Microchip Studio

Getting Started with Microchip Studio

Introduction

This Getting Started training for Microchip Studio will guide you through all the major features of the IDE. It is designed as a video series with accompanying hands-on. Each section starts with a video, which covers that section.

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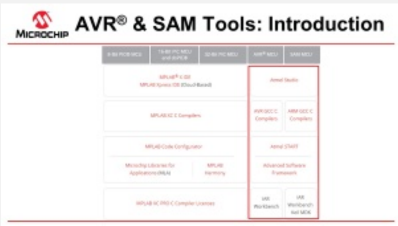
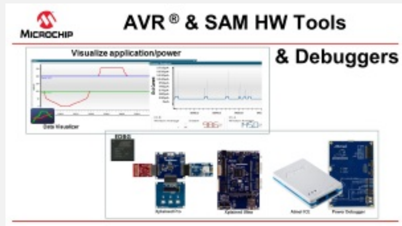
1. Getting Started

Getting Started with Microchip Studio - playlist. Note that Atmel Studio has been renamed to Microchip Studio.



Video Description



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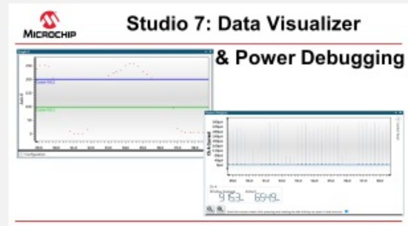
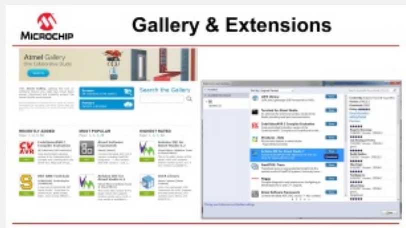
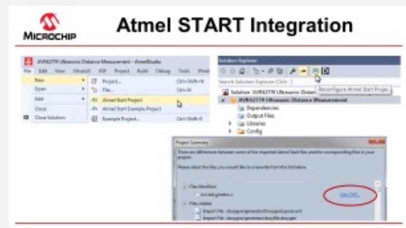


Video Demo code

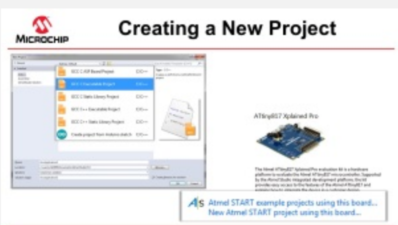
Video Hands-on



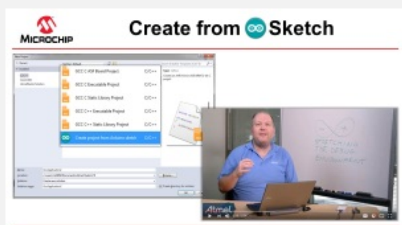
Video Hands-on



Video Hands-on



Video Hands-on



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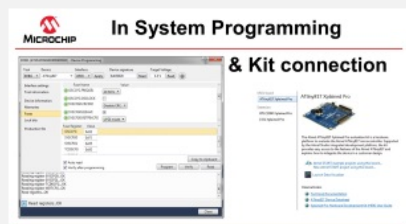

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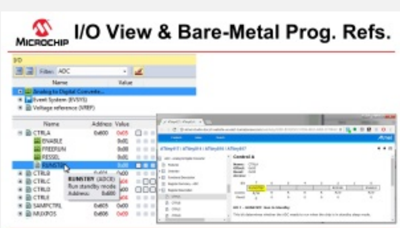

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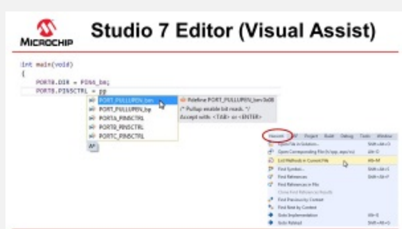
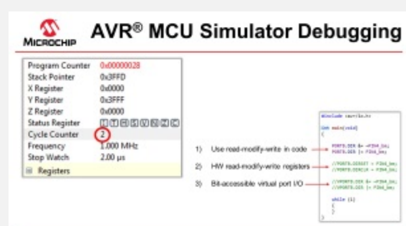
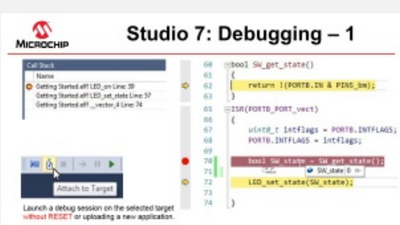


Video Hands-on



Video Hands-on



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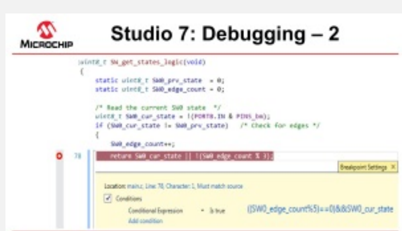
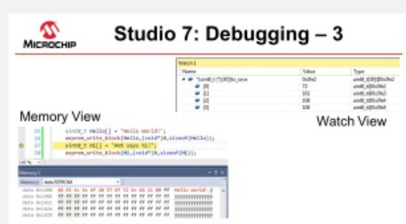


Video Hands-on



Video Hands-on

Prerequisites
Much of the training could be completed by using the editor and simulator. However, to cover everything, the following is recommended.

Hardware prerequisites:
- ATtiny817 Xplained Pro
- Standard-A to Micro-B USB cable

Software prerequisites:
- Microchip Studio for AVR and SAM Devices
- avr-gcc toolchain
- Latest Part Pack for tinyAVR® devices

Microchip Studio plugins used:
- Atmel START 1.0.113.0 or later
- Data Visualizer Extension 2.14.709 or later

Icon Key Identifiers
The following icons are used in this document to identify different assignment sections and to reduce complexity.

Info: Delivers contextual information about a specific topic.

Tip: Highlights useful tips and techniques.

To do: Highlights objectives to be completed.

Result: Highlights the expected result of an assignment step.

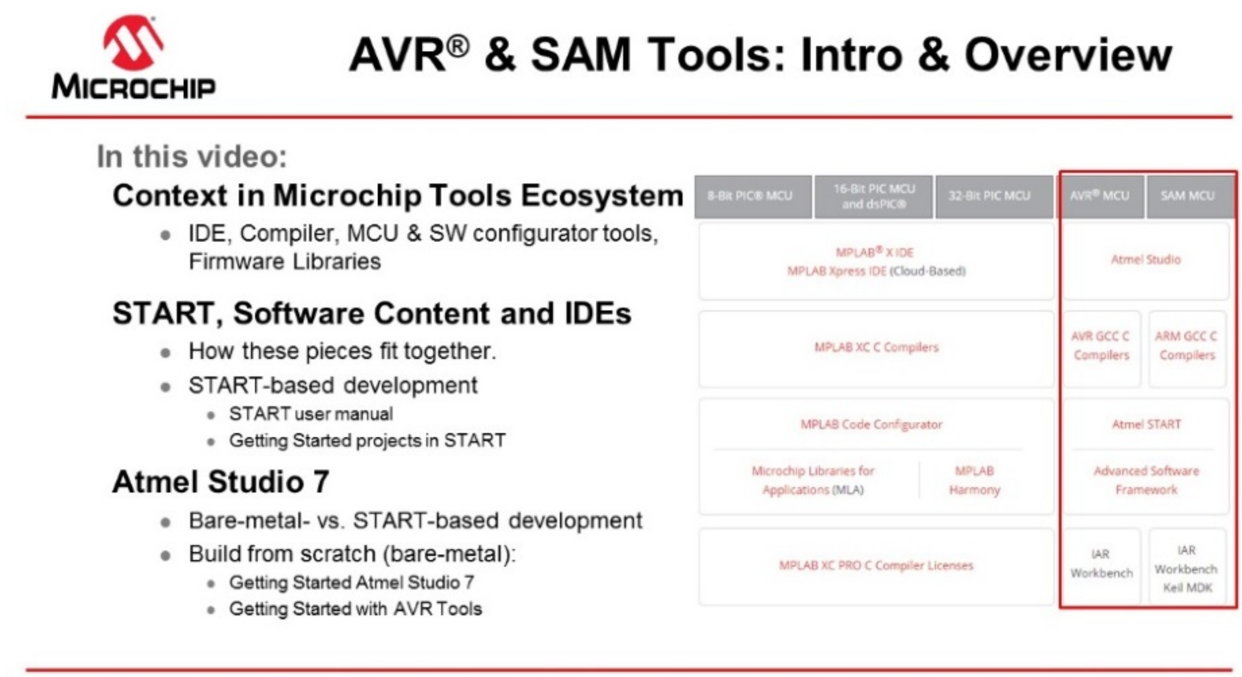
WARNING Indicates important information.

Execute: Highlights actions to be executed out of the target when necessary.

1.1 Microchip Studio, START, and Software Content

This section gives an overview of the various pieces in the AVR® and SAM Tools ecosystem and how they relate to each other.

Getting Started Topics



Video: AVR and SAM Tools ecosystem overview

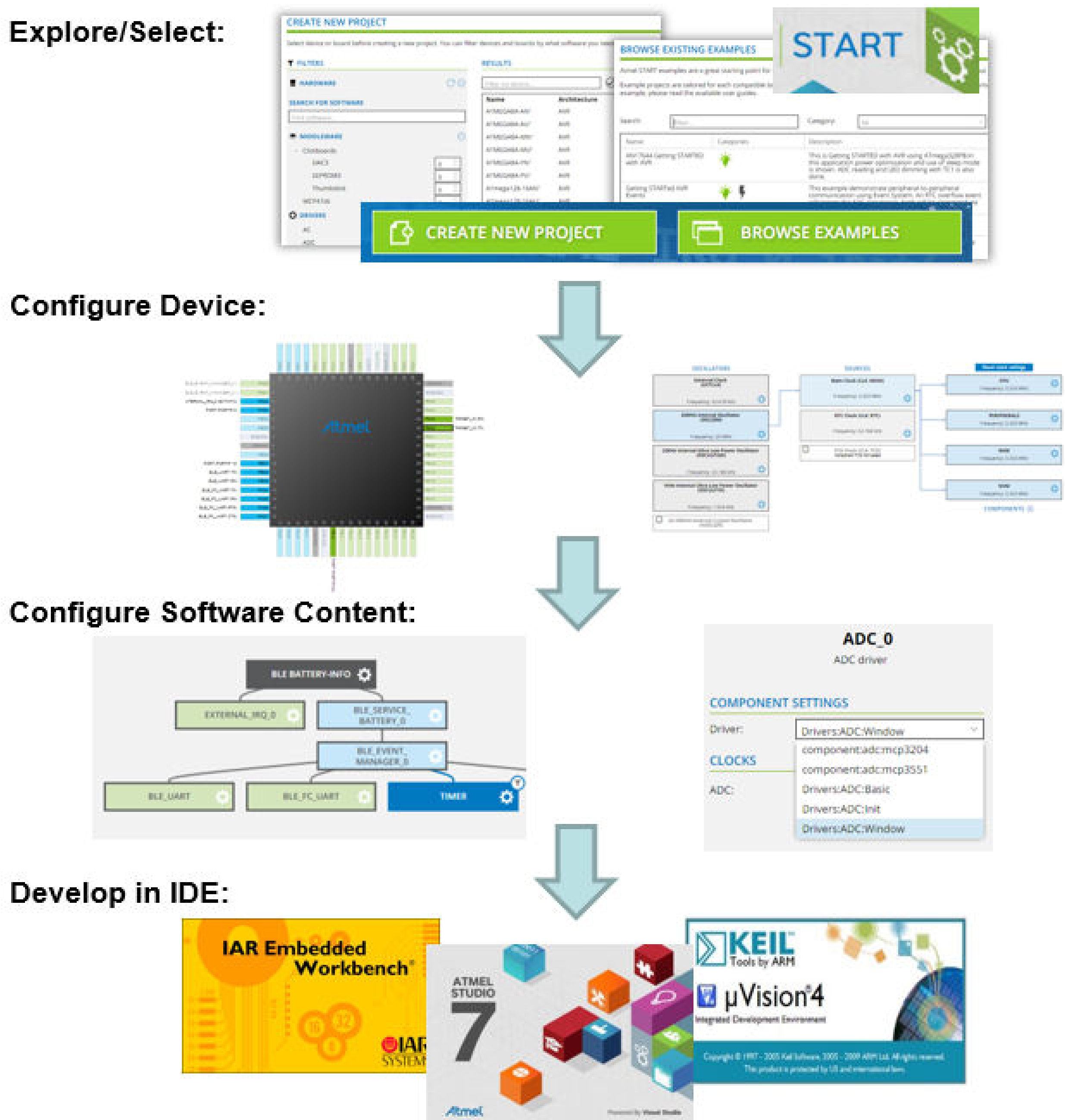
1.1.1 Atmel START

Atmel START is a web-based software configuration tool for various software frameworks, which helps you get started with MCU development. Starting from either a new project or an example project, Atmel START allows you to select and configure software components (from **ASF4** and **AVR Code**), such as drivers and middleware to tailor your embedded application in a usable and optimized manner. Once an optimized software configuration is done, you can download the generated code project and open it in the IDE of your choice, including Studio 7, IAR Embedded Workbench®, Keil® µVision®, or simply generate a makefile.

Atmel START enables you to:

- Get help with selecting an MCU, based on both software and hardware requirements
- Find and develop examples for your board
- Configure drivers, middleware, and example projects
- Get help with setting up a valid PINMUX layout
- Configure system clock settings

Figure 1-1. Relation Between START, Software Content, and IDEs



1.1.2 Software Content (Drivers and Middlewares)

Advanced Software Framework (ASF)

ASF, the Advanced Software Framework, provides a rich set of proven drivers and code modules developed by experts to reduce customer design-time. It simplifies the usage of microcontrollers by providing an abstraction to the hardware through drivers and high-value middlewares. ASF is a free and open-source code library designed to be used for evaluation, prototyping, design, and production phases.

ASF4, supporting the SAM product line, is the fourth major generation of ASF. It represents a complete re-design and -implementation of the whole framework, to improve the memory footprint, code performance, and the integration with the Atmel START web user interface. ASF4 must be used in conjunction with Atmel START, which replaces the ASF Wizard of ASF2 and 3.

microchip.com: ASF Product Page

AVR® Code

AVR Code, supporting the AVR product line, is a simple firmware framework for AVR 8-bit MCUs, equivalent to Foundation Services, which supports 8- and 16-bit **PIC®** MCUs. **AVR Code** is optimized for code-size and -speed, as well as simplicity and readability of code. AVR Code is configured by Atmel START.

1.1.3 Integrated Development Environment (IDE)

An **IDE** (Integrated Development Environment) is used to develop an application (or further develop an example application) based on the software components, such as drivers and middlewares, configured in and exported from Atmel START. Atmel START supports a range of IDEs, including Microchip Stuido, IAR Embedded Workbench®, Keil® µVision®.

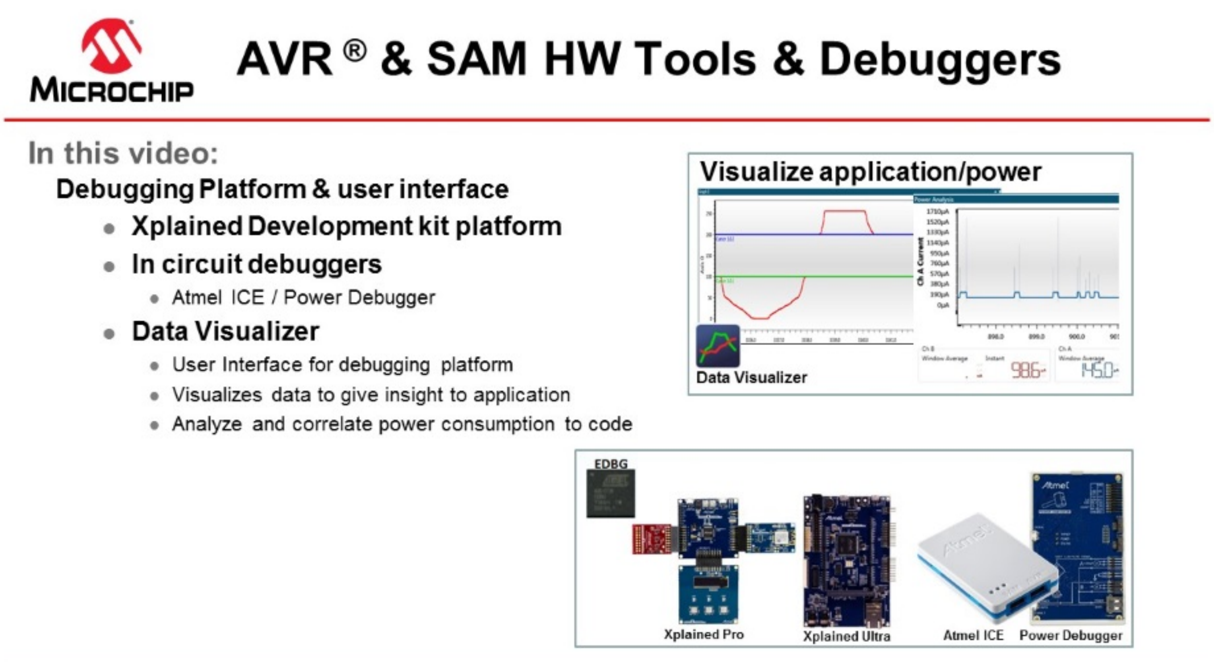
Microchip Stuido is the integrated development platform (IDP) for developing and debugging all AVR and SAM microcontroller applications. The Microchip Studio IDP gives you a seamless and easy-to-use environment to write, build, and debug your applications written in C/C++ or assembly code. It also connects seamlessly to the debuggers, programmers, and development kits that support AVR and SAM devices. The development experience between Atmel START and Microchip Studio has been optimized. Iterative development of START-based projects in Mirochip Studio is supported through re-configure and merge functionality.

