiny1627 Curiosity Nano.

5.2 Atmel Studio with STK600

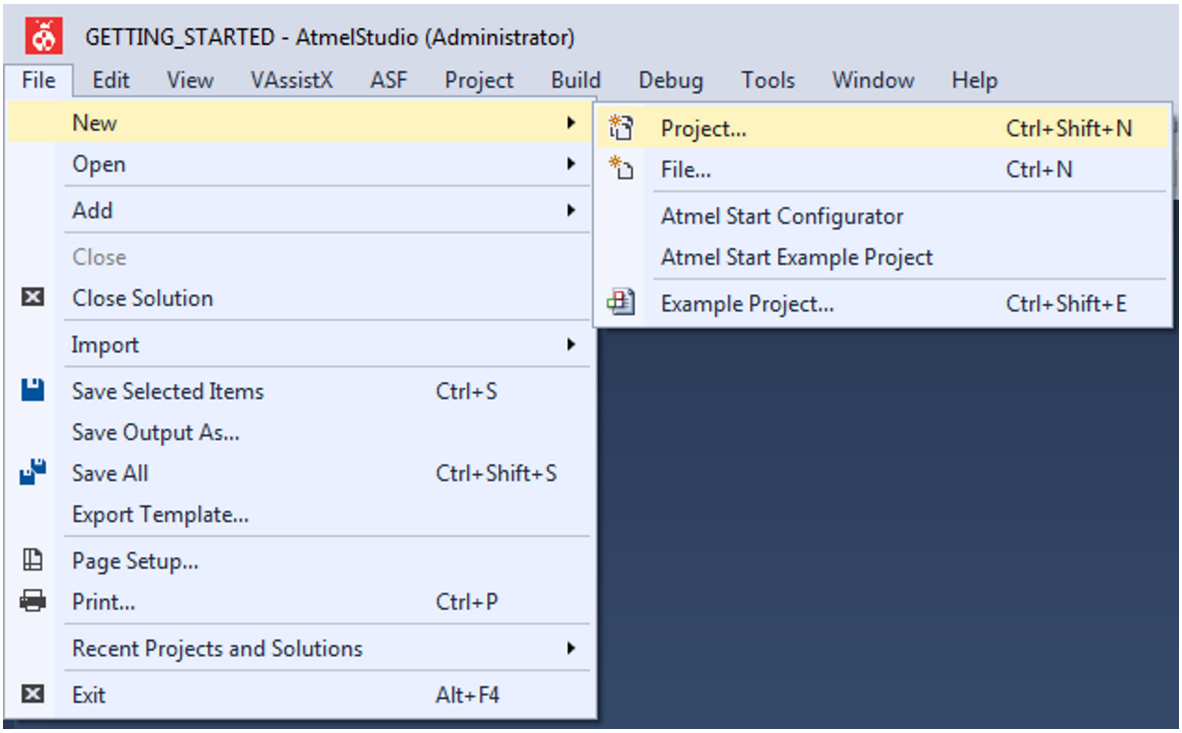
Prerequisites

- Atmel Studio 7.0 2397 or later installed
- The STK600 board connected to Atmel Studio 7.0 via the on-board USB connector.

Workflow

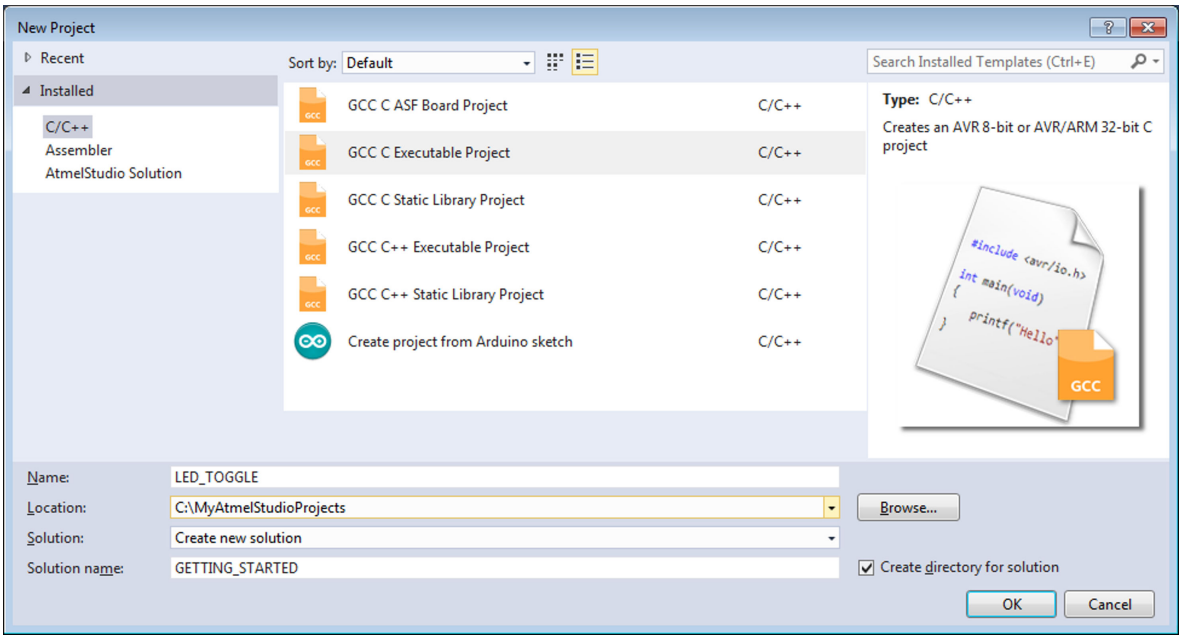
1. Launch Atmel Studio 7.0.
2. Start creating a new project by clicking *New → Project...* or by using the shortcut *Ctrl+Shift+N*, as shown in the figure below.

Figure 5-7. Create New Project in Atmel Studio



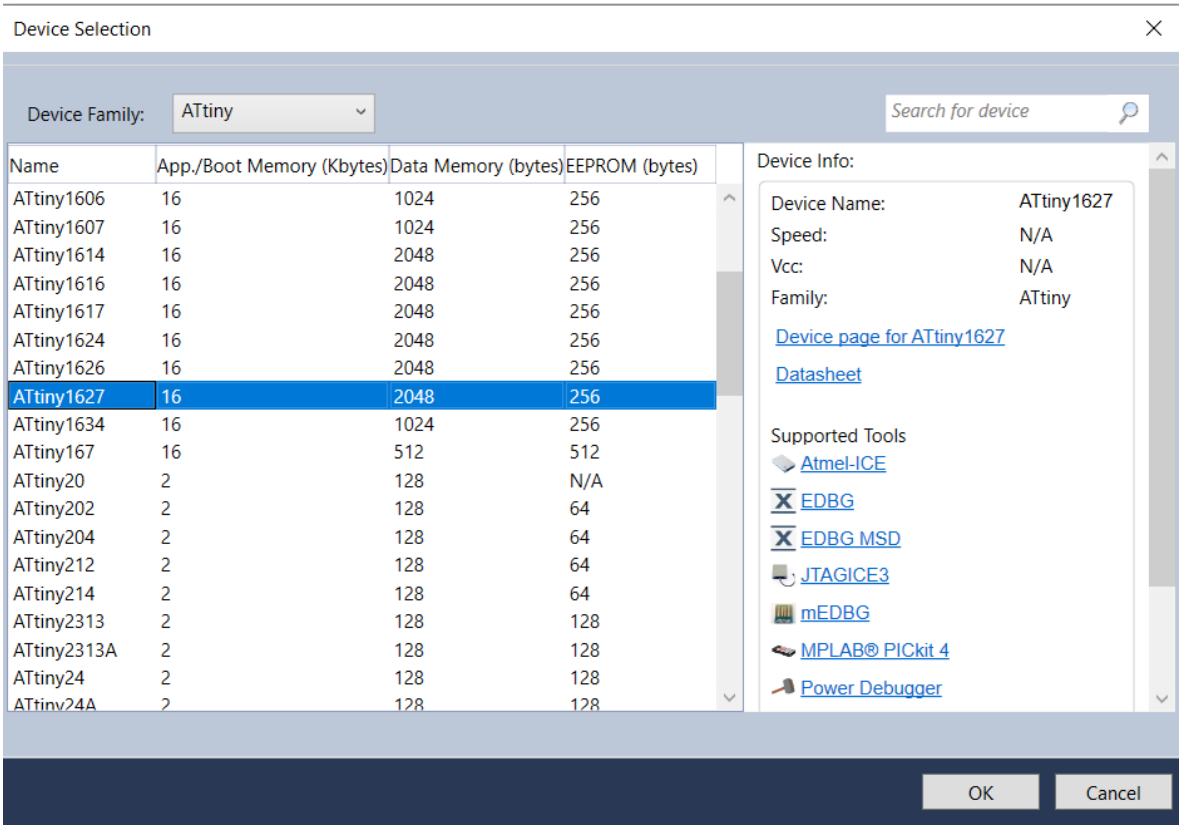
3. Select the *GCC C Executable Project* template from the new project wizard shown in the following figure, type in the name of the solution and project (e.g., *GETTING_STARTED* and *LED_TOGGLE*), and click **OK**.