This Getting Started training for Microchip Studio 7 will guide you through all the major features of the IDE. It is designed as a video series with accompanying hands-on. Each section starts with a video, which covers that section.

1.2 AVR® and SAM HW Tools and Debuggers

This section describes the HW Tools ecosystem for AVR® and SAM MCUs.

Getting Started Topics



Video: AVR & SAM HW Tools & Debuggers

Data Visualizer

The Data Visualizer is a program to process and visualize data. The Data Visualizer is capable of receiving data from various sources such as the Embedded Debugger Data Gateway Interface (DGI) and COM ports. Track your application's run-time using a terminal or graph, or analyze the power consumption of your application through correlation of code execution and power consumption, when used together with a supported probe or board. Having full control of your codes' run-time behavior has never been easier.

Both a stand-alone and a plug-in version for Microchip Studio are available at the website link below.

Website: Data Visualizer.

Atmel-ICE

Atmel-ICE is a powerful development tool for debugging and programming AVR microcontrollers using UPDI, JTAG, PDI, debugWIRE, aWire, TPI, or SPI target interfaces and Arm® Cortex®-M based SAM microcontrollers using JTAG or SWD target interfaces.

Atmel-ICE is a powerful development tool for debugging and programming Arm Cortex-M based SAM and AVR microcontrollers with on-chip debug capability.

Website: Atmel-ICE

Power Debugger:

Power Debugger is a powerful development tool for debugging and programming AVR microcontrollers using UPDI, JTAG, PDI, debugWIRE, aWire, TPI, or SPI target interfaces and Arm Cortex-M based SAM microcontrollers using JTAG or SWD target interfaces.

In addition, the Power Debugger has two independent current sensing channels for measuring and optimizing the power consumption of a design.

Power Debugger also includes a CDC virtual COM port interface as well as Data Gateway Interface channels for streaming application data to the host computer from an SPI, USART, TWI, or GPIO source.

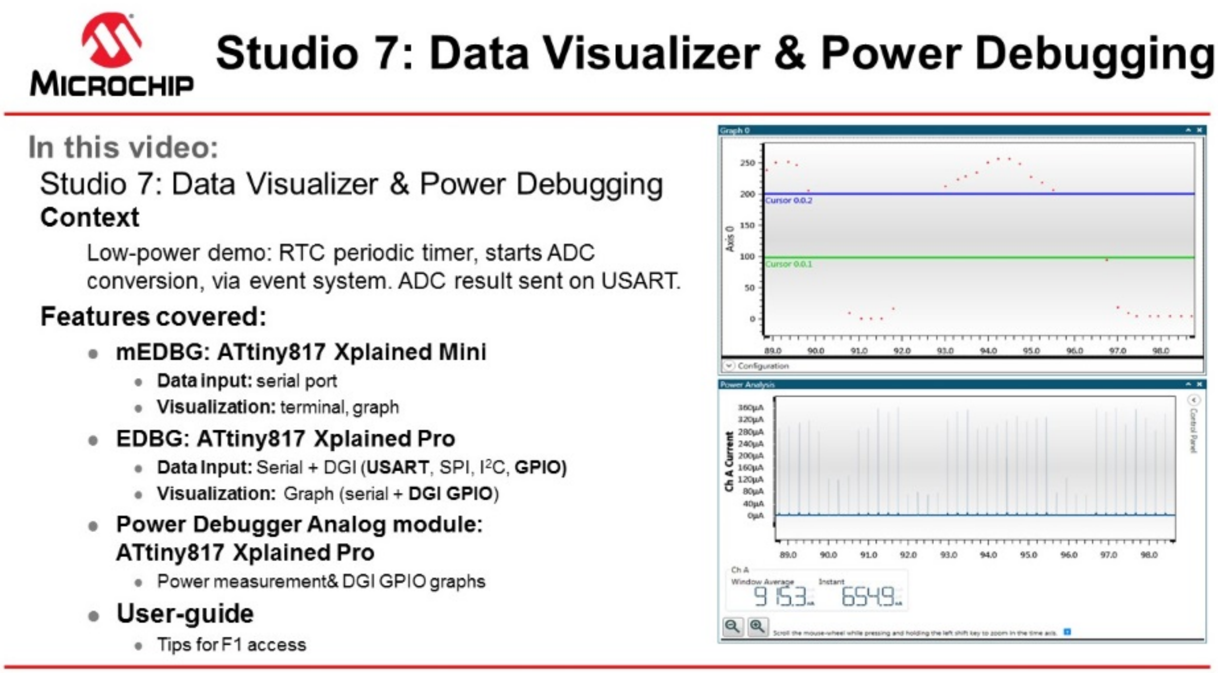
The Power Debugger is a CMSIS-DAP compatible debugger which works with Microchip Studio, or other frontend software capable of connecting to a generic CMSIS-DAP unit. The Power Debugger streams power measurements and application debug data to the Data Visualizer for real-time analysis.

Website: Power Debugger

1.3 Data Visualizer and Power Debugging Demo

This section shows a demo using the Data Visualizer including Power Debugging.

Getting Started Topics



Video: Data Visualizer and Power Debugging Demo

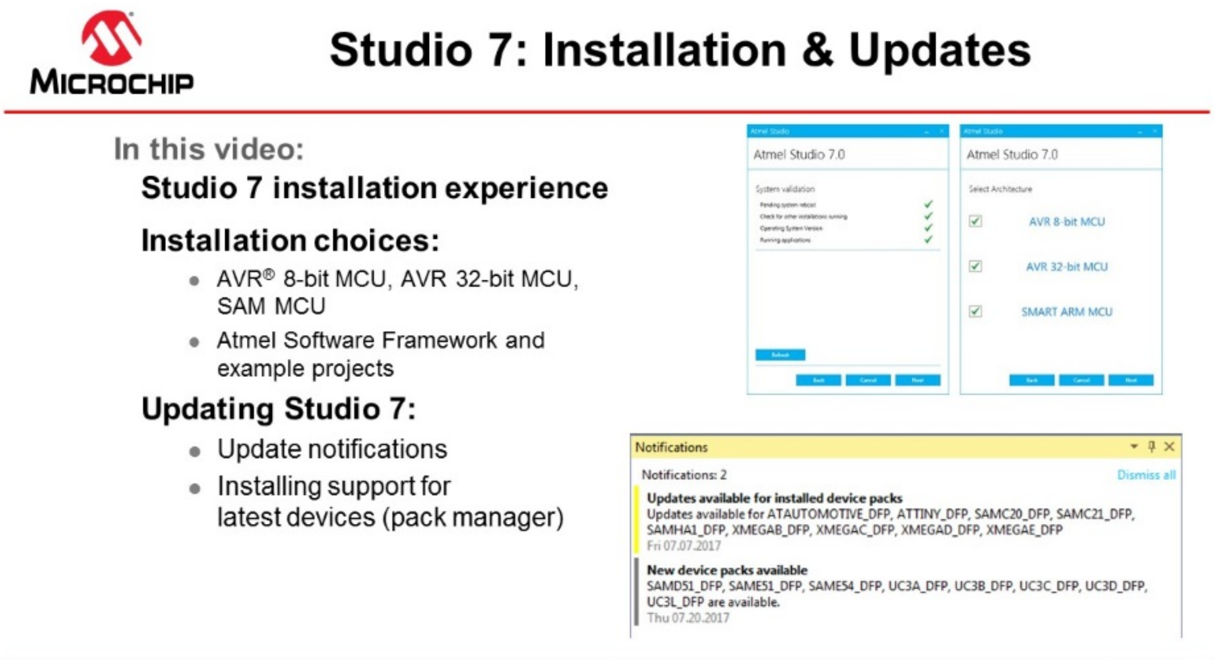
```
/*
* Power_Demo_ADC_SleepWalking.c
* Device/board: ATtiny817 Xplained Pro
* Created: 8/6/2017 3:15:21 PM
*/

#include <avr/io.h>
#include <avr/interrupt.h>
#include <avr/sleep.h>

#define F_CPU (20E6/2)

void sys_init(void)
{
       _PROTECTED_WRITE(CLKCTRL.MCLKCTRLB, CLKCTRL_PEN_bm | CLKCTRL_PDIV_2X_gc);
}

void rtc_pit_init(void)
{
       RTC.CLKSEL = RTC_CLKSEL_INT1K_gc;
       RTC.PITCTRLA = RTC_PITEN_bm | RTC_PERIOD_CYC256_gc;
}

//picoPower 4: Event system vs. IRQ. Compare to not using IRQ
void evsys_init(void)
{
       EVSYS.ASYNCCH3 = EVSYS_ASYNCCH3_PIT_DIV128_gc;
       EVSYS.ASYNCUSER1 = EVSYS_ASYNCUSER1_ASYNCCH3_gc;
}

//picoPower 3: Evaluate own sample, e.g. window mode.
//             Significantly reduce awake time.

void adc_init(void)
{
       ADC0.CTRLC  = ADC_PRESC_DIV8_gc | ADC_REFSEL_VDDREF_gc;
       ADC0.CTRLA  = ADC_ENABLE_bm | ADC_RESSEL_8BIT_gc;
       ADC0.MUXPOS = ADC_MUXPOS_AIN6_gc;

    ADC0.CTRLA |= ADC_RUNSTBY_bm;       //picoPower 1: So can run in sleep.
       ADC0.CTRLE = ADC_WINCM_OUTSIDE_gc;  //picoPower 3: So can evaluate own sample.
```

```
        ADC0.INTCTRL = ADC_WCMP_bm;
        ADC0.WINHT = 200;
        ADC0.WINLT = 100;

        ADC0.EVCTRL = ADC_STARTEI_bm;        //picoPower 4: So event can trigger conversion
}

uint8_t adc_get_result(void)
{
        return ADC0.RESL;
}

//picoPower 5: Send quickly, then back to sleep: compare 9600, 115200, 1250000 baud rates
//note only sending 1 byte
#define BAUD_RATE 57600
void usart_init()
{
        USART0.CTRLB = USART_TXEN_bm;
        USART0.BAUD = (F_CPU * 64.0) / (BAUD_RATE * 16.0);
}
void usart_put_c(uint8_t c)
{
        VPORTB.DIR |= PIN2_bm | PIN6_bm;  //picoPower 2b: see Disable Tx below
        USART0.STATUS = USART_TXCIF_bm;

    VPORTB.OUT |= PIN6_bm;
        USART0.TXDATAL = c;
        while(!(USART0.STATUS & USART_TXCIF_bm));
    VPORTB.OUT &= ~PIN6_bm;
        VPORTB.DIR &= ~PIN2_bm | PIN6_bm;
                       //picoPower 2b: Disable Tx pin in-between transmissions
}

//picoPower 2: Disable unused GPIO
//               compare: Nothing, PORT_ISC_INPUT_DISABLE_gc, PORT_PULLUPEN_bp

void io_init(void)
{
        for (uint8_t pin=0; pin < 8; pin++)
        {
                (&PORTA.PIN0CTRL)[pin] = PORT_ISC_INPUT_DISABLE_gc;
                (&PORTB.PIN0CTRL)[pin] = PORT_ISC_INPUT_DISABLE_gc;
                (&PORTC.PIN0CTRL)[pin] = PORT_ISC_INPUT_DISABLE_gc;
        }
}

int main(void)
{
        sys_init();
        rtc_pit_init();
        evsys_init();
        adc_init();
        io_init();
        usart_init();

    VPORTB.DIR |= PIN6_bm;
    VPORTB.OUT &= ~PIN6_bm;
        sei();

        //picoPower 1: Go to sleep.  Compare with no sleep, IDLE and STANDBY
        set_sleep_mode(SLEEP_MODE_STANDBY);

    while (1)
    {
          sleep_mode();
    }
}

ISR(ADC0_WCOMP_vect)        //picoPower 3: Only called if relevant sample
{
        ADC0.INTFLAGS = ADC_WCMP_bm;
        usart_put_c(adc_get_result());
}
```

1.4 Installation and Updates

This section describes the process of installing Microchip Studio for AVR and SAM Devices, installing updates for Studio or plugins, as well as adding support for new devices.

Getting Started Topics



Video: Installation and Updates

1.4.1 Installation

Supported Operating Systems

- Windows 7 Service Pack 1 or higher
- Windows Server 2008 R2 Service Pack 1 or higher
- Windows 8/8.1
- Windows Server 2012 and Windows Server 2012 R2
- Windows 10

Supported Architectures

- 32-bit (x86)
- 64-bit (x64)

Hardware Requirements

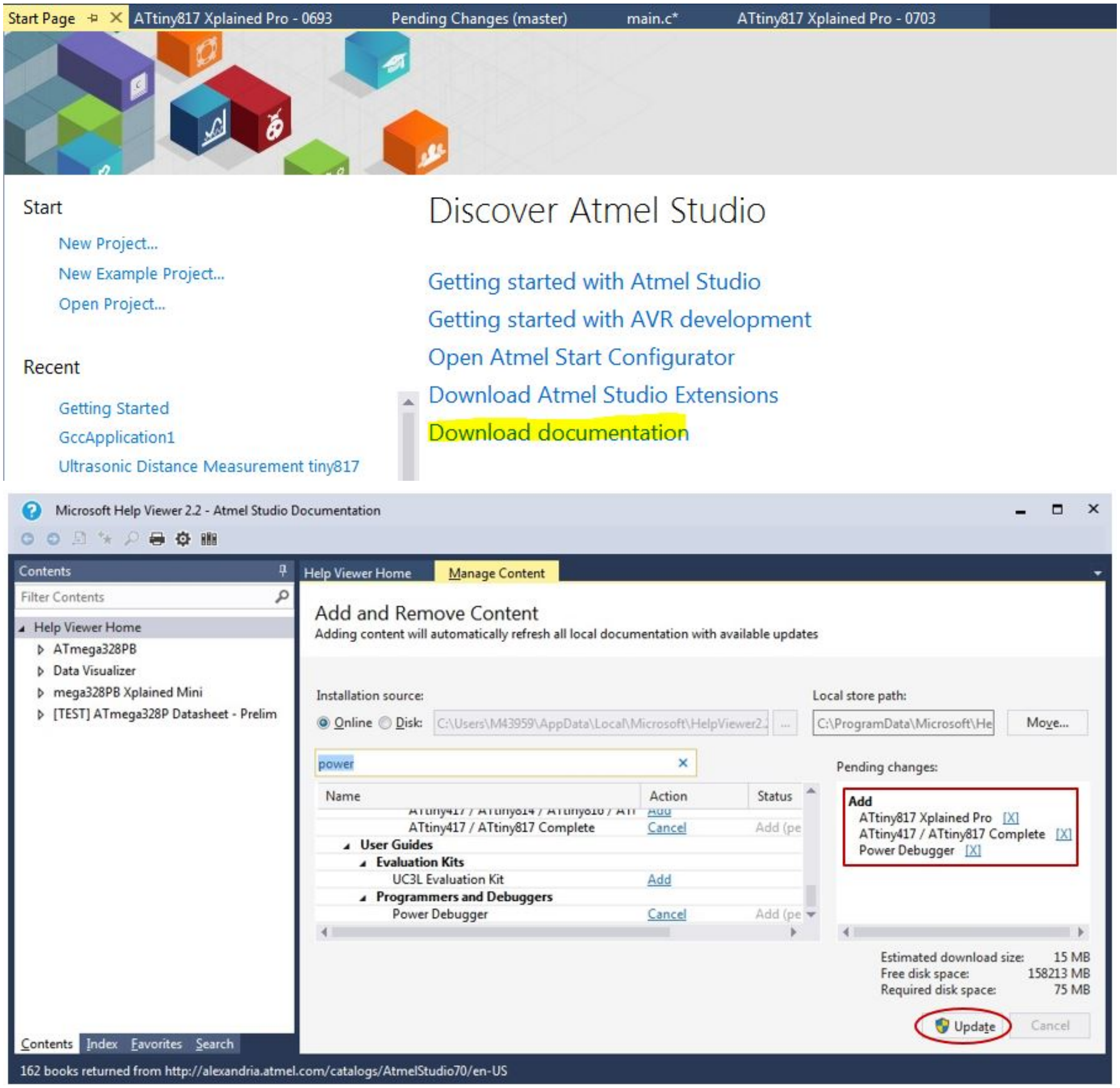
- A computer that has a 1.6 GHz or faster processor
- RAM
  - 1 GB RAM for x86
  - 2 GB RAM for x64
  - An additional 512 MB RAM if running in a Virtual Machine
- 6 GB available hard disk space

Downloading and Installing

- Download the latest Microchip Studio installer: Microchip Studio
  – The web installer is a small file (<10 MB) and will download specified components as needed
  – The offline installer has all components embedded
- Microchip Studio can be run side-by-side with Atmel Studio 6.2 and older and AVR Studio®. Uninstallation of any previous versions is not required. Microchip Studio can not run side-by-side with Atmel Studio 7.
- Verify the hardware and software requirements from the 'System Requirements' section
- Make sure your user has local administrator privileges
- Save all your work before starting. The installation might prompt you to restart if required.
- Disconnect all USB/Serial hardware devices
- Double-click the installer executable file and follow the installation wizard
- Once finished, the installer displays an option to **Start Microchip Studio after completion**. If you choose to open, then note that Microchip Studio will launch with administrative privileges since the installer was either launched as the administrator or with elevated privileges.
- If upgrading Microchip Studio from an earlier versions of Atmel Studio 7 or Microchip Studio and running the application with a different user account the local application user cache may have to be cleared. The reason for this is that the installer only clears the cache for the users it is installed with. This is done by deleting the folder: %localappdata%\Atmel\AtmelStudio\7.0 from the Windows File Exporer.
- In Microchip Studio you may see an update notification (flag symbol) next to the Quick Launch field in the title bar. Here you may select and install updated components or device support.

1.4.2 Downloading Offline Documentation

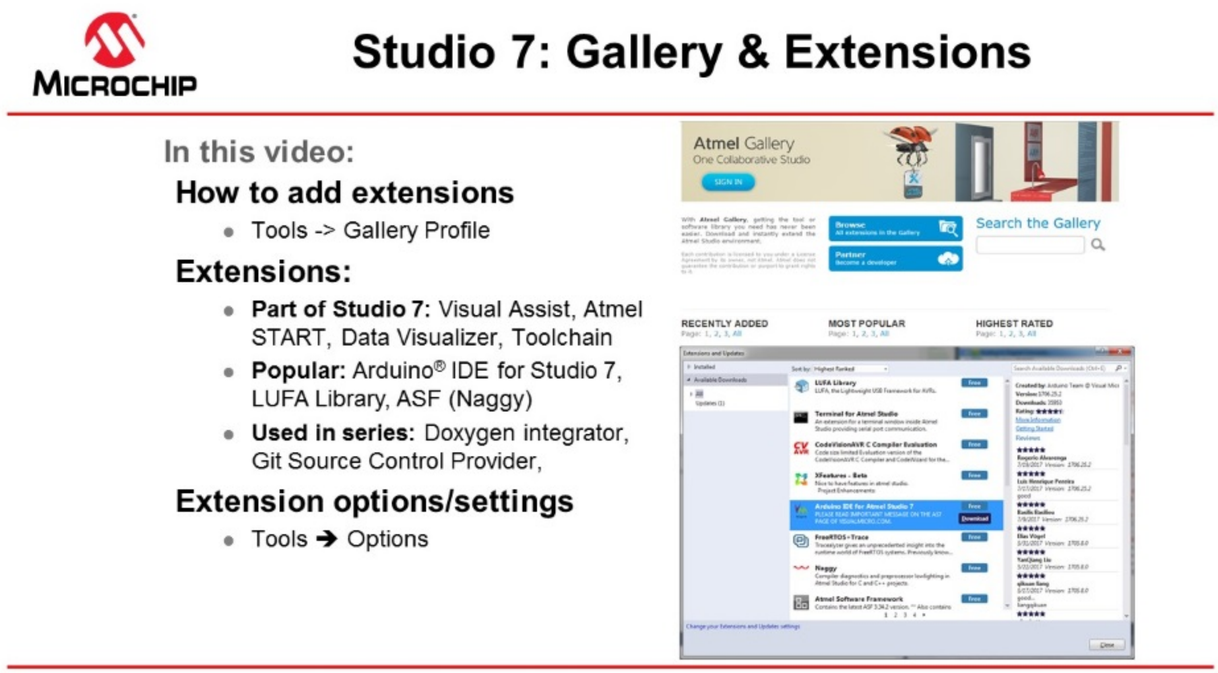
If you would like to work offline, it would be advisable to use the offline documentation for Microchip Studio.
To do this, from the *Microchip Studio Start Page,* click on *Download documentation*. When the help viewer pops up, first click the *Online button* and search for documentation of interest, such as *data sheets*, *user manuals*, and *application notes* (wait for the available documents to show up).
In the example below, we are choosing to download the *Power Debugger user manual*, the *ATtiny817 Xplained Pro user manual*, as well as the *ATtiny817 Complete data sheet*. Clicking update will then initiate the download.



1.5 Microchip Gallery and Studio Extensions

This section describes how Microchip Studio can be extended and updated through the Microchip Gallery. Some of the most useful and popular extensions are described.

Getting Started Topics



Video: Gallery, Studio Extensions, and Updates

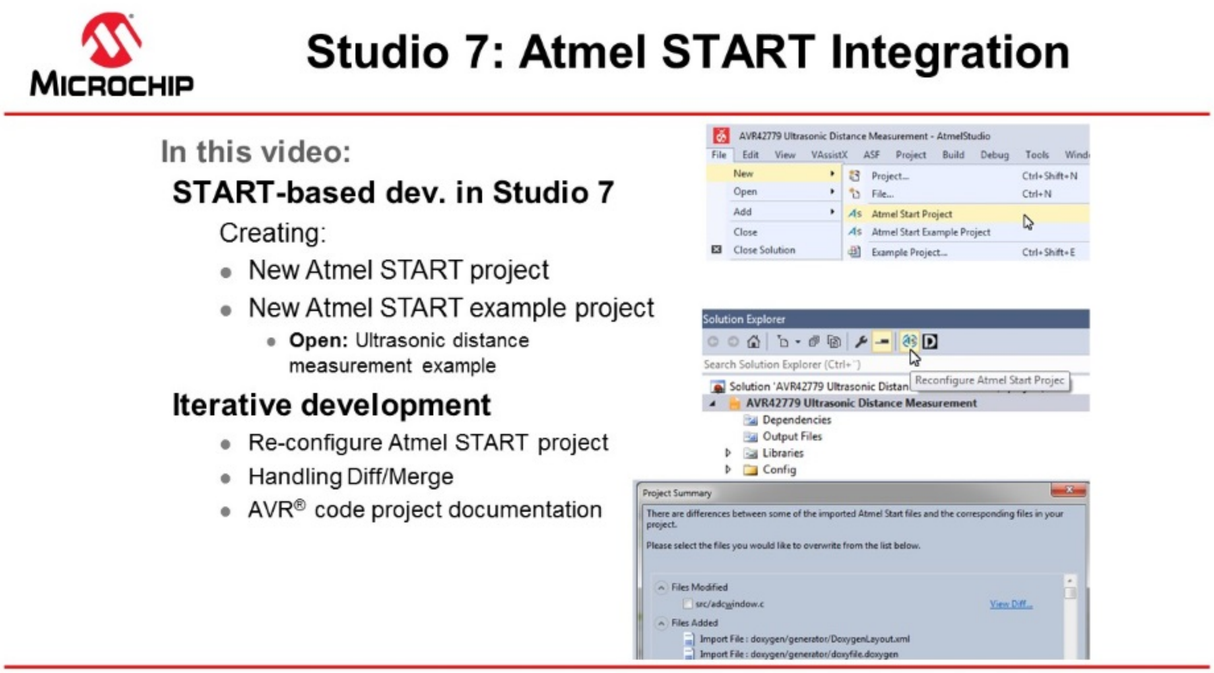
This short video describes the process of adding extensions to Microchip Studio. It covers extensions included by default, what these are used for. Popular extensions are also covered, as well as how to modify Extension Options and Settings.

Website: Microchip Gallery.

1.6 Atmel START Integration

The development experience between Atmel START and Microchip Studio has been optimized. This section demonstrates the iterative development process of START-based projects in Microchip Studio, through the *re-configure* and *merge* functionality.

Getting Started Topics

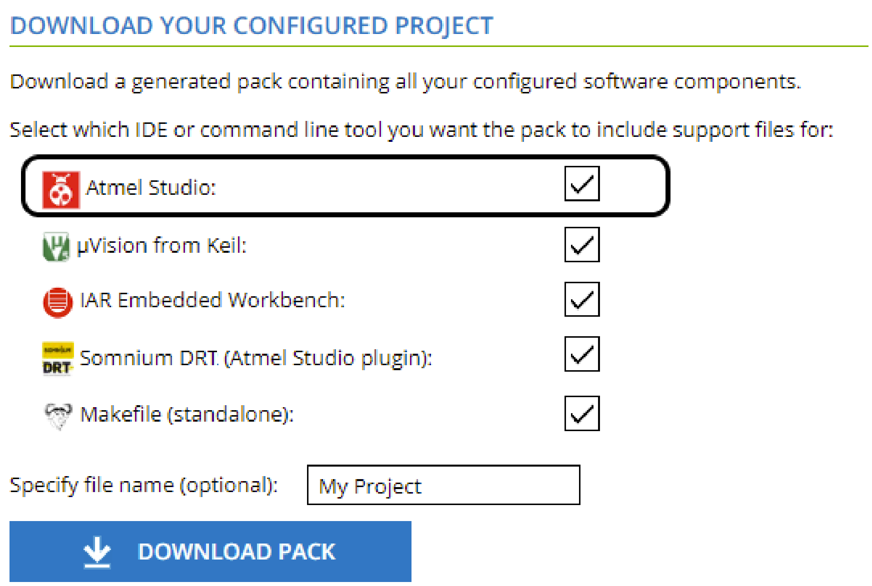


[Video: Atmel START Integration]

To do: Exporting the Project from Atmel START.

1. On the Atmel START website, create a new project (Example or Board).
2. Click on the Export Software Component button. Make sure the Microchip Studio check-box is checked.
3. Click on Download pack. An atmelstart.atzip pack file will be downloaded.

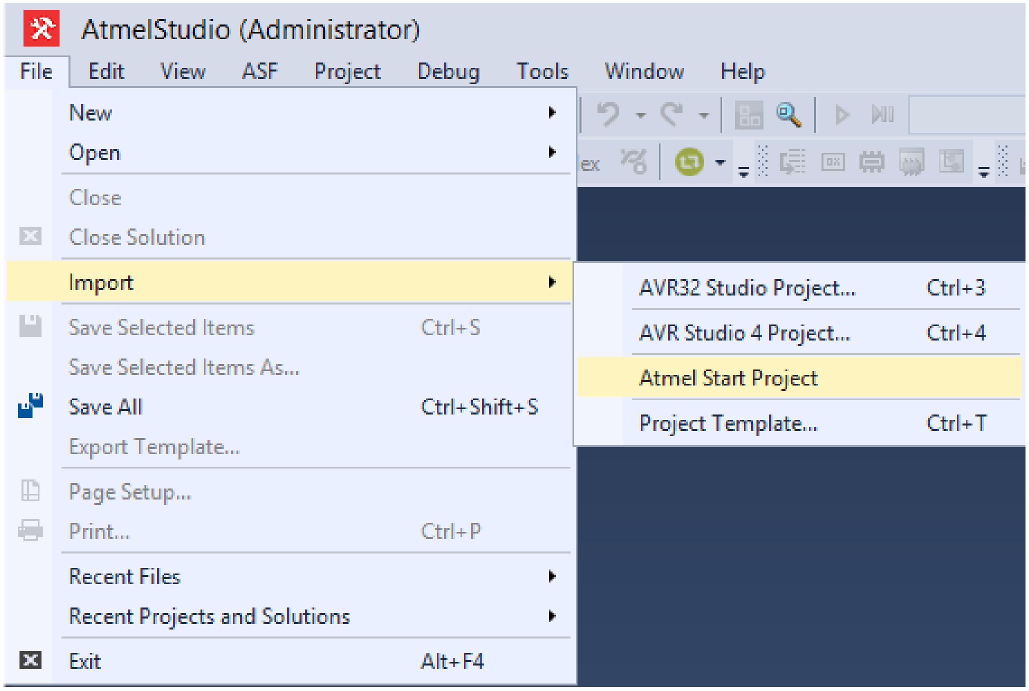
Figure 1-2. Download Your Configured Project



To do: Import the Atmel START Output into Microchip Studio.

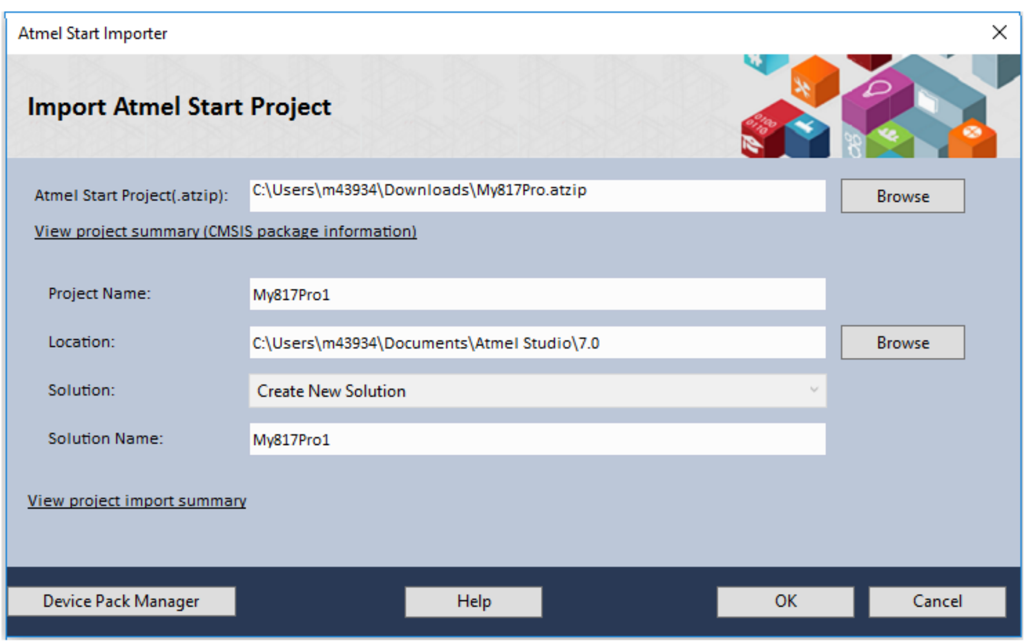
4. Launch Microchip Studio.
5. Select File > Import > Atmel START Project.