Figure 5-8. New Project Wizard



4. Select ATtiny1627 from the device selection wizard as shown in the figure below, and click **OK**.

Figure 5-9. Device Selection Wizard



A new project with a `main.c` file associated with it will be generated in Atmel Studio.

5. Replace the '`main`' function in the `main.c` file with the following code snippet:

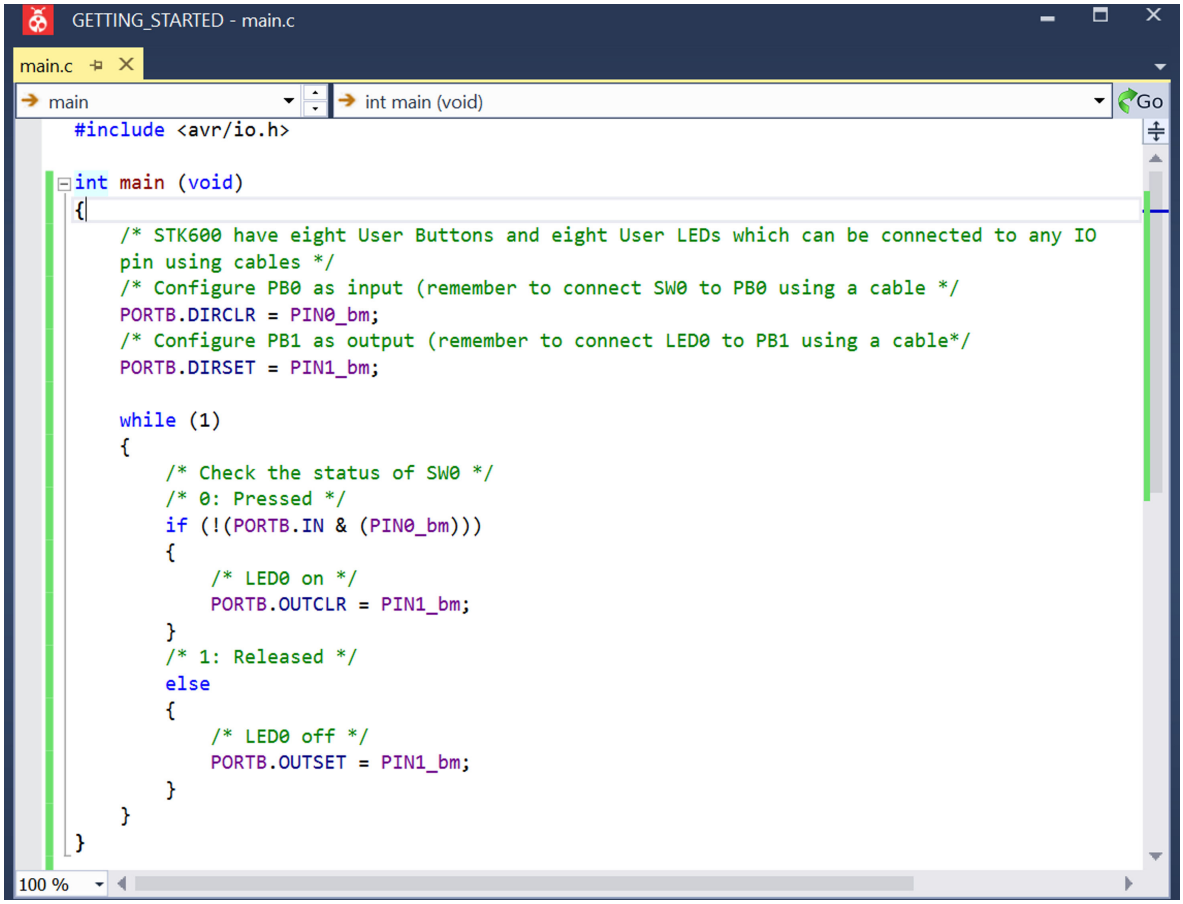
```
int main (void)
{
  /* STK600 have eight User Buttons and eight User LEDs which can be connected to any IO
pin using cables */
  /* Configure PB0 as input (remember to connect SW0 to PB0 using a cable */
  PORTB.DIRCLR = PIN0_bm;

  /* Configure PB1 as output (remember to connect LED0 to PB1 using a cable*/
  PORTB.DIRSET = PIN1_bm;

  while (1)
  {
    /* Check the status of SW0 */
    /* 0: Pressed */
    if (!(PORTB.IN & (PIN0_bm)))
    {
      /* LED0 on */
      PORTB.OUTCLR = PIN1_bm;
    }
    /* 1: Released */
    else
    {
      /* LED0 off */
      PORTB.OUTSET = PIN1_bm;
    }
  }
}
```