Figure 1-3. Import Atmel START Project

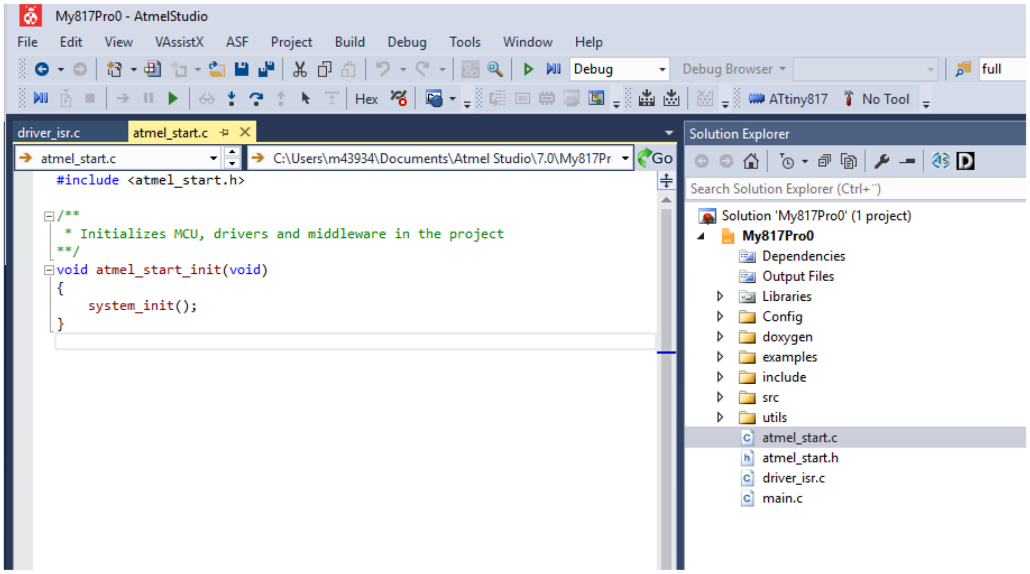


6. Browse and select the downloaded atmelstart.atzip file.
7. The Atmel START Importer dialog box will open. Enter the project details as Project name, Location, and Solution name. Click OK.

Figure 1-4. Atmel START Project Importer



8. A new Microchip Studio project will be created and the files will be imported.



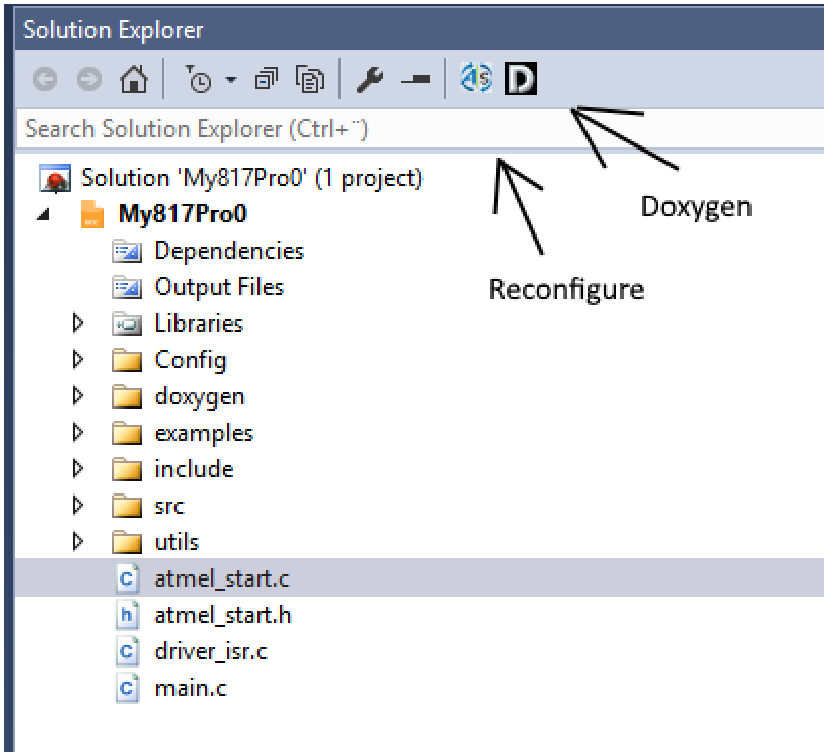
To do: Import the Atmel START Output into Microchip Studio.

9. Some projects contain documentation formatted for Doxygen.
Note: Doxygen must be downloaded from http://www.doxygen.org and installed. You will be asked to configure Studio to locate Doxygen executable, this defaults to C:\Program Files\doxygen\bin \doxygen.exe.
10. Click on the Doxygen button to generate the documentation. Doxygen will run and the generated documentation will open in a new window.

To do: Reconfigure the project using Atmel START.

11. Click on the Reconfigure button or right-click on the project node in the Solution Explorer, and, from the menu, select Reconfigure Atmel START Project.
12. Atmel START will open in a window inside Microchip Studio.

Figure 1-5. Reconfigure Atmel START Project and Doxygen Buttons

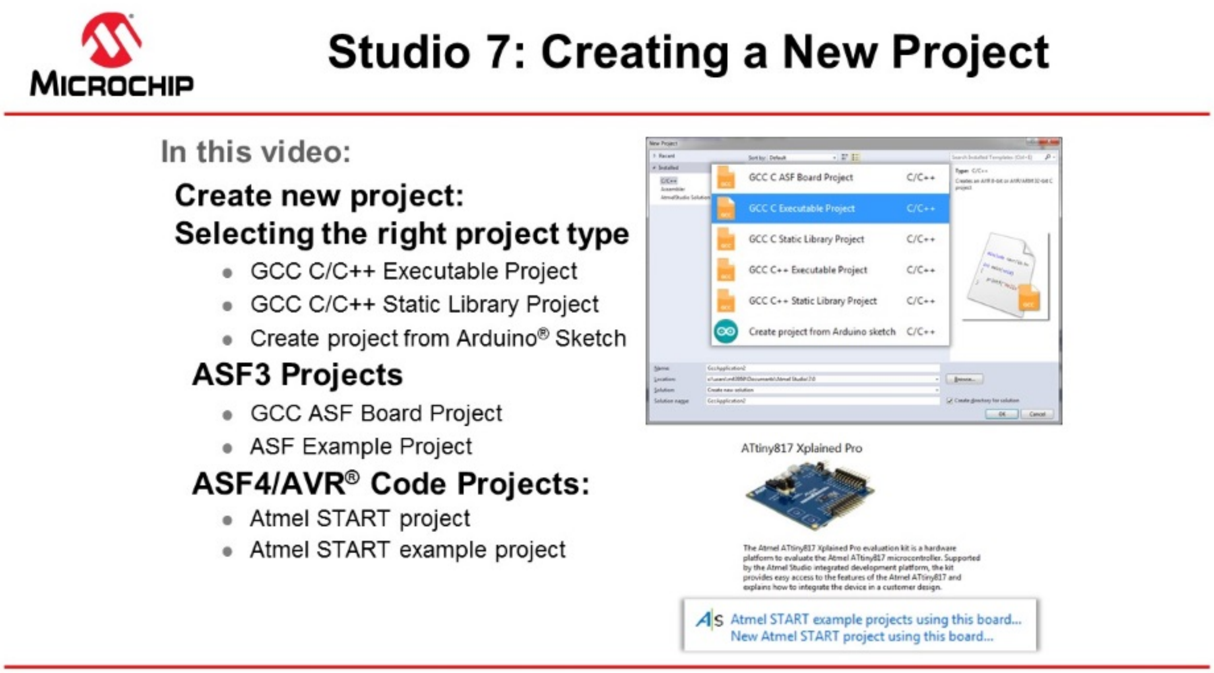


13. Do the necessary changes to the project. Click the GENERATE PROJECT button at the bottom of the Atmel START window.

1.7 Creating a New Project

This section will outline the process of creating a new Microchip Studio project.

Getting Started Topics

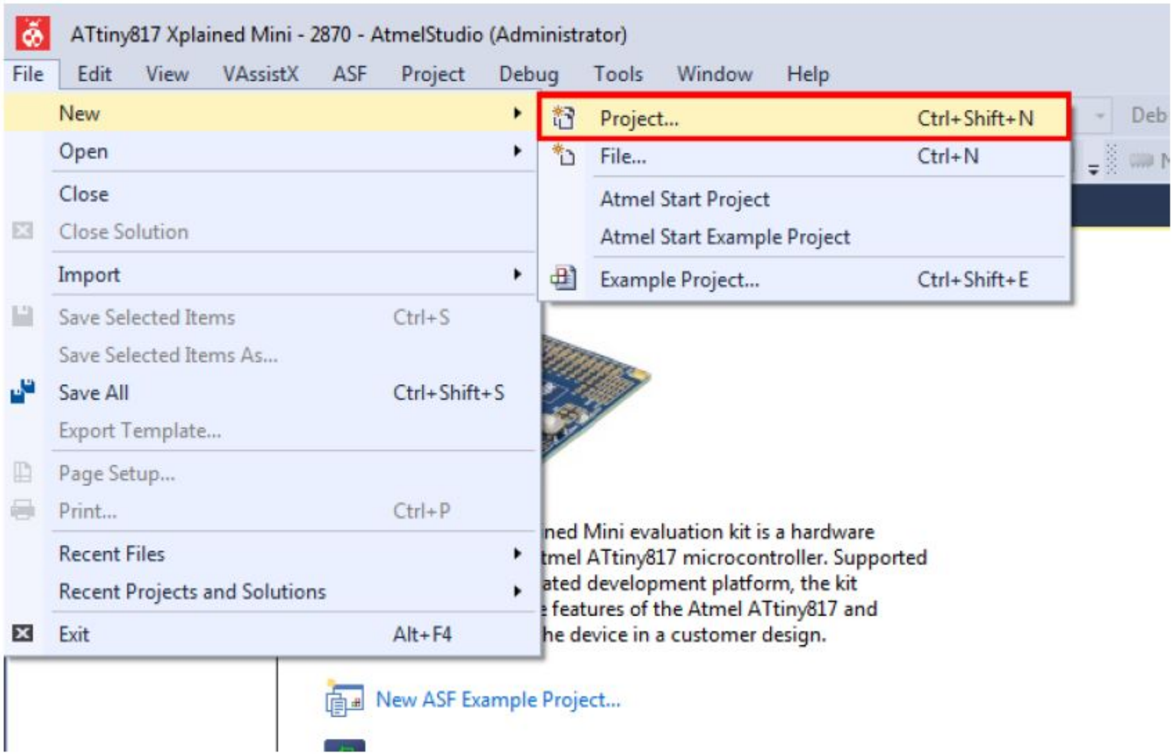


Video: Create New Project

To do: Create a new bare-metal GCC C Executable project for the ATtiny817 device.

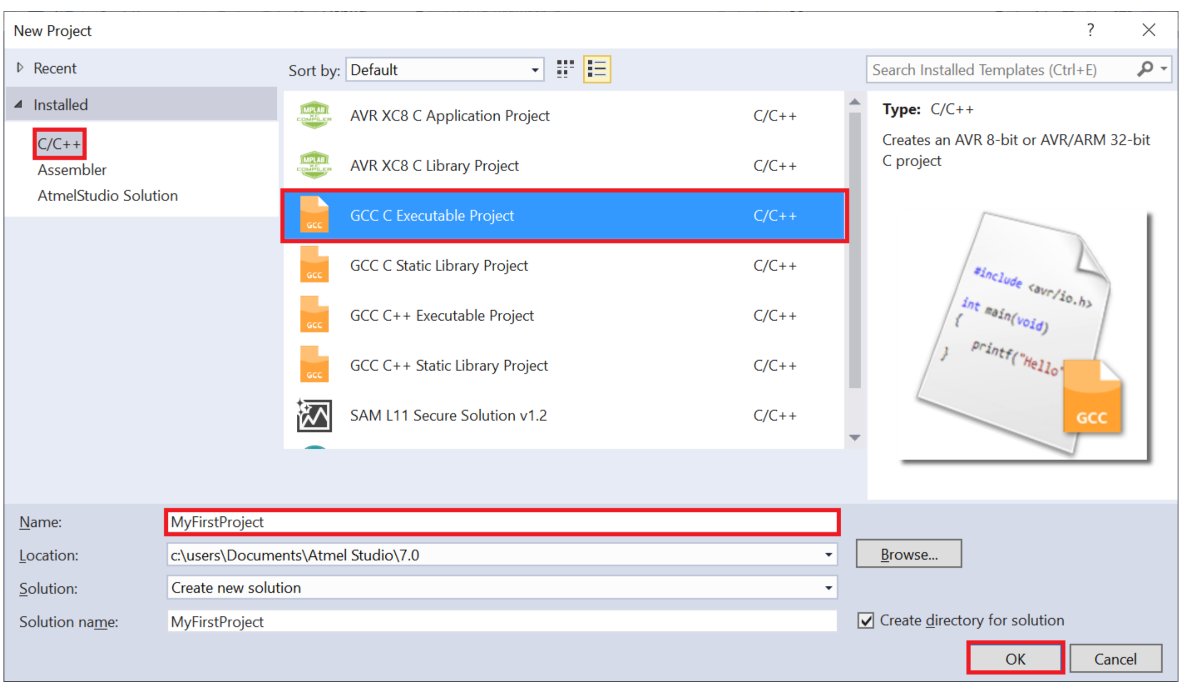
1. Open **Microchip Studio**.
2. In **Microchip Studio**, go to **File** → **New** → **Project** as depicted in Figure 1-6.

Figure 1-6. Creating a New Project in Microchip Studio



3. The project generation wizard will appear. This dialog provides the option to specify the programming language and project template to be used. This project will use C, so make sure **C/C++** is selected in the upper left corner. Select the **GCC C Executable Project** option from the template list to generate a bare-bones executable project. Give the project a **Name** and click **OK**. See Figure 1-7.

Figure 1-7. New Project Programming Language and Template Selection



Tip: All Microchip Studio projects belong to a solution, and by default, Microchip Studio will use the same name for both the newly created solution and the project. The solution name field can be used to manually specify the solution name.

Tip: The *create directory for solution* check-box is checked by default. When this box is ticked, Microchip Studio will generate a new folder with the specified solution name at the location specified by the Location field.

About Project Types

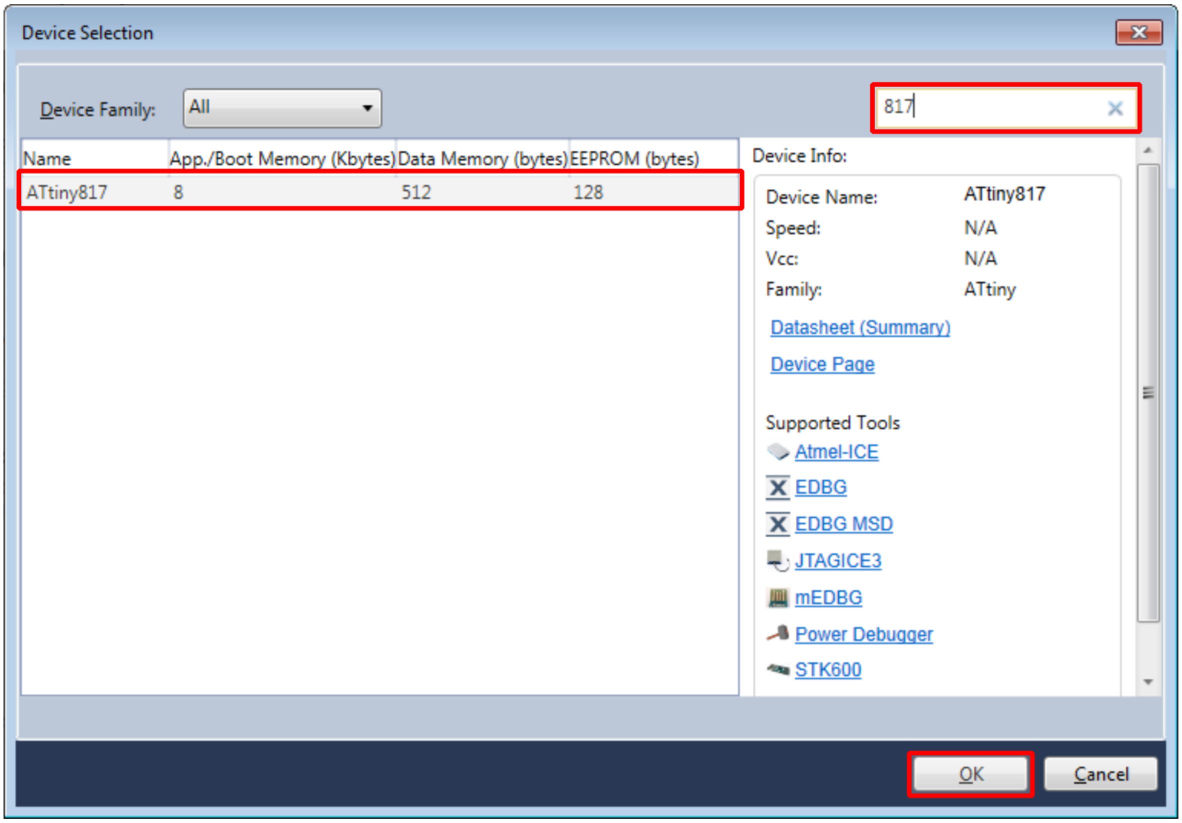
Table 1-1. Project Types

Category	Project Templates	Description
C	AVR XC8 C Appliction Project	Select this template to create an AVR 8-bit project configured to use the MPLAB XC8 compiler.
C	AVR XC8 Library Project	Select this template to create an AVR 8-bit MPLAB XC8 static library(LIB) project. This pre-compiled library (.a) can be used to link to other projects (closed source) or referenced from applications that need the same functionality (code reuse).
C/C++	GCC C ASF Board Project	Select this template to create an AVR 8-bit or AVR/Arm 32-bit ASF3 Board project. Choose between the different boards supported by ASF3.
C/C++	GCC C Executable Project	Select this template to create an AVR 8-bit or AVR/Arm 32-bit GCC project.
C/C++	GCC C Static Library Project	Select this template to create an AVR 8-bit or AVR/Arm 32-bit GCC static library(LIB) project. This pre-compiled library (.a) can be used to link to other projects (closed source) or referenced from applications that need the same functionality (code reuse).
C/C++	GCC C++ Executable Project	Select this template to create an AVR 8-bit or AVR/Arm 32-bit C++ project.
C/C++	GCC C++ Static Library Project	Select this template to create an AVR 8-bit or AVR/Arm 32-bit C++ static library (LIB) project. This pre-compiled library (.a) can be used to link to other projects (closed source) or referenced from applications that need the same functionality (code reuse).
Assembler	Assembler Project	Select this template to create an AVR 8-bit Assembler project.
Category	Project Templates	Description

Attention: This table only lists the default project types. Other project types may be added by extensions.

4. Next, it is necessary to specify which device the project will be developed for. A list of devices will be presented in the *Device Selection* dialog, which can be scrolled through, as depicted in Figure 1-8. It is possible to narrow the search by using the *Device Family* drop-down menu or by using the search box. This project will be developed for the ATtiny817 AVR device, so enter **'817'** in the search box in the top right corner. Select the **ATtiny817** entry in the device list and confirm the device selection by clicking **OK**.

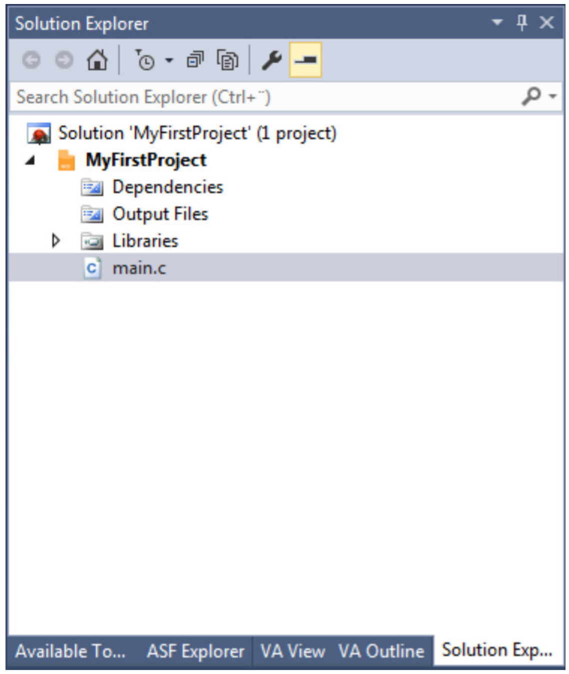
Figure 1-8. New Project Device Selection



Tip: A search for 'tiny' will provide a list of all supported ATtiny devices. A search for 'mega' will provide a list of all supported ATmega devices. **Tools** → **Device Pack Manager** can be used to install support for additional devices.

Result: A new GCC C Executable project has now been created for the ATtiny817 device. The **Solution Explorer** will list the content of the newly generated solution, as depicted in Figure 1-9. If not already open, it can be accessed through **View** → **Solution Explorer** or by pressing Ctrl+Alt+L.

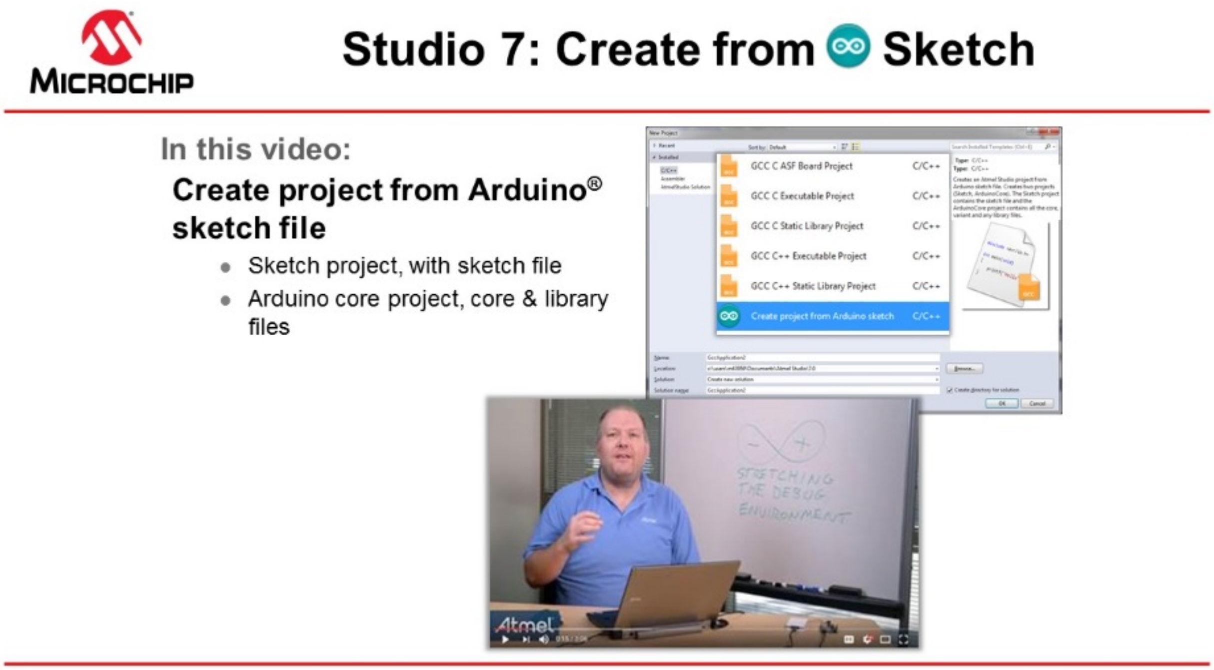
Figure 1-9. Solution Explorer



1.8 Creating From Arduino® Sketch

This section will outline the process of creating a new Microchip Studio project from an Arduino® Sketch.

Getting Started Topics



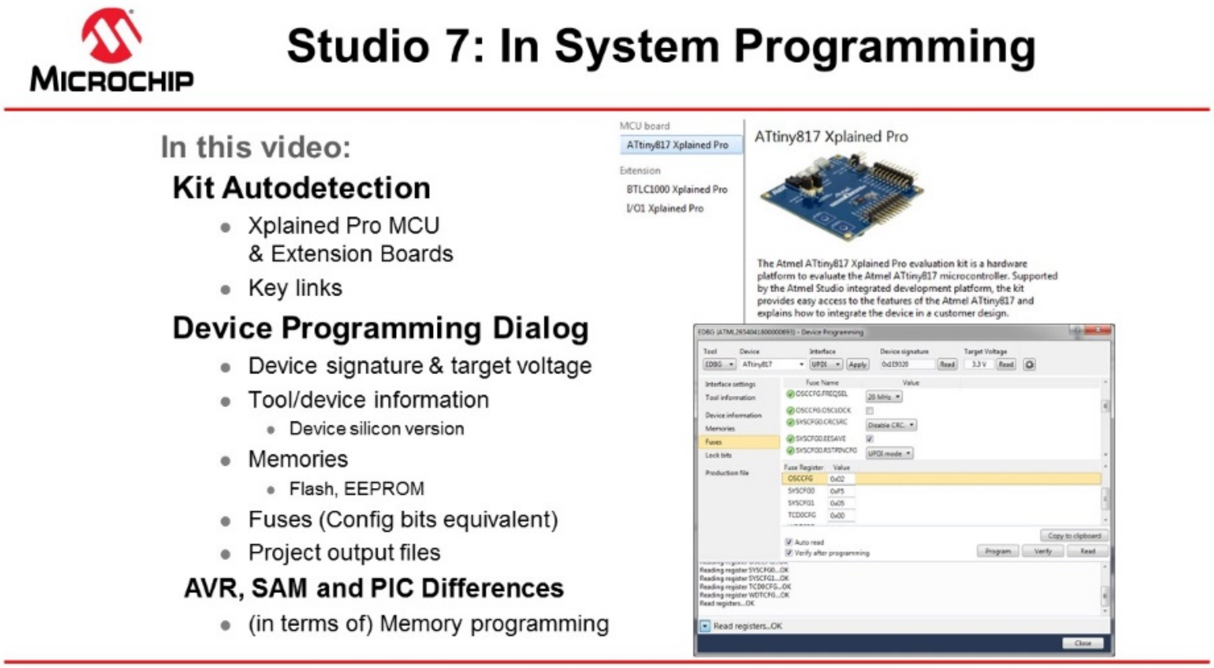
Video: Create from Arduino Sketch

To do: Create a new project from an Arduino Sketch.

1.9 In-System Programming and Kit Connection

This video gives an overview of the Device Programming dialog box, to check the kit connection. The ATtiny817 Xplained Pro kit has an on-board embedded debugger (EDBG) which eliminates the need for a dedicated programmer/debugger. This section will also go through the process of associating the EDBG with your project.

Getting Started Topics

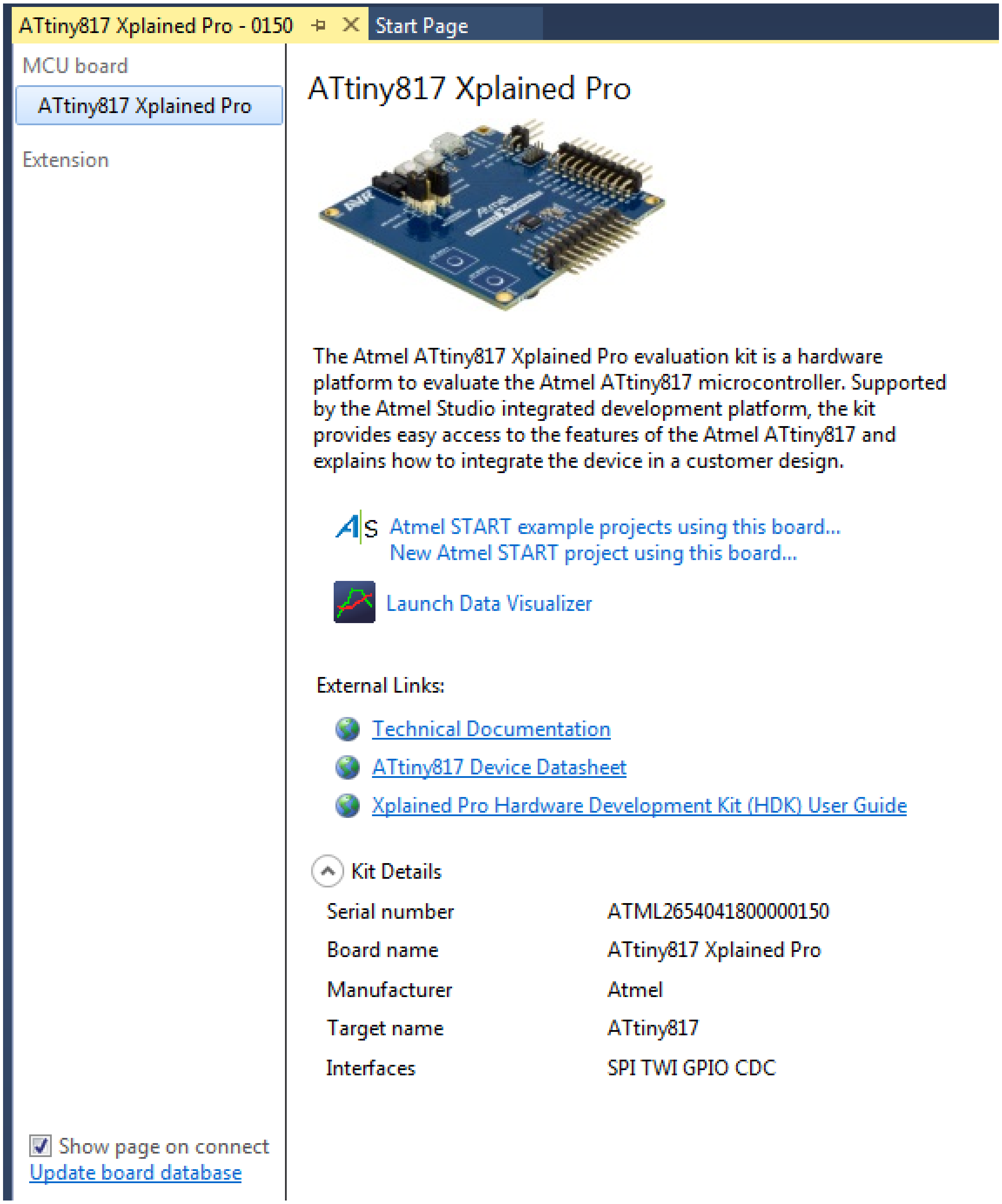


Video: Kit Connection and In-System Programming

To do: Associate the EDBG on your ATtiny817 Xplained Pro kit with your project.

1. Connect the **ATtiny817 Xplained Pro** board to the computer using the provided Micro-USB cable. The kit page should be present in Microchip Studio as in the figure below.

Figure 1-10. ATtiny817 Xplained Pro Start Page



1.1. There are links to documentation for the board and data sheet for the device.

1.2. It is possible to create an Atmel START project for the board. Clicking on the Atmel START links project links will bring you into Atmel START where you get options for this specific board.

2. Opening the **Programming Dialog** by Tools → Device Programming.

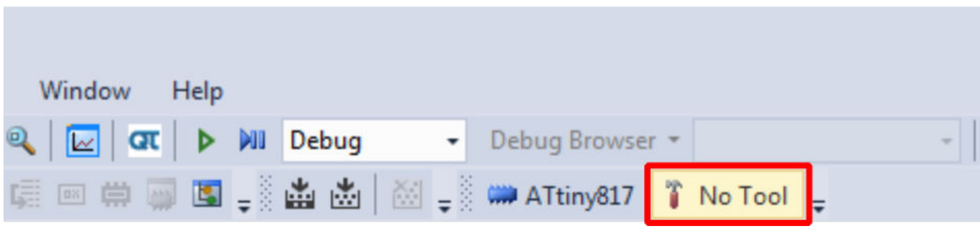
2.1. Select EDBG Tool and assure that Device = ATtiny817, then you may read Device Signature and Target Voltage.