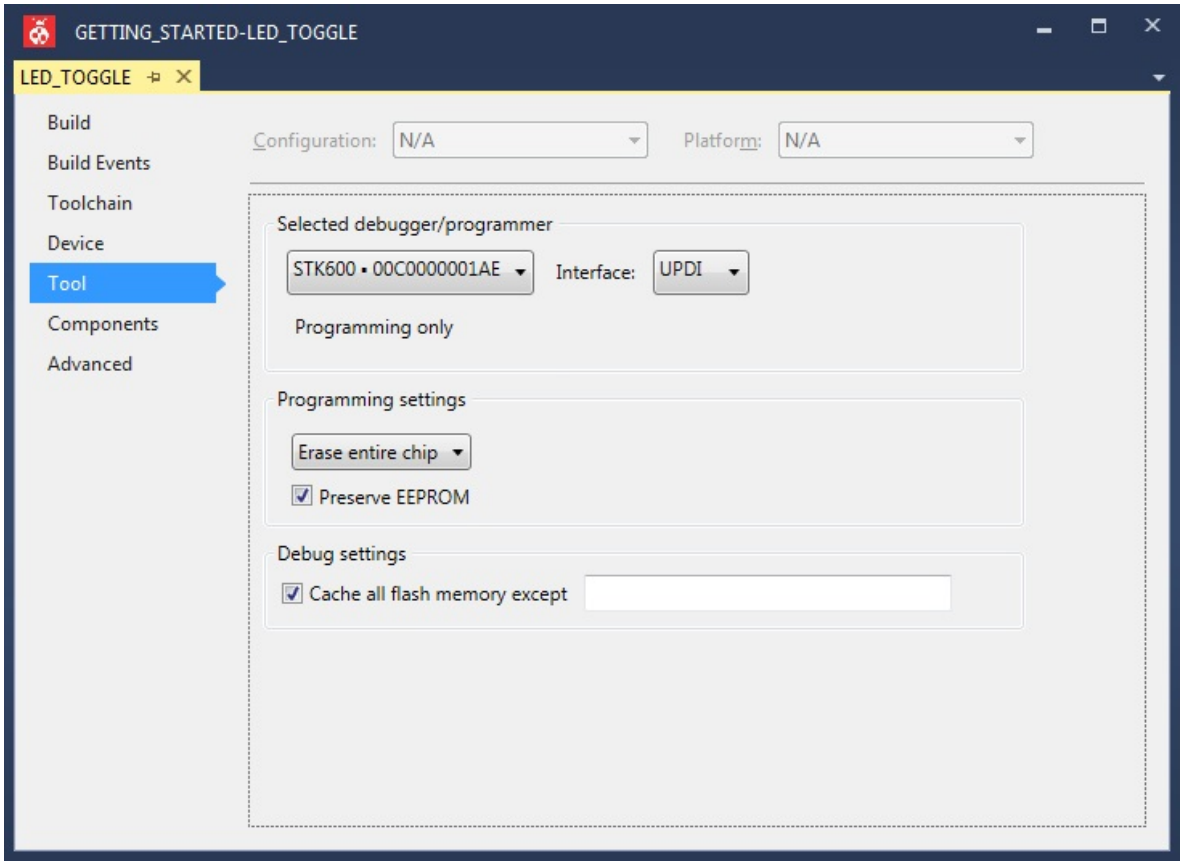
In the code editor, the code may appear as shown in the figure below.

Figure 5-10. Code Editor Window



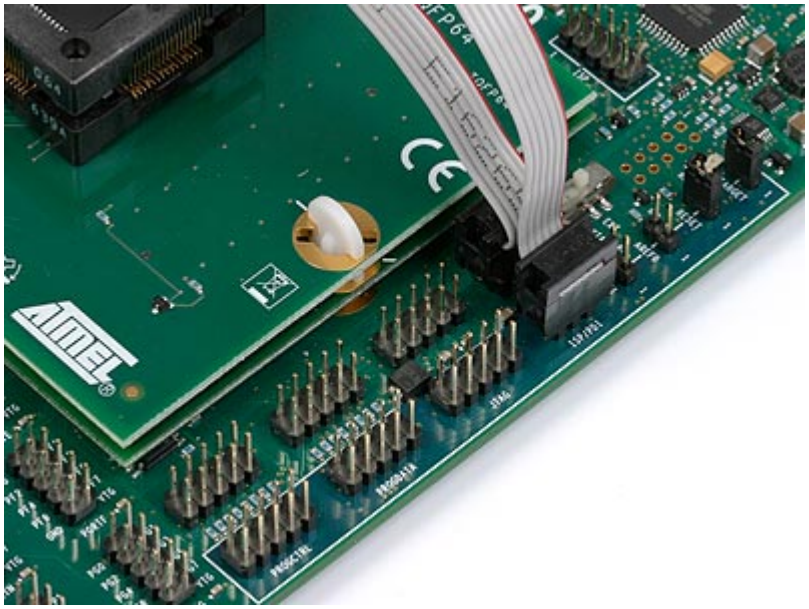
6. Open project properties by clicking *Project → Properties* or by using the shortcut ***ALT+F7***.
7. In *Tool* view (figure below), set *Selected debugger/programmer* to STK600 and *Interface* to UPDI.

Figure 5-11. Debugger and Interface for ATtiny1627



8. Build the project by clicking *Build → Build Solution* or using the shortcut ***F7***.
9. Connect the embedded debugger on STK600 to ATtiny1627 by connecting a cable between the ISP/PDI headers, as shown in the figure below.

Figure 5-12. UPDI Connection on STK600



10. Connect PC4 to SW0, and PB7 to LED0 by using cables.

11. Load the code onto the STK600 and start debugging by clicking *Debug → Start debugging and break* or by using the shortcut ***ALT+F5***. The application is programmed onto the device and the program execution should break in main.
12. Run the code by clicking *Debug → Continue* or by using the shortcut ***F5***.
13. Verify that LED0 is lit when SW0 is pushed on STK600.

6. MPLAB® X Users Getting Started

6.1 MPLAB® X with ATtiny1627 Curiosity Nano

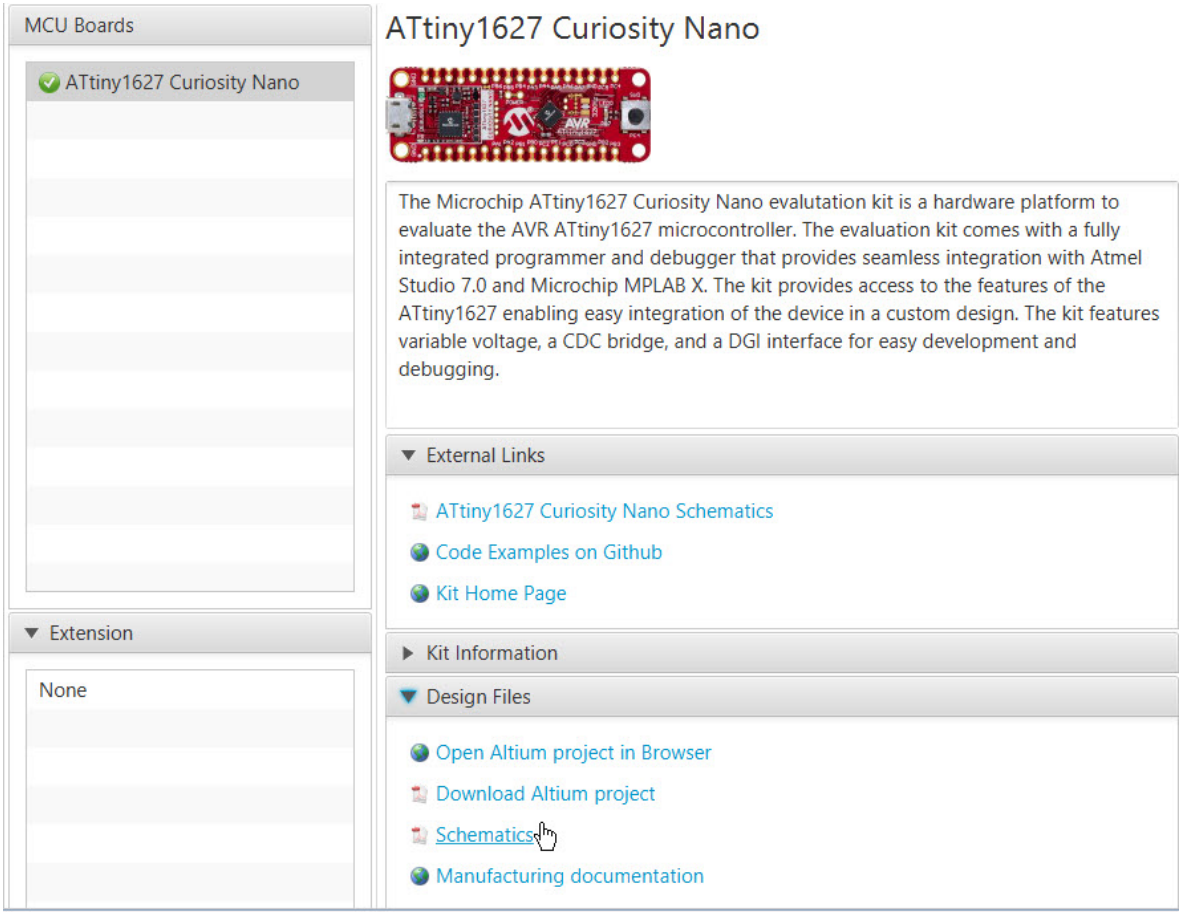
Prerequisites

- MPLAB X installed
- The ATtiny1627 Curiosity Nano Board connected to MPLAB X via the on-board USB connector, which is connected to the embedded debugger. The kit will be powered by the USB, and the embedded debugger will enable debugging and programming via the USB.