2.2. Interface settings: You may see and change the interface clock frequency.

2.3. Tool information: Shows information about the EDBG tool.

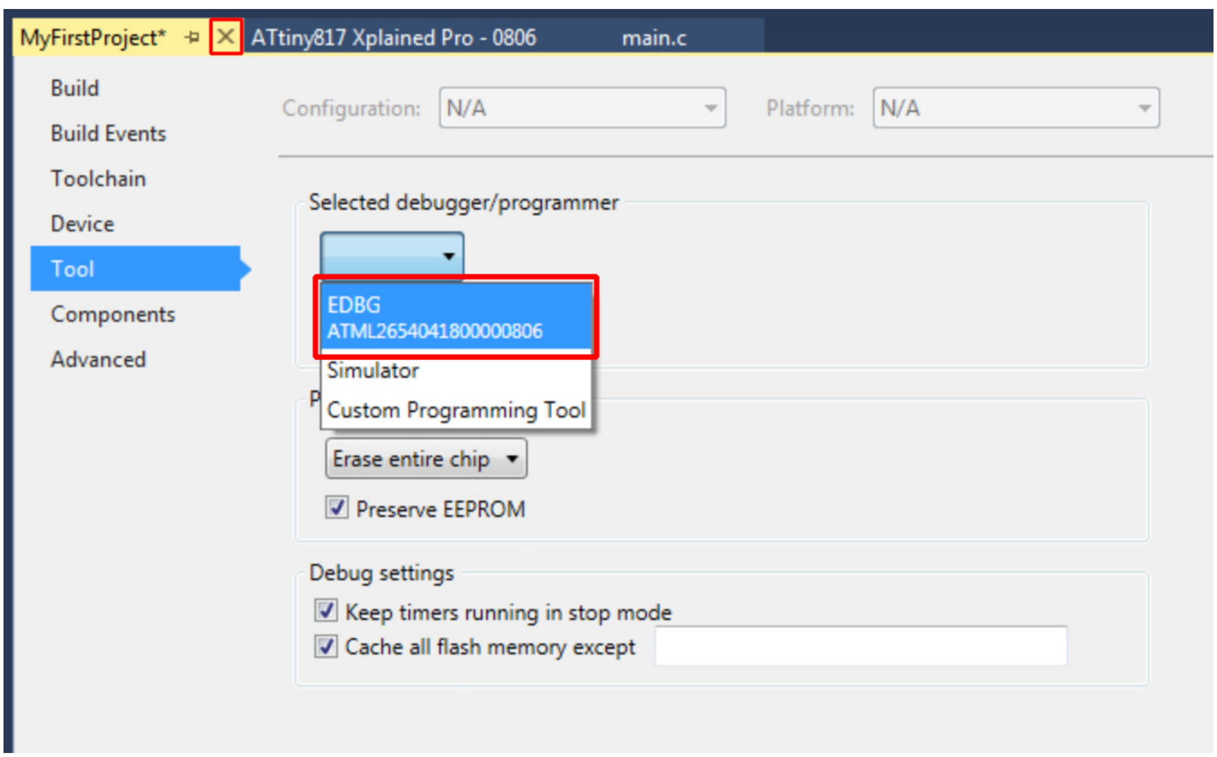
   2.4. Device information: Shows information about the device. Note that you can also see the silicon revision of the device. This may be useful in customer support cases.
   2.5. Memories: May program the flash, EEPROM, and user signature separately from the files.
   2.6. Fuses: Read and set fuses, for instance, oscillator frequency (16 or 20 MHz), brown-out voltage detection etc.
   2.7. Lock bits: Lock memory.
   2.8. Production file: Program the device using a production file to program flash, EEPROM, and user signatures.
   2.9. Note that AVR has flash in the HEX file and EEPROM in the EEP files, while PIC has everything, even fuses, in a HEX file.
   2.10. For instance, SAML21J devices don't have EEPROM (may be emulated in flash). It also has a security bit option to lock the device.
3. **Create a new project** by selecting File → New project, select for instance C executable project, select the device by filtering on the device name. Different project types are discussed in another Getting Started video.
4. If a project is selected, click the **Tool** button located in the top menu bar to open the tool dialog as indicated in the figure below.

Figure 1-11. Tool Button



5. The *Tool* tab of the **Project Properties** will open. In the drop-down menu, select the **EDBG** tool, as indicated in the figure below. The interface should automatically initiate to UPDI (Unified Programming Debugging Interface).

Figure 1-12. Select Debugger/Programmer in Project Properties



Tip: The serial number of the tool will accompany its name in the drop-down menu. This serial number is printed on the backside of each tool, allowing differentiation when more than one is connected.

Tip: These steps can always be repeated if a different tool should be used for the next debug/program session.

WARNING On the ATtiny817 Xplained Pro, the EDBG is permanently connected to the target MCU, but for a custom hardware solution it is necessary to ensure the target device is powered and properly connected before a debug session can be launched.

Result: The tool to be used by Microchip Studio when a debug/programming session is launched, has now been specified.

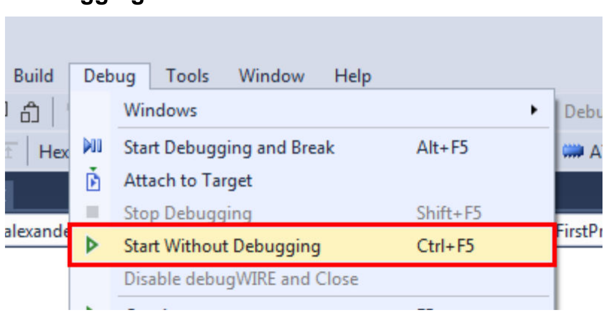
1.9.1 Settings Verification

This section is a guide to verifying the tool and project configuration setup by compiling the empty project and writing it to the ATtiny817.

To do: Verify the tool and project configuration setup done in the previous sections.

1. Click the **Start Without Debugging** button located in the **Debug** menu, as shown in the figure below. This will compile the project and write it to the specified target MCU using the configured tool.

Figure 1-13. Start Without Debugging



2. When *Microchip Studio* builds the project (automatically done when pressing **Start Without Debugging**), several **generated output files** will show up in the Solution Explorer window. The following output files are generated:
   2.1. EEP file: EEPROM content written to the device.
   2.2. ELF file: Contains everything written to the device, including program, EEPROM, and fuses.
   2.3. HEX file: Flash content written to the device.
   2.4. LSS file: Disassembled ELF file.
   2.5. MAP file: Linker info, what did the linker do, decisions about where to put things.
   2.6. SREC file: Same as HEX but in Motorola format.

Info: If there is new firmware available for the selected tool, the **Firmware Upgrade** dialog will appear, as depicted in Figure 1-14. Click the **Upgrade** button to start the firmware upgrade.

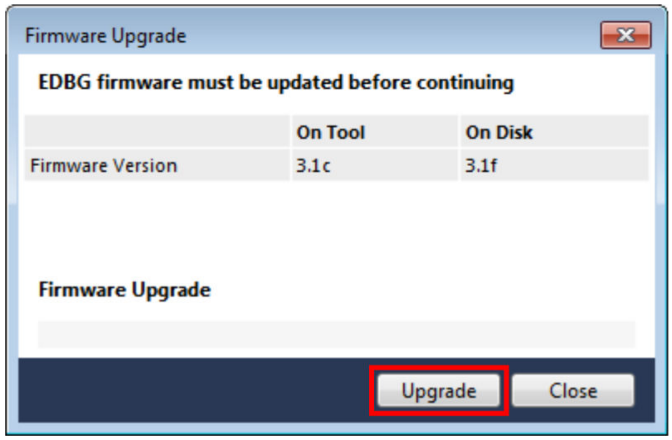


Figure 1-14. Firmware Upgrade Dialog

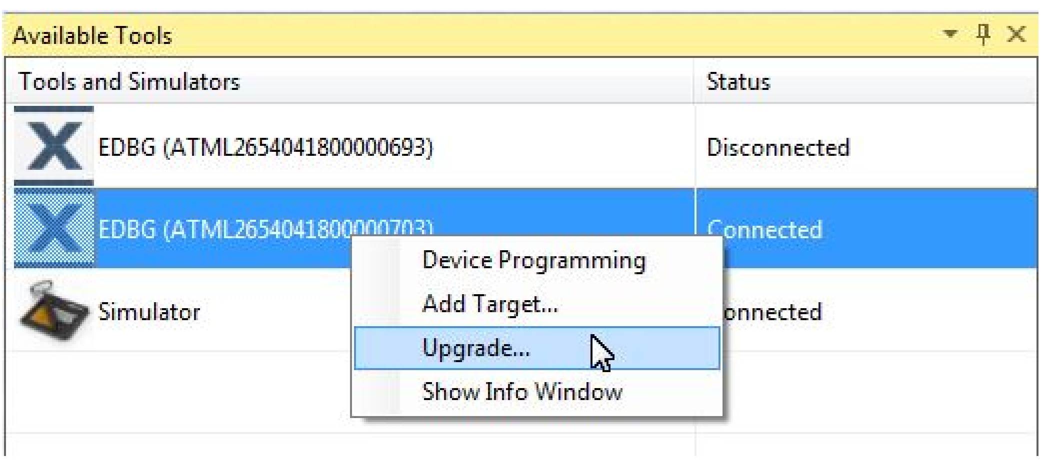
Depending on the state of the connected tool and the actual firmware upgrade, the upgrade may fail on the first attempt. This is normal and can be resolved by disconnecting and reconnecting the kit before clicking **Upgrade** again. After the upgrade has completed, the dialog should say 'EDBG Firmware Successfully Upgraded'. **Close** the dialog box and make a new attempt at programming the kit by clicking the **Start Without Debugging** button again.

Result: By compiling the empty project and writing it to the ATtiny817 the following has been verified:

- The project is configured for the correct MCU
- The correct tool has been selected
- The tool's firmware is up-to-date

Under *View* > *Available Tools* you are able to see a list of available or recently used Tools. Here you can specifically ask *Microchip Studio* to upgrade the firmware for a tool.

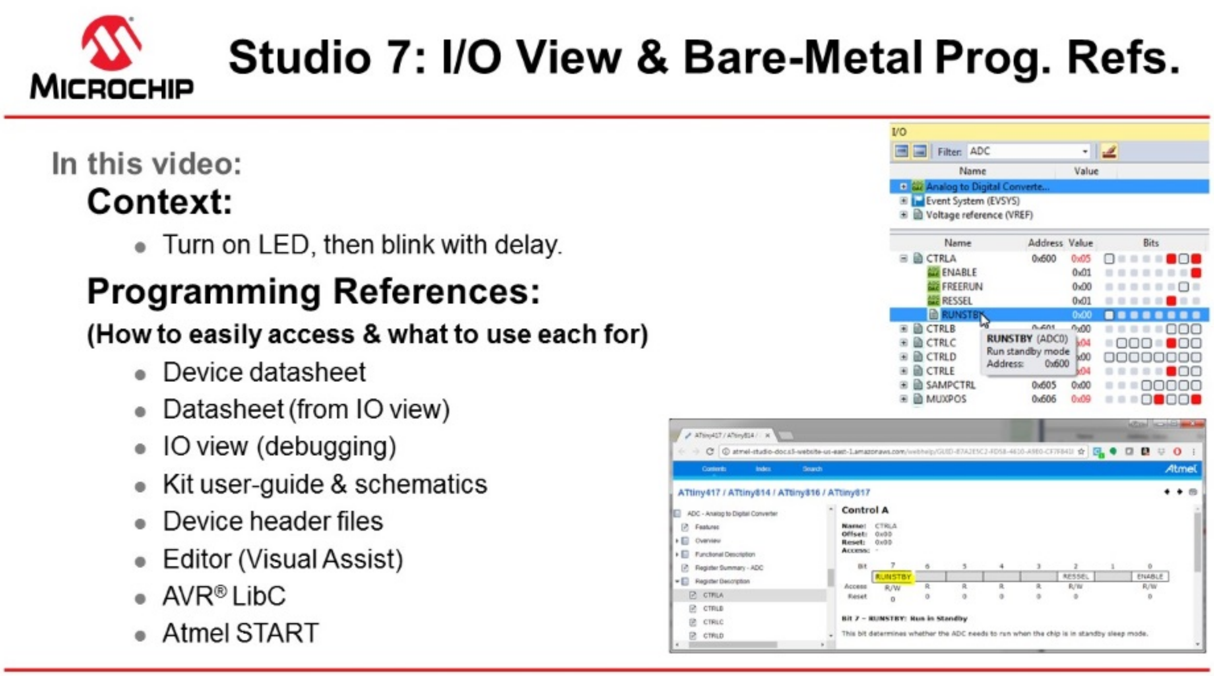
Figure 1-15. Microchip Studio Available Tools (on view menu)



1.10 I/O View and Other Bare-Metal Programming References

This section describes how you would typically write code in *Microchip Studio*, independent of a software configuration tool or framework, i.e., bare-metal. This is covered both as video (linked below) and hands-on document. The main focus is on each of the relevant programming references, how each is accessed, and what each is used for. The project context is to turn ON an LED, then blink with a delay. Although the *ATtiny817 Xplained Pro* is used the principles are general enough to use with any kit in *Microchip Studio*, though the principles apply to most devices supported in *Microchip Studio*.

Getting Started Topics



Video: I/O View and Bare-metal programming references

The list below is an overview of the programming references which are typically used. Particular emphasis is placed on I/O View, which provides a way to navigate data sheet register descriptions when editing or debugging, as well as to understand the current configuration when debugging. This second use of I/O view when debugging is also used to test new register configurations.

This topic is closely related to both 1.15 Debugging 3: I/O View Memory View and Watch as well as 1.11 Editor: Writing and Re-Factoring Code (Visual Assist).

- Device data sheet
- Data sheet (from I/O view)
- Kit user guide and schematics
- I/O View (debugging)
- Editor (Visual Assist)
- Device header files
- AVR Libc (AVR specific)
- Atmel START: ATtiny817 project

In the process the following code is written. Although the code is simple, the decision process, using the list of programming references above, is described.

```
#include <avr/io.h>
#define F_CPU 3333333
#include <util/delay.h>

int main(void)
{
    PORTB.DIR = PIN4_bm;

    while (1)
    {
```

```
        _delay_ms(500);
        PORTB.OUTTGL = PIN4_bm;
    }
}
```

⚠WARNING Be sure to keep the `#include <avr/io.h>` line at the top of *main.c*. This header file will include the correct register map for the selected device, and without this statement, the compiler will not recognize any of the macros referenced in the code above.

Device Data Sheet (PDF)
Although I/O View allows easy access to navigate the data sheet at a register level, the PDF version still has a role. The device data sheet, in PDF format, tends to be used at least to get an understanding of the peripheral, through the **block diagram** and **functional description**. For example, to understand the PORT peripheral of the ATtiny817, we consulted the *PORT Block Diagram* and *Functional Description > Principle of operation* sections of the data sheet. These two sections together, connecting the description to the diagram, give a basic understanding of the PORT peripheral.

Figure 1-16. PORT Block Diagram from the PDF Data Sheet

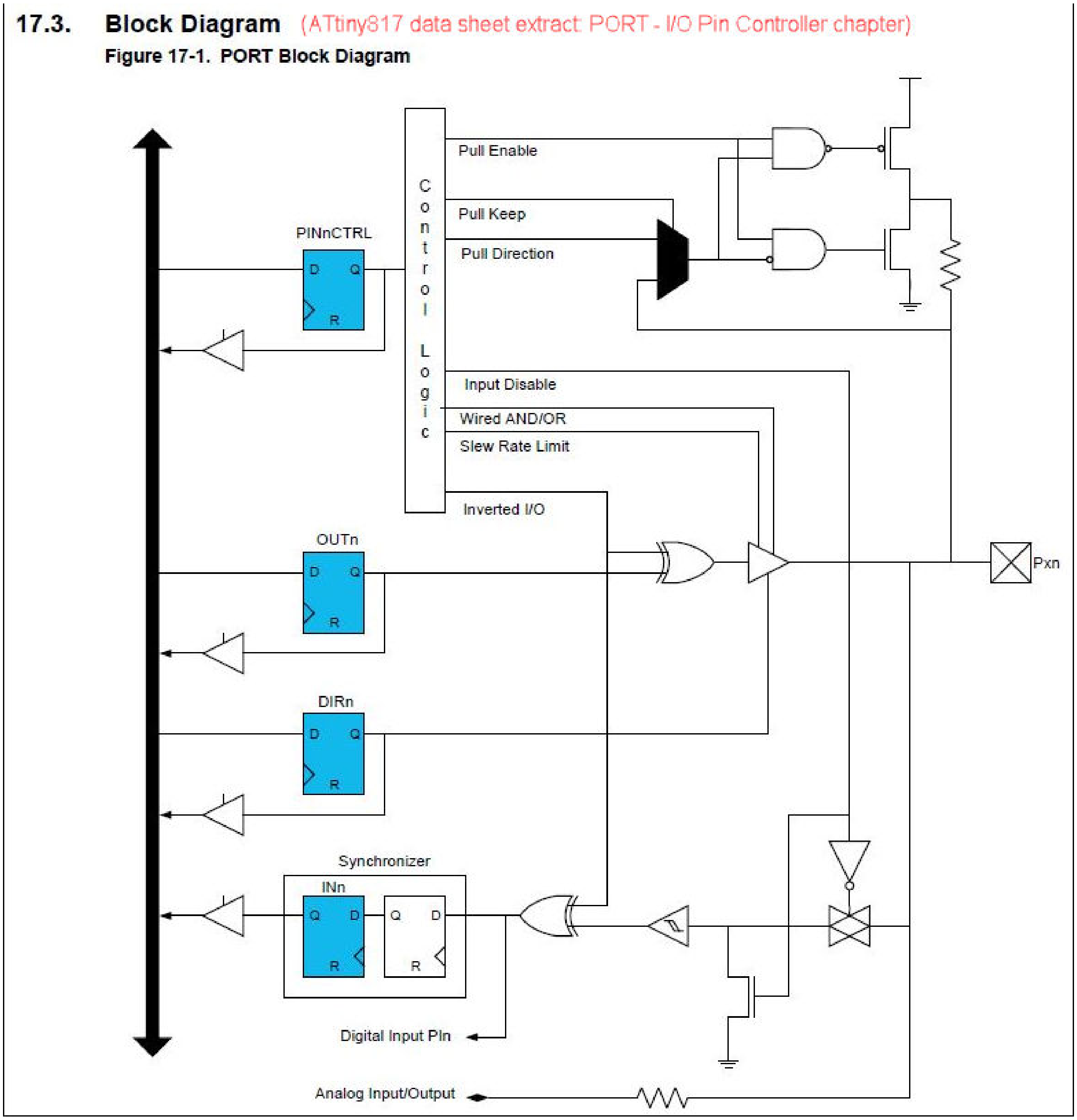
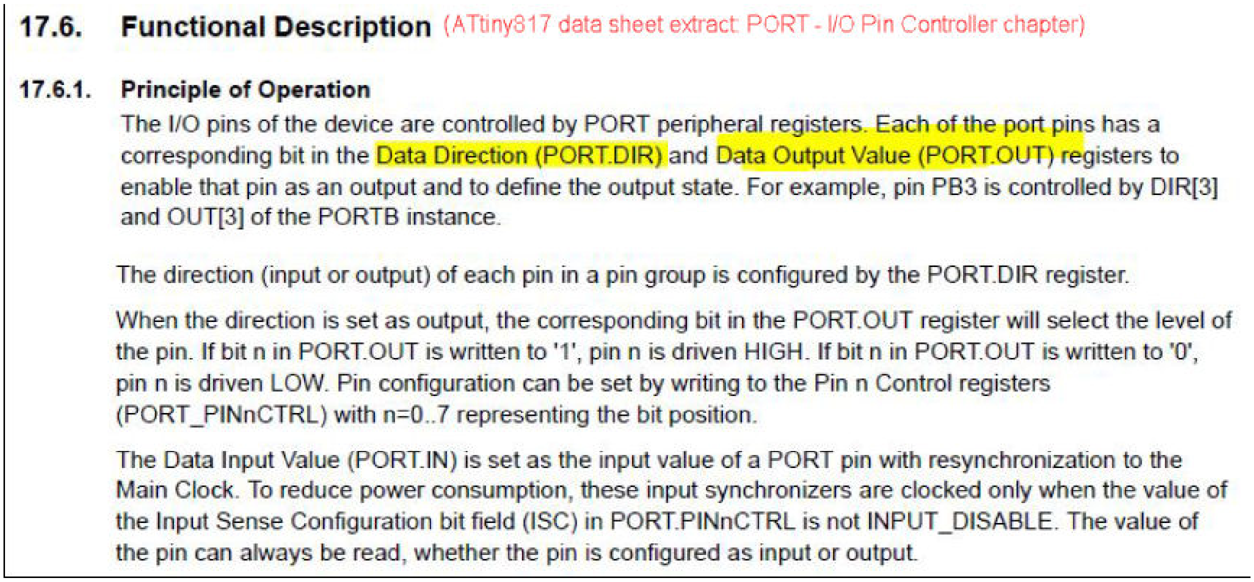