Workflow

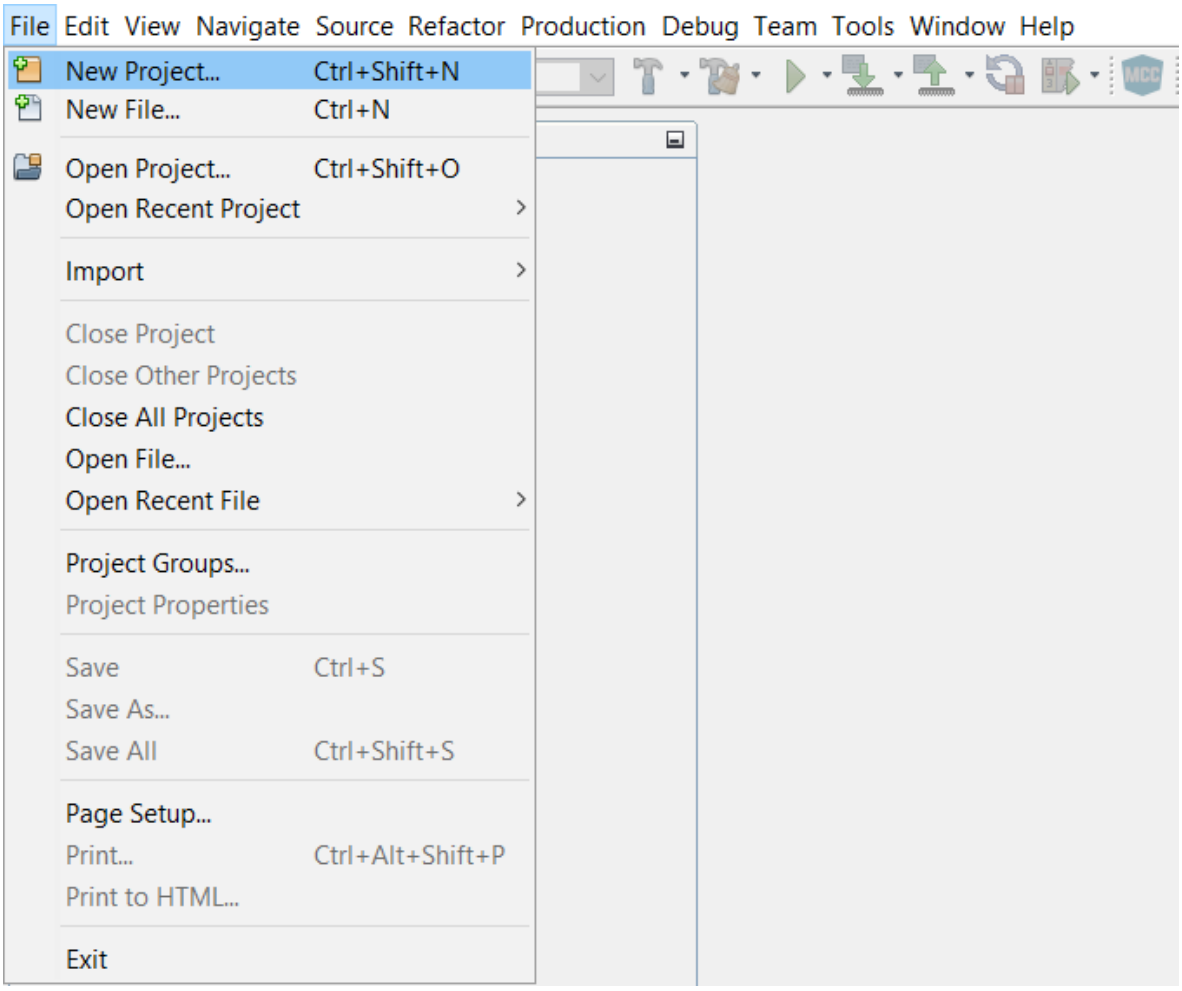
1. Launch MPLAB X.
2. The page shown in Figure 6-1 will appear when ATtiny1627 Curiosity Nano is connected to MPLAB X.

Figure 6-1. ATtiny1627 Curiosity Nano Page in MPLAB® X



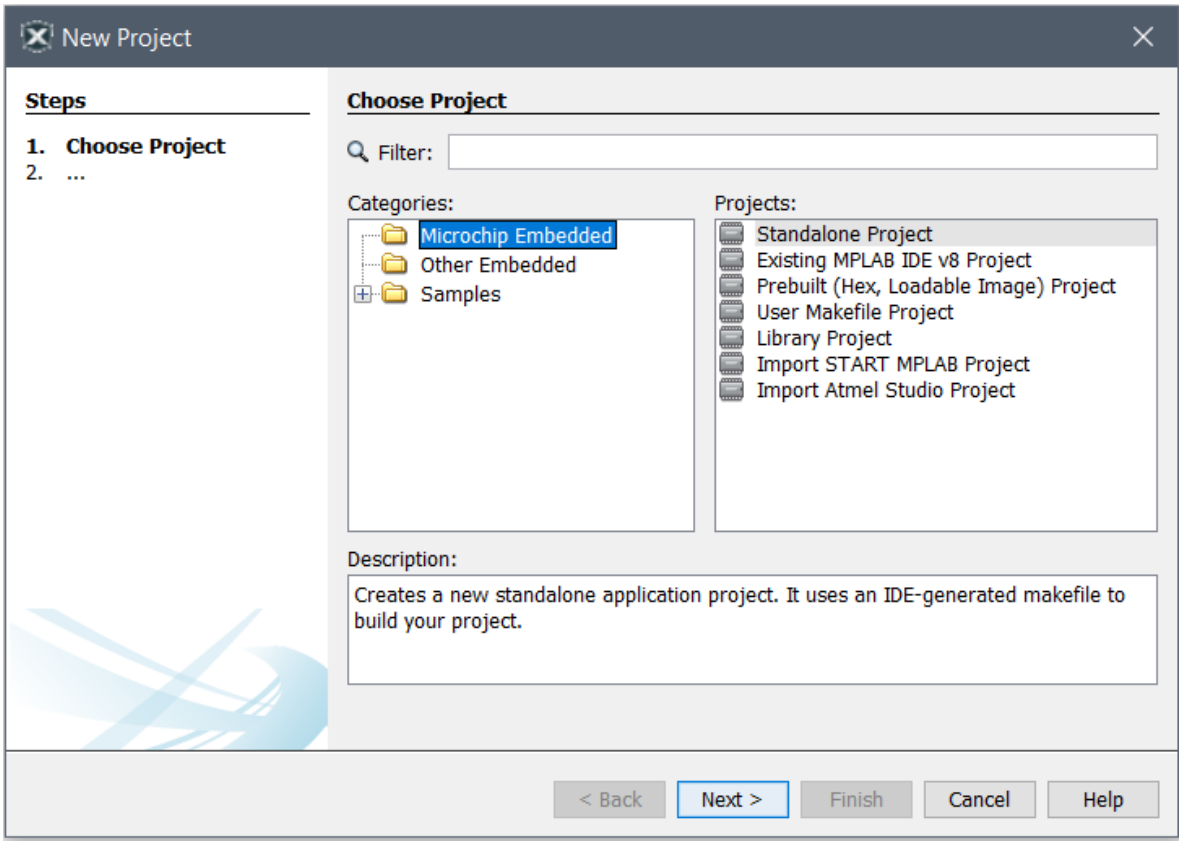
3. Start creating a new project by clicking **File** → **New Project...** or by using **Ctrl+Shift+N** shortcut, as shown in Figure 6-2.

Figure 6-2. Create New Project in MPLAB® X



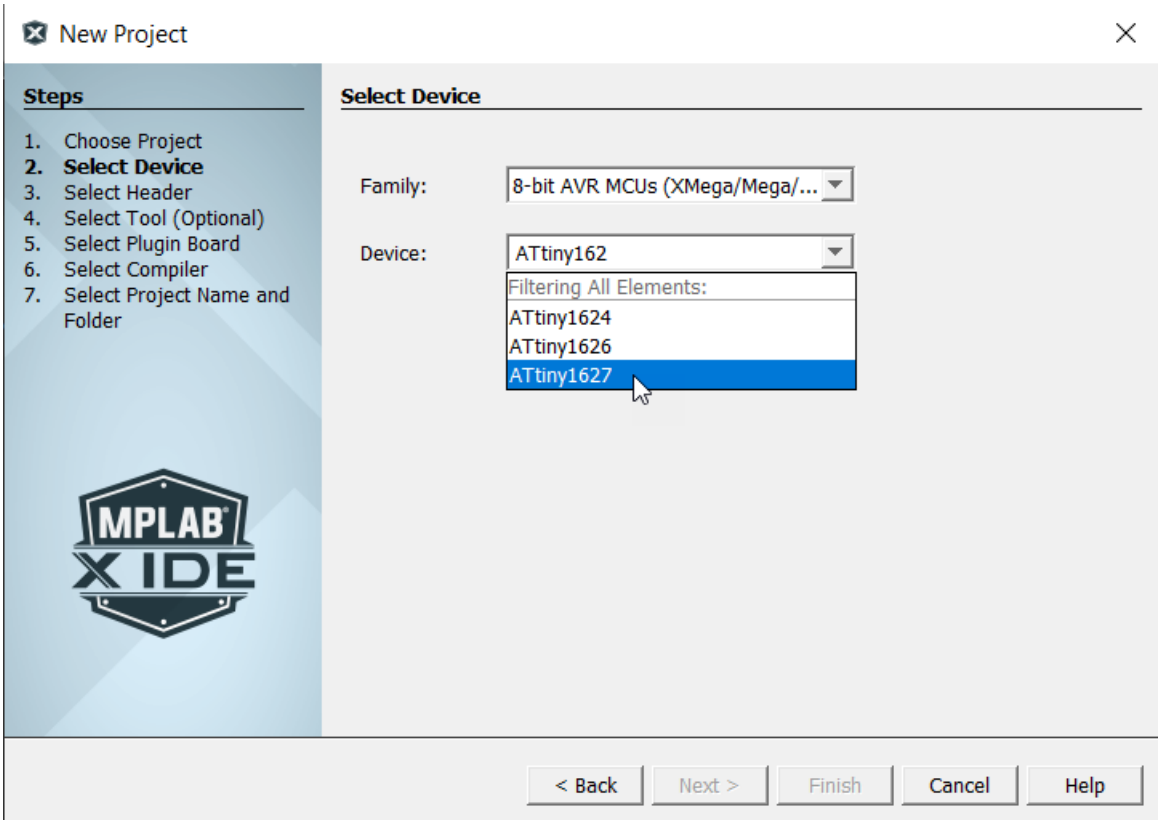
4. Select the **Categories** → **Microchip Embedded** and **Projects** → **Standalone Project** template from Figure 6-6, and click **Next**.

Figure 6-3. New Project Window



5. Select ATtiny1627 from Figure 6-4, and click **Next**.

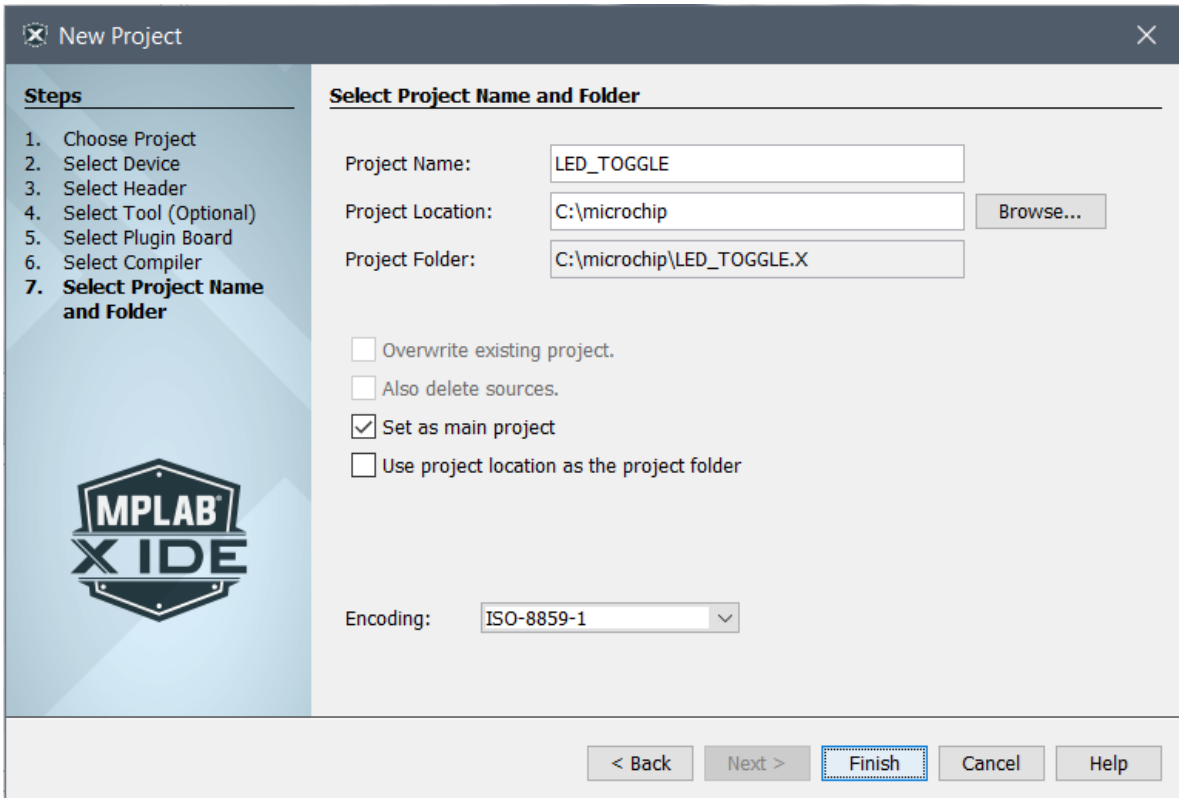
Figure 6-4. Device Selection Window



Then select the board and the desired compiler, if there are any.