Figure 1-17. Principle of Operation from the PDF Data Sheet of ATtiny817



17.6. Functional Description (ATtiny817 data sheet extract: PORT - I/O Pin Controller chapter)

17.6.1. Principle of Operation

The I/O pins of the device are controlled by PORT peripheral registers. Each of the port pins has a corresponding bit in the Data Direction (PORT.DIR) and Data Output Value (PORT.OUT) registers to enable that pin as an output and to define the output state. For example, pin PB3 is controlled by DIR[3] and OUT[3] of the PORTB instance.

The direction (input or output) of each pin in a pin group is configured by the PORT.DIR register.

When the direction is set as output, the corresponding bit in the PORT.OUT register will select the level of the pin. If bit n in PORT.OUT is written to '1', pin n is driven HIGH. If bit n in PORT.OUT is written to '0', pin n is driven LOW. Pin configuration can be set by writing to the Pin n Control registers (PORT_PINnCTRL) with n=0..7 representing the bit position.

The Data Input Value (PORT.IN) is set as the input value of a PORT pin with resynchronization to the Main Clock. To reduce power consumption, these input synchronizers are clocked only when the value of the Input Sense Configuration bit field (ISC) in PORT.PINnCTRL is not INPUT_DISABLE. The value of the pin can always be read, whether the pin is configured as input or output.

Note: We used the **device data sheet** for the **peripheral block diagram**, as well as a description of the **PORT DIR and OUT registers**.

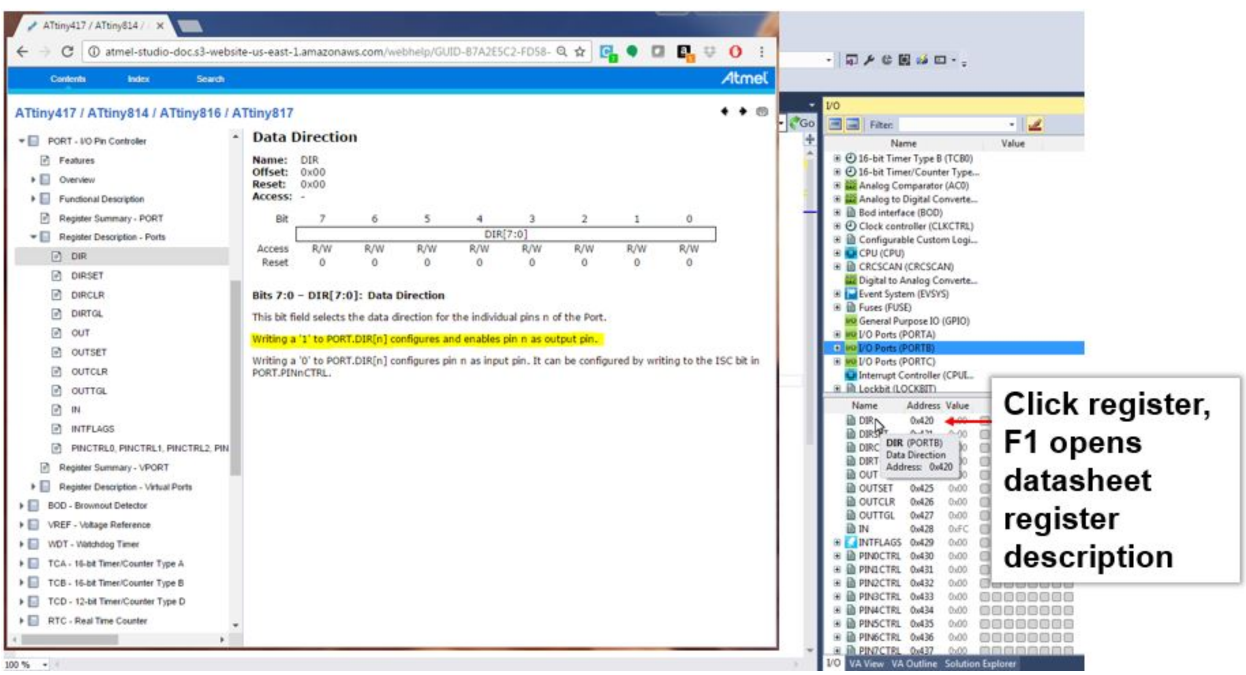
I/O View Data Sheet

Microchip Studio allows to easily access the data sheet register descriptions by clicking F1 on the relevant register description. The HTML version of the data sheet opens online (by default). The data sheet will open in the context of the relevant register description.

Notes: In this way we use the **Data sheet from I/O View** to understand that:

1. Writing a '1' to PORT.DIR[n] configures and enables pin n as an output pin.
2. If OUT[n] is written to '0', pin n is driven low.

Figure 1-18. Opening an Online Data Sheet from I/O View



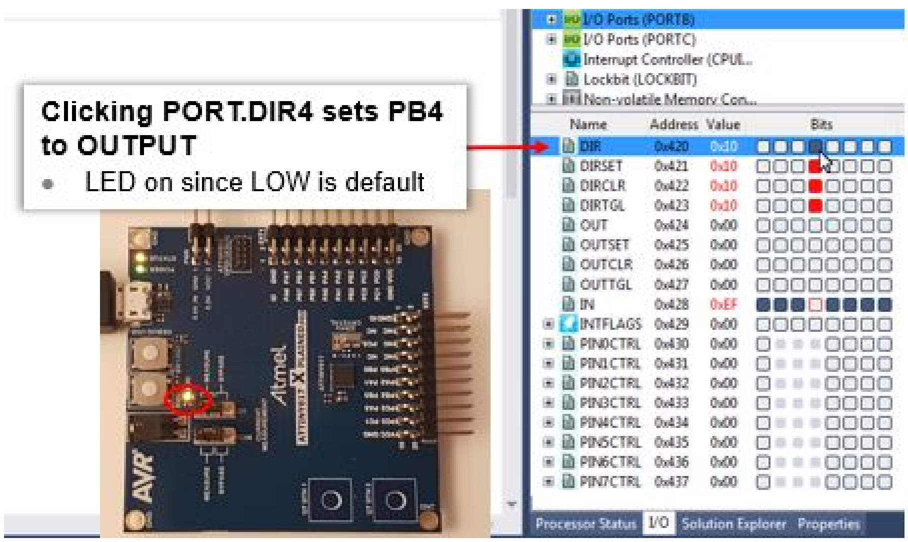
I/O View (Debugging)
This functionality can directly be tested by starting a debug session, using *Start Debugging and Break*. So we are now able to begin testing functionality, as shown in the image below.
I/O View is covered in more detail in 1.15 Debugging 3: I/O View Memory View and Watch.
Notes: I/O View when debugging is used to:

1. Verify that writing a '1' to PORT.DIR4, sets pin as OUTPUT, LOW by default to LED turns ON.
2. Verify that writing a '1' to PORT.OUT4, turns OFF the LED.

Table 1-2. Microchip Studio Button Functionality (Programming and Launching Debug Sessions)

Button	Functionality	Keyboard Shortcut
	Start Debugging and Break	Alt + F5
	Attach to Target	
	Start Debugging	F5
	Break All	Ctrl + Alt + Break
	Start Without Debugging	Ctrl + F5

Figure 1-19. Turning ON/OFF Kit LEDs Through Manipulating I/O View Registers when Debugging



Downloading Microchip Studio Documentation
The data sheet can also be downloaded by using the Microchip Studio help system. In this case, a similar functionality will work offline. This is described here: 1.4.2 Downloading Offline Documentation.

Microchip Studio Editor (Visual Assist)
The Microchip Studio Editor, powered by Visual Assist has powerful features to help you write and refactor code, as well as easily navigate large projects. Suggestion functionality is shown in Figure 1-20, while an overview of the code navigation is shown in Figure 1-21. In the next section, 1.11 Editor: Writing and Re-Factoring Code (Visual Assist), the editor features are covered in more detail.

Figure 1-20. Suggestion Functionality in the Microchip Studio Editor for Writing Code

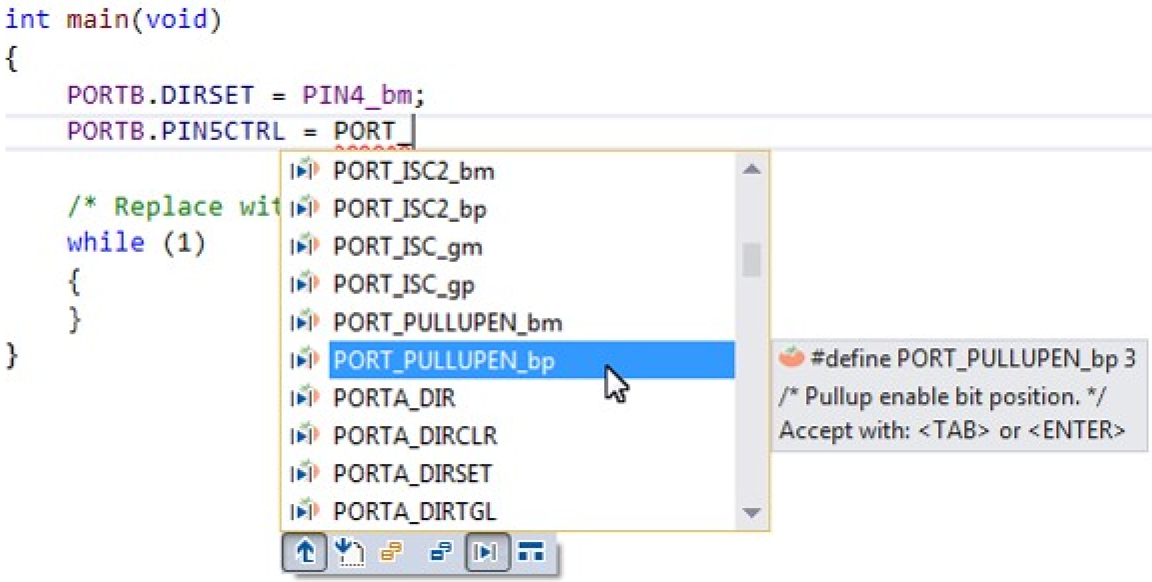
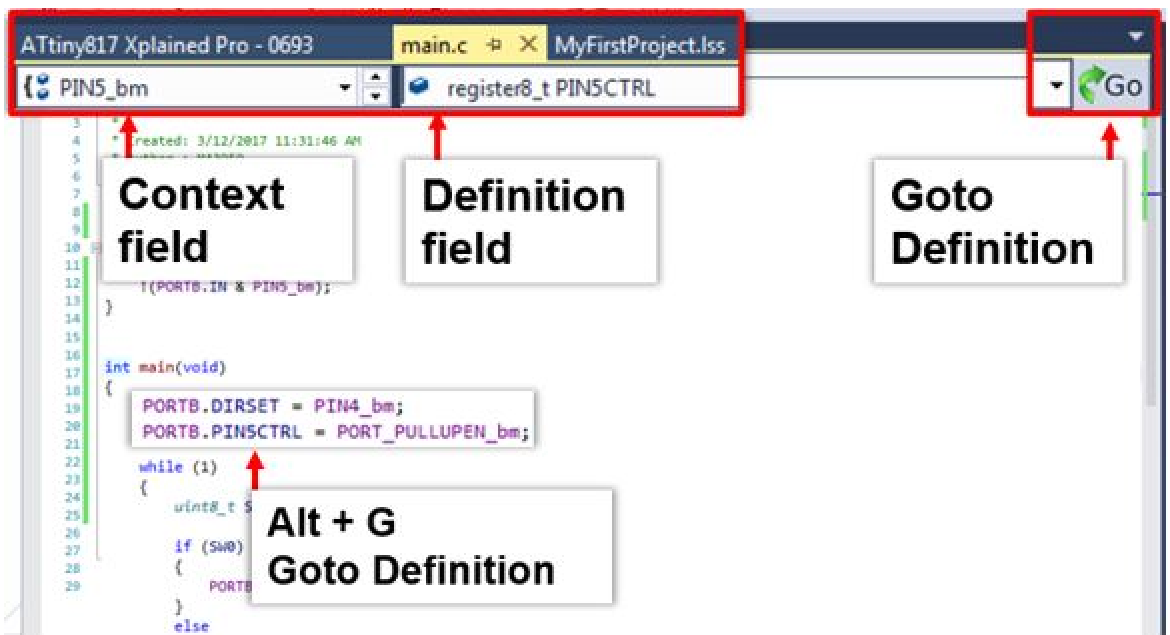


Figure 1-21. Microchip Studio Editor Navigation Overview

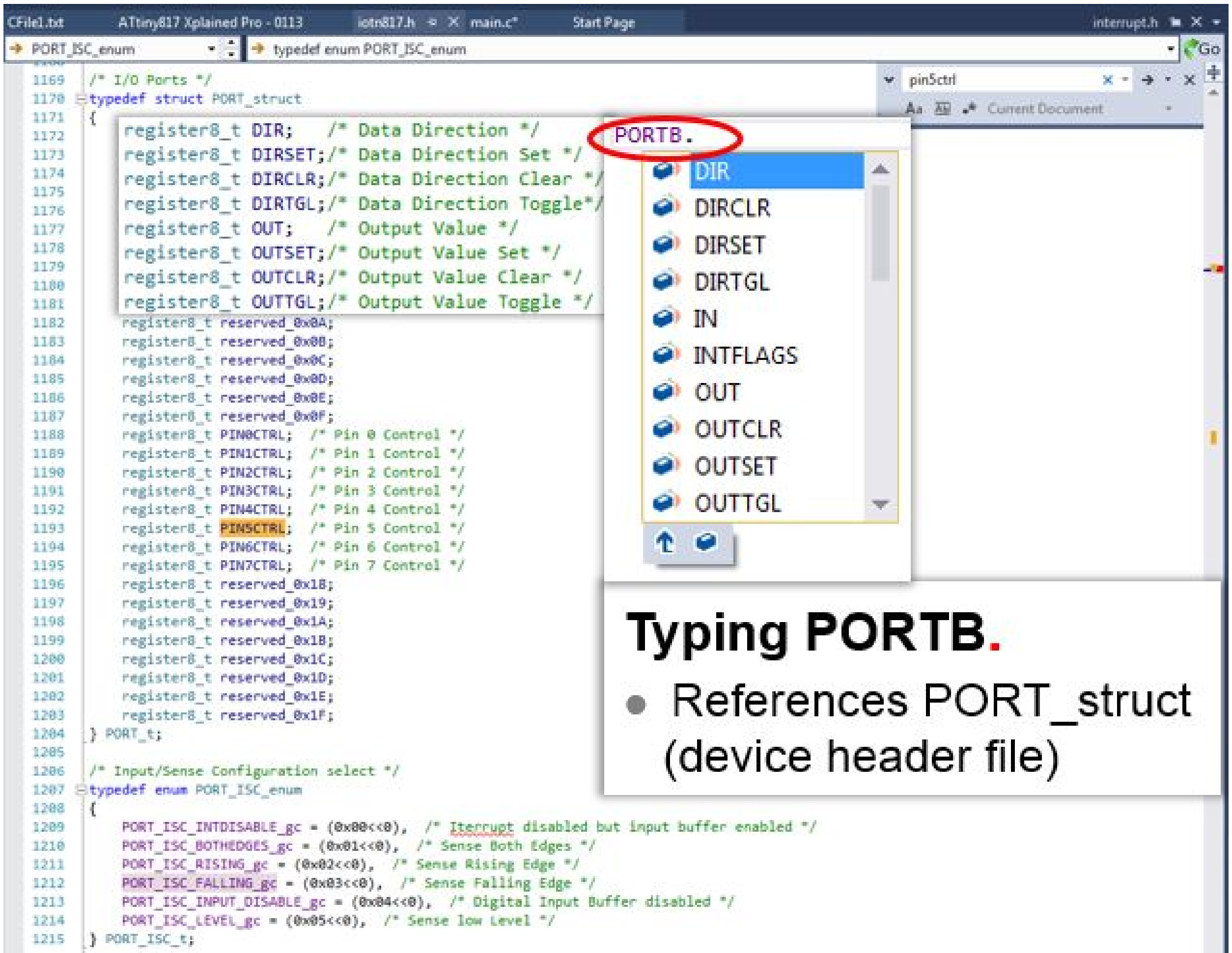


Specifically in the video related to this section, the editor is used for the following.

Device Header Files

Through the *Goto Definition* functionality of the editor, it is easy to access the MCU device header files, i.e., by clicking on any register and then clicking on the goto button, or typing Alt+G. Writing PORTB. gives a suggestion list of potential registers, from the PORT structure, shown in figure Suggestion lists and the MCU device header files. For more information about how the AVR header files are structured, see **AVR1000** for more information.

Figure 1-22. Suggestion Lists and the MCU Device Header Files



Kit Schematics and User Guide

The kit schematics and user guide are useful to understand the MCU pin connections on the kit. Full schematics and kit design files, such as Gerbers, are available on www.microchip.com, on the kit's product page.

Figure 1-23. How to Find Schematics for a Particular Development Board

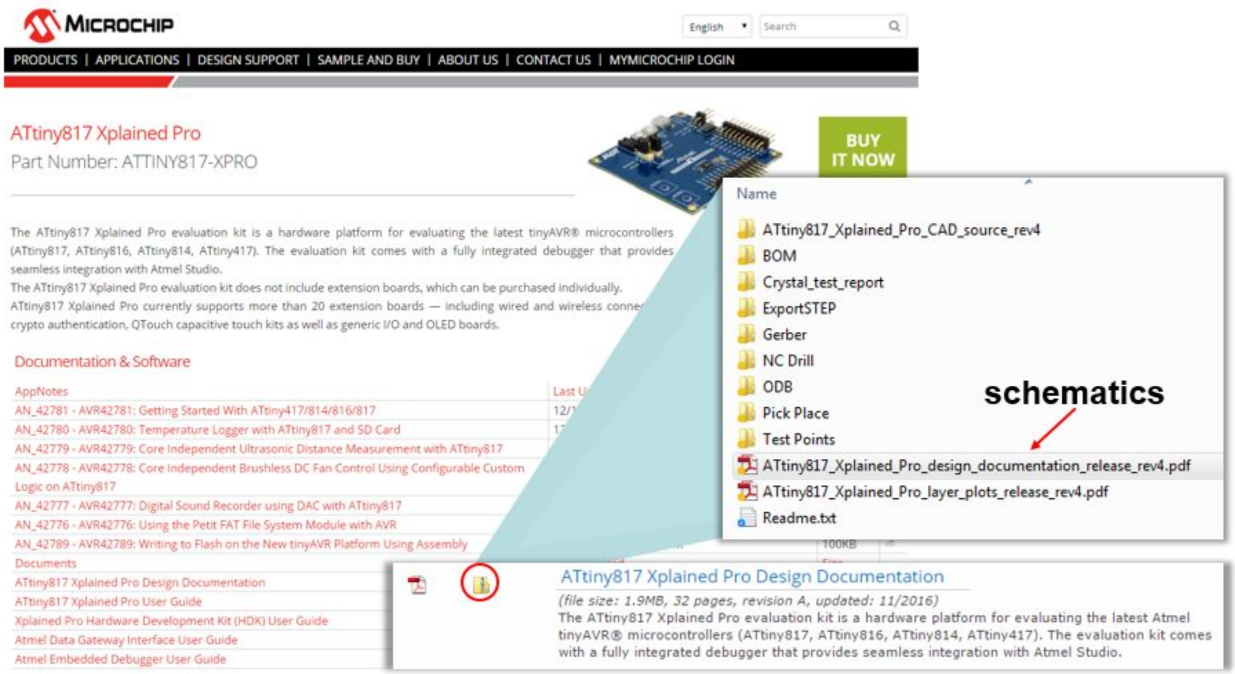
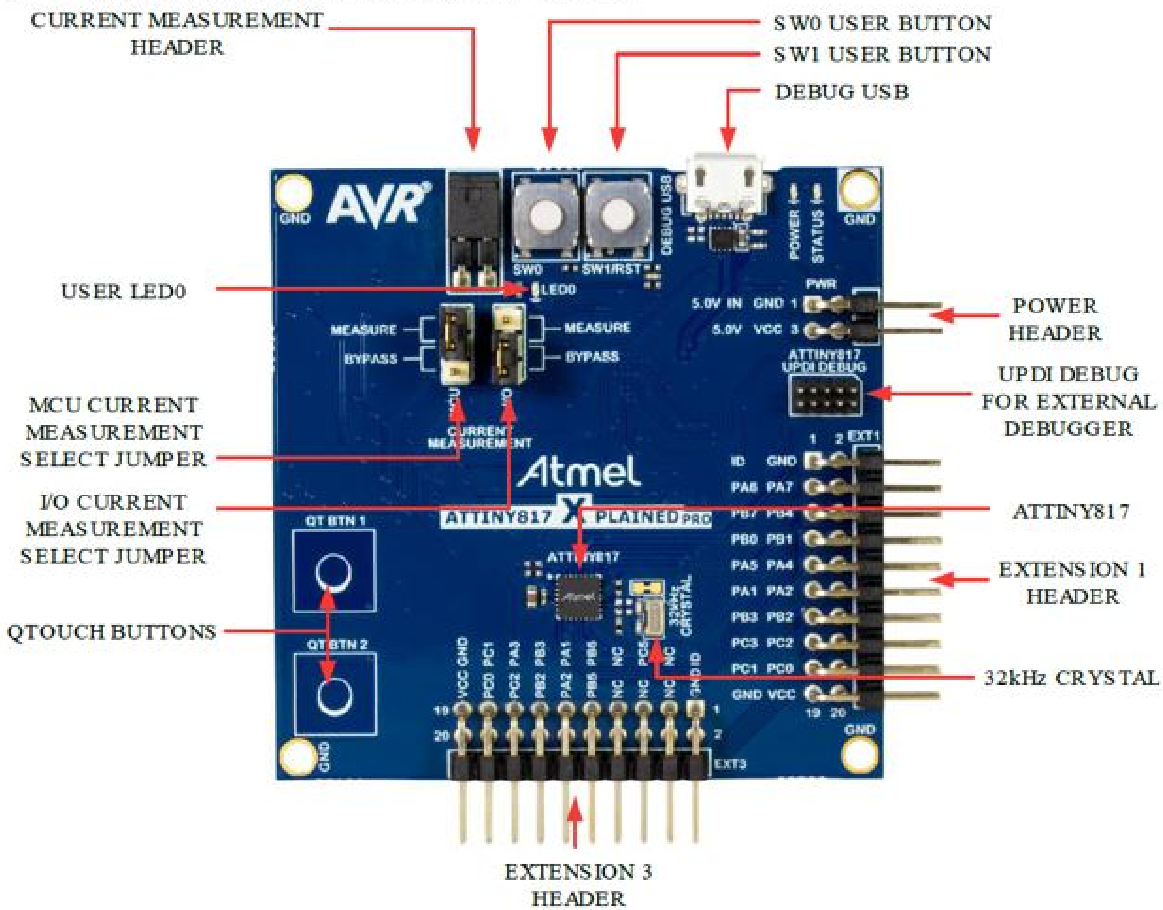


Figure 1-1. ATtiny817 Xplained Pro Evaluation Kit Overview



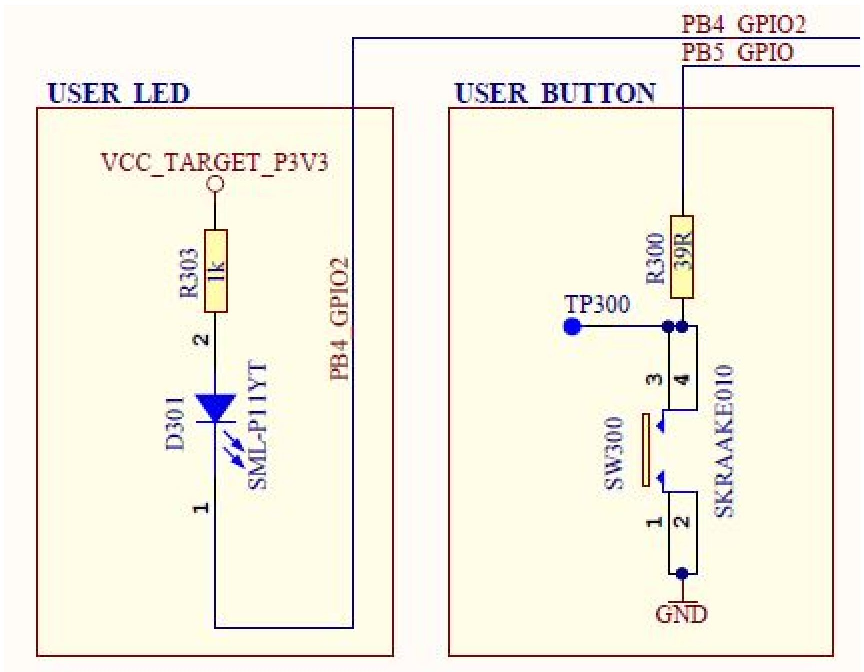
The LED and button are connected to the pins as per the table below, from the ATtiny817 Xplained Pro User Guide.

Table 1-3. ATtiny817 Xplained Pro GPIO Connections

Silkscreen Text	ATtiny817 GPIO Pin
LED0	PB4
SW0	PB5

The ATtiny817 Xplained Pro design documentation schematic shows the connections for the LED and button, as in the figure below.

Figure 1-24. ATtiny827 Xplained Pro GPIO Connection Schematics



From the schematics, it is concluded that:

- The LED can be turned ON by driving PB4 low
- SW0 is connected directly to GND and to PB5 through a current limiting resistor
- SW0 does not have an external pull-up resistor
- SW0 will be read as '0' when pushed and as '1' when released, if the ATtiny817 internal pull-up is enabled

AVR® Libc

All the references covered to this point are just as relevant for SAM as for AVR, however, as the name suggests, this one is specific to AVR. AVR Libc is a Free Software project whose goal is to provide a high-quality C library for use with GCC on AVR microcontrollers. Together, avr-binutils, avr-gcc, and avr-libc form the heart of the Free Software toolchain for the AVR microcontrollers. Further, they are accompanied by projects for in-system programming software (avrdude), simulation (simulavr), and debugging (avr-gdb, AVaRICE).

The library reference is usually a quick interface into AVR Libc, as shown in Figure 1-25. One can quickly search the page for a relevant library. Relevant header files, which should be added to the project, are indicated in the module name. For example searching for 'interrupts', the relevant include will be #include <avr/interrupt.h>. Clicking into the module, a list of available functions and relevant interrupt callbacks can be found, as shown in Figure 1-26.

Figure 1-25. AVR® Libc Library Reference

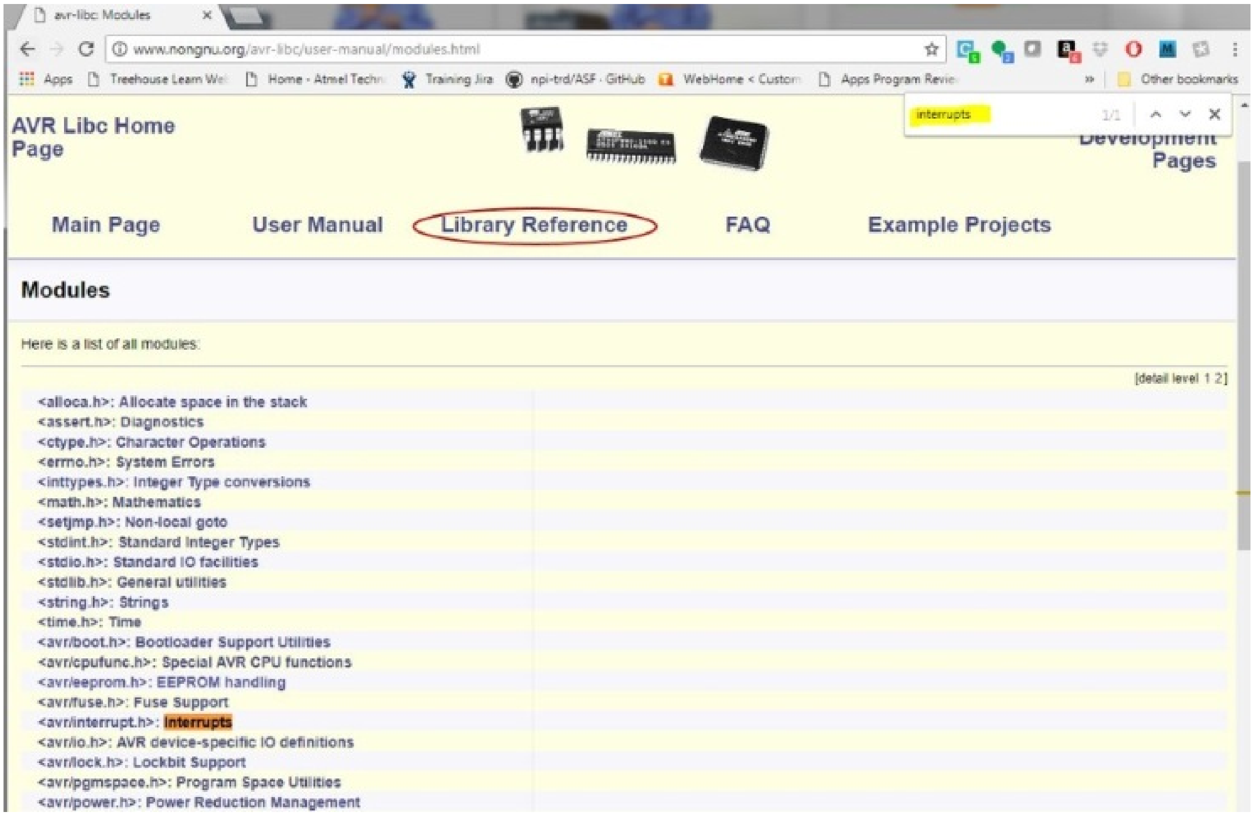