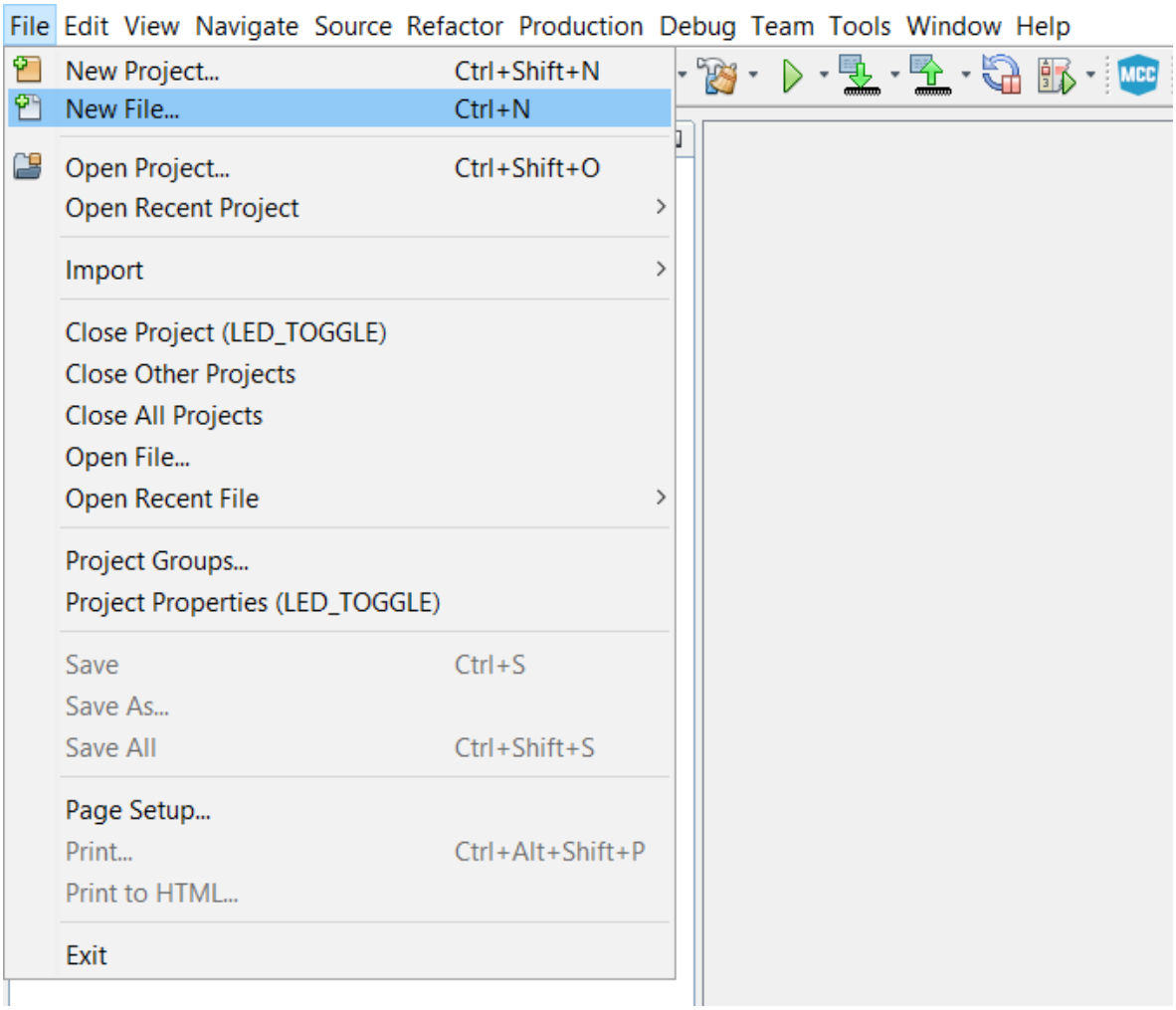
6. Type in the name of the project (e.g., *LED_TOGGLE*) and the project location (e.g., *C:\microchip*), and click **Finish**.

Figure 6-5. Project Name and Location Selection Window



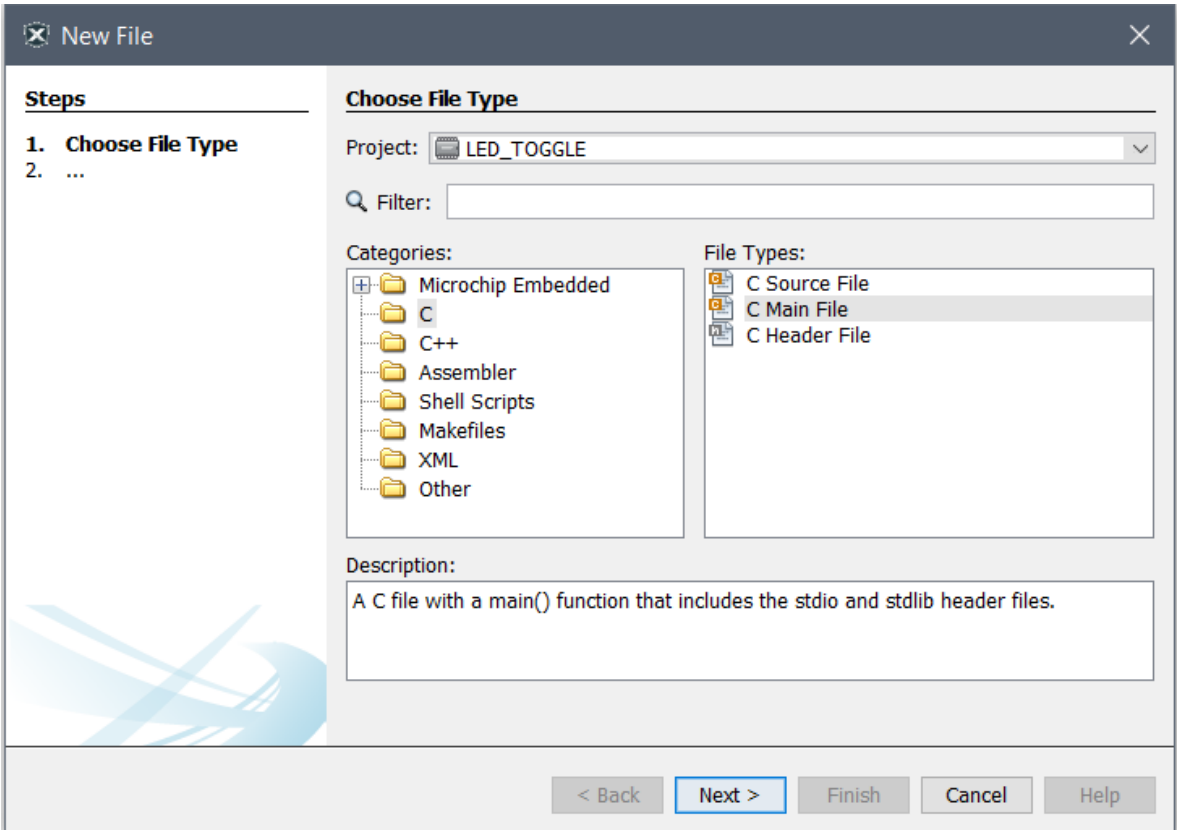
7. Create a new `main.c` file by clicking **File** → **New File...** or by using **Ctrl+N** shortcut, as shown in Figure 6-6.

Figure 6-6. Create a New File in MPLAB® X



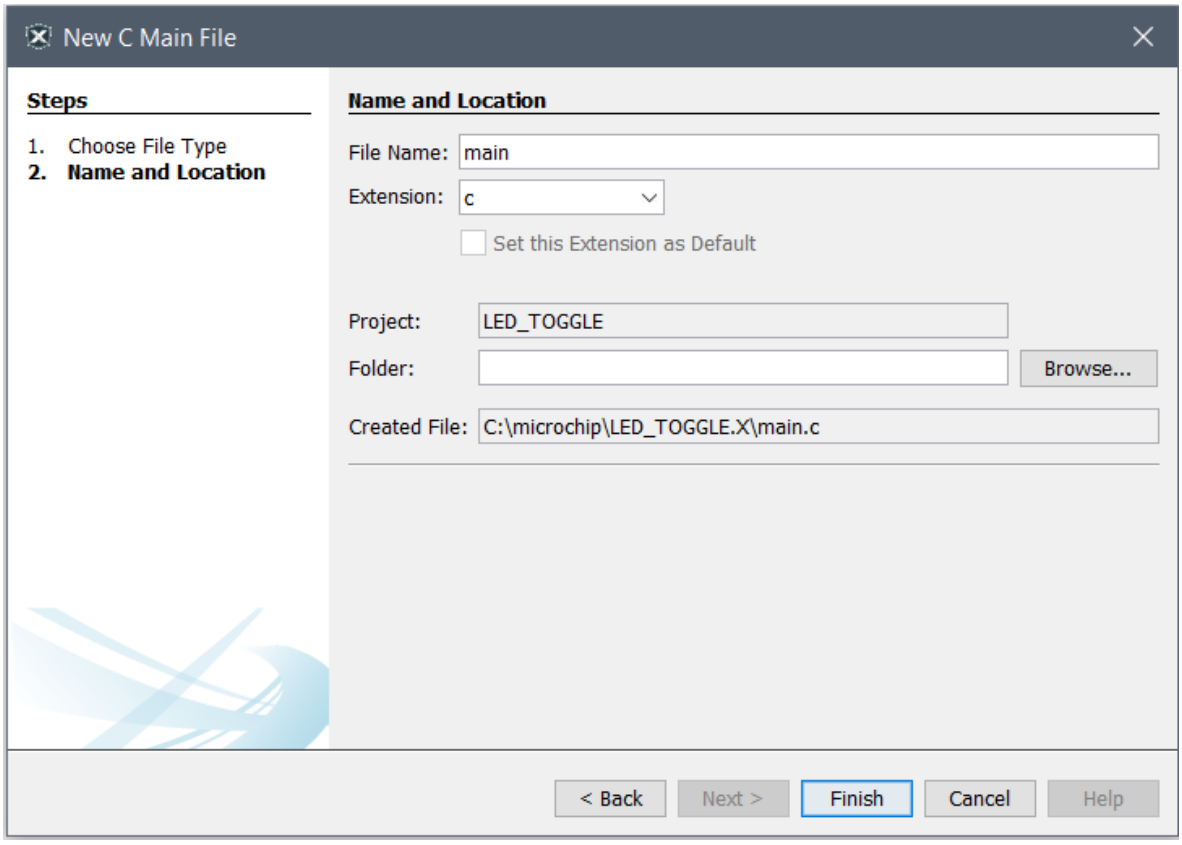
8. Select the **Categories** → **C** and **File Types** → **C Main File** template from Figure 6-7, and click **Next**.

Figure 6-7. New File Window



9. Type in the name of the file (e.g., *main*) and click **Finish**.

Figure 6-8. File Name Window



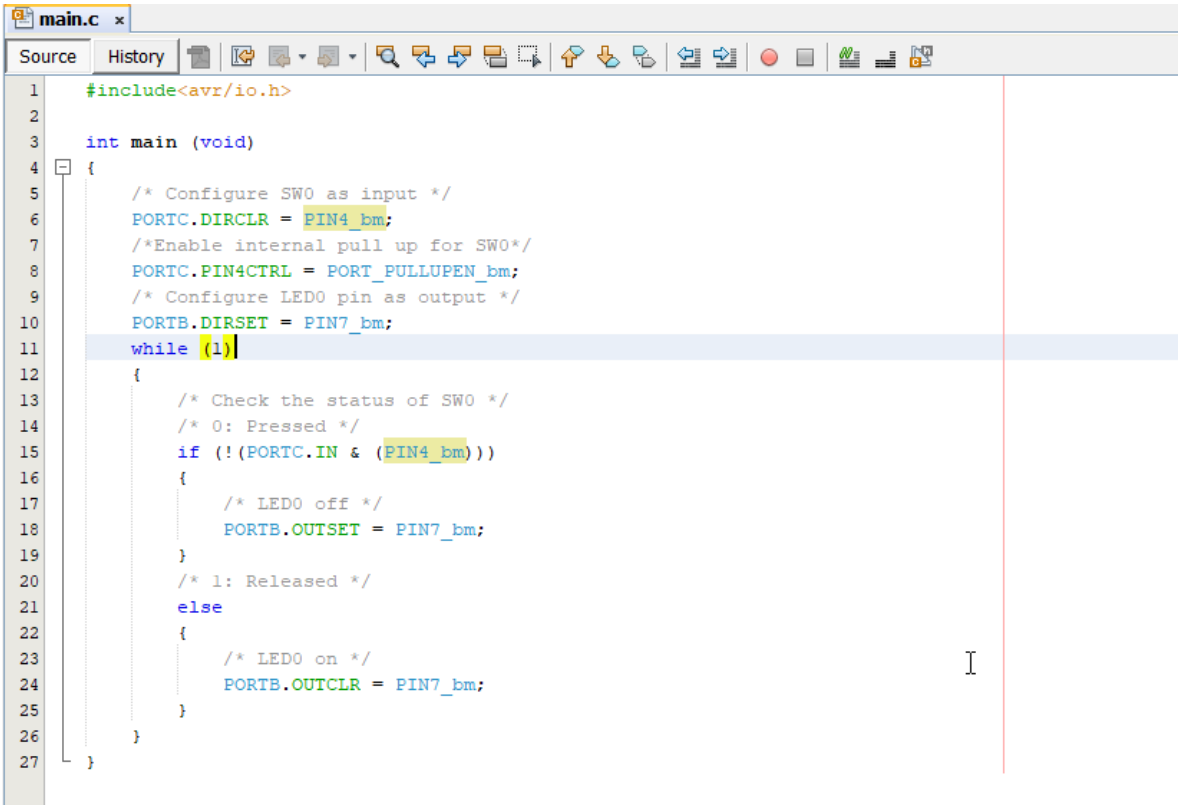
10. Replace the `main.c` file with the following code snippet:

```
int main (void)
{
  /* Configure SW0 as input */
  PORTC.DIRCLR = PIN4_bm;
  /*Enable internal pull up for SW0*/
  PORTC.PIN4CTRL  = PORT_PULLUPEN_bm;
  /* Configure LED0 pin as output */
  PORTB.DIRSET = PIN7_bm;

  while (1)
  {
    /* Check the status of SW0 */
    /* 0: Pressed */
    if (!(PORTC.IN & (PIN4_bm)))
    {
      /* LED0  off */
      PORTB.OUTSET = PIN7_bm;
    }
    /* 1: Released */
    else
    {
      /* LED0 on */
      PORTB.OUTCLR = PIN7_bm;
    }
  }
}
```

Add `#inlude<avr/io.h>` in main.c. In the code editor, the code will appear as shown in Figure 6-9.

Figure 6-9. Code Editor Window



11. Build the code by clicking on **Production → Clean and Build Main Project** or by using **Shift + F11** shortcut.
12. Program ATtiny1627 with the project code and start debugging by clicking **Debug → Debugging Main Project**.
13. Verify that LED0 is lit when SW0 is pushed on the ATtiny1627 Curiosity Nano.

7. What's Next

For further information on related AVR products and IDE, refer to the links below:

Software:

- Atmel Studio: www.microchip.com/avr-support/atmel-studio-7
- Atmel Studio help: *Help → View Help* (shortcut *CTRL+F1*)
- Atmel Gallery: gallery.microchip.com/
- MPLAB X: https://www.microchip.com/mplab/mplab-x-ide
- IAR Embedded Workbench for AVR :www.iar.com/iar-embedded-workbench/#!?architecture=AVR

Firmware:

- Atmel START documentation: http://start.atmel.com
- Atmel START examples: microchip.com/start/#examples
- GitHub examples: https://github.com/search?q=microchip-pic-avr-examples%2F

Hardware:

- AVR042: AVR Hardware Design Considerations:ww1.microchip.com/downloads/en/appnotes/atmel-2521-avr-hardware-design-considerations_applicationnote_avr042.pdf
- AVR IBIS files: www.microchip.com/doclisting/TechDoc.aspx?type=IBIS
- AVR BDSL files: www.microchip.com/doclisting/TechDoc.aspx?type=BSDL

Recommended Programming/Debugging Tools:

- Atmel-ICE:
  - Documentation: http://www.microchip.com/Atmel-ICE_Debugger_User_Guide
  - Buy: https://www.microchip.com/Development-Tools/atatmel-ice
- Power debugger:
  - Documentation: http://www.microchip.com/42696D_Power_Debugger_User_Guide
  - Buy: https://www.microchip.com/Development-Tools/atpowerdebugger
- MPALB Snap:
  - www.microchip.com/developmenttools/ProductDetails/PartNO/PG164100
- MPLAB PICkit4:
  - www.microchip.com/developmenttools/ProductDetails/PG164140

Other:

- AVR Freaks®: www.avrfreaks.net/
- Application notes: www.microchip.com/paramChartSearch/chart.aspx?branchID=30047, find the preferred device and go to the product page. All relevant application notes can be found under the documentation tab.
- AVR product selector: www.microchip.com/paramChartSearch/chart.aspx?branchID=30047
- More technical documentation concerning various products: https://www.microchip.com/webdoc
- Microchip Technical Support: www.microchip.com/support/hottopics.aspx

8. Revision History

Doc. Rev.	Date	Comments
A	07/2020	Initial document release

The Microchip Website

Microchip provides online support via our website at www.microchip.com/. This website is used to make files and information easily available to customers. Some of the content available includes:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip design partner program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

Product Change Notification Service

Microchip's product change notification service helps keep customers current on Microchip products. Subscribers will receive email notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, go to www.microchip.com/pcn and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Embedded Solutions Engineer (ESE)
- Technical Support

Customers should contact their distributor, representative or ESE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in this document.

Technical support is available through the website at: www.microchip.com/support

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Legal Notice

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with

your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TempTrackr, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, Vite, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

ISBN: 978-1-5224-6465-5

Quality Management System

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200 Fax: 480-792-7277 Technical Support: www.microchip.com/support Web Address: www.microchip.com **Atlanta** Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455 **Austin, TX** Tel: 512-257-3370 **Boston** Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088 **Chicago** Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075 **Dallas** Addison, TX Tel: 972-818-7423 Fax: 972-818-2924 **Detroit** Novi, MI Tel: 248-848-4000 **Houston, TX** Tel: 281-894-5983 **Indianapolis** Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380 **Los Angeles** Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800 **Raleigh, NC** Tel: 919-844-7510 **New York, NY** Tel: 631-435-6000 **San Jose, CA** Tel: 408-735-9110 Tel: 408-436-4270 **Canada - Toronto** Tel: 905-695-1980 Fax: 905-695-2078	**Australia - Sydney** Tel: 61-2-9868-6733 **China - Beijing** Tel: 86-10-8569-7000 **China - Chengdu** Tel: 86-28-8665-5511 **China - Chongqing** Tel: 86-23-8980-9588 **China - Dongguan** Tel: 86-769-8702-9880 **China - Guangzhou** Tel: 86-20-8755-8029 **China - Hangzhou** Tel: 86-571-8792-8115 **China - Hong Kong SAR** Tel: 852-2943-5100 **China - Nanjing** Tel: 86-25-8473-2460 **China - Qingdao** Tel: 86-532-8502-7355 **China - Shanghai** Tel: 86-21-3326-8000 **China - Shenyang** Tel: 86-24-2334-2829 **China - Shenzhen** Tel: 86-755-8864-2200 **China - Suzhou** Tel: 86-186-6233-1526 **China - Wuhan** Tel: 86-27-5980-5300 **China - Xian** Tel: 86-29-8833-7252 **China - Xiamen** Tel: 86-592-2388138 **China - Zhuhai** Tel: 86-756-3210040	**India - Bangalore** Tel: 91-80-3090-4444 **India - New Delhi** Tel: 91-11-4160-8631 **India - Pune** Tel: 91-20-4121-0141 **Japan - Osaka** Tel: 81-6-6152-7160 **Japan - Tokyo** Tel: 81-3-6880- 3770 **Korea - Daegu** Tel: 82-53-744-4301 **Korea - Seoul** Tel: 82-2-554-7200 **Malaysia - Kuala Lumpur** Tel: 60-3-7651-7906 **Malaysia - Penang** Tel: 60-4-227-8870 **Philippines - Manila** Tel: 63-2-634-9065 **Singapore** Tel: 65-6334-8870 **Taiwan - Hsin Chu** Tel: 886-3-577-8366 **Taiwan - Kaohsiung** Tel: 886-7-213-7830 **Taiwan - Taipei** Tel: 886-2-2508-8600 **Thailand - Bangkok** Tel: 66-2-694-1351 **Vietnam - Ho Chi Minh** Tel: 84-28-5448-2100	**Austria - Wels** Tel: 43-7242-2244-39 Fax: 43-7242-2244-393 **Denmark - Copenhagen** Tel: 45-4485-5910 Fax: 45-4485-2829 **Finland - Espoo** Tel: 358-9-4520-820 **France - Paris** Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79 **Germany - Garching** Tel: 49-8931-9700 **Germany - Haan** Tel: 49-2129-3766400 **Germany - Heilbronn** Tel: 49-7131-72400 **Germany - Karlsruhe** Tel: 49-721-625370 **Germany - Munich** Tel: 49-89-627-144-0 Fax: 49-89-627-144-44 **Germany - Rosenheim** Tel: 49-8031-354-560 **Israel - Ra'anana** Tel: 972-9-744-7705 **Italy - Milan** Tel: 39-0331-742611 Fax: 39-0331-466781 **Italy - Padova** Tel: 39-049-7625286 **Netherlands - Drunen** Tel: 31-416-690399 Fax: 31-416-690340 **Norway - Trondheim** Tel: 47-72884388 **Poland - Warsaw** Tel: 48-22-3325737 **Romania - Bucharest** Tel: 40-21-407-87-50 **Spain - Madrid** Tel: 34-91-708-08-90 Fax: 34-91-708-08-91 **Sweden - Gothenberg** Tel: 46-31-704-60-40 **Sweden - Stockholm** Tel: 46-8-5090-4654 **UK - Wokingham** Tel: 44-118-921-5800 Fax: 44-118-921-5820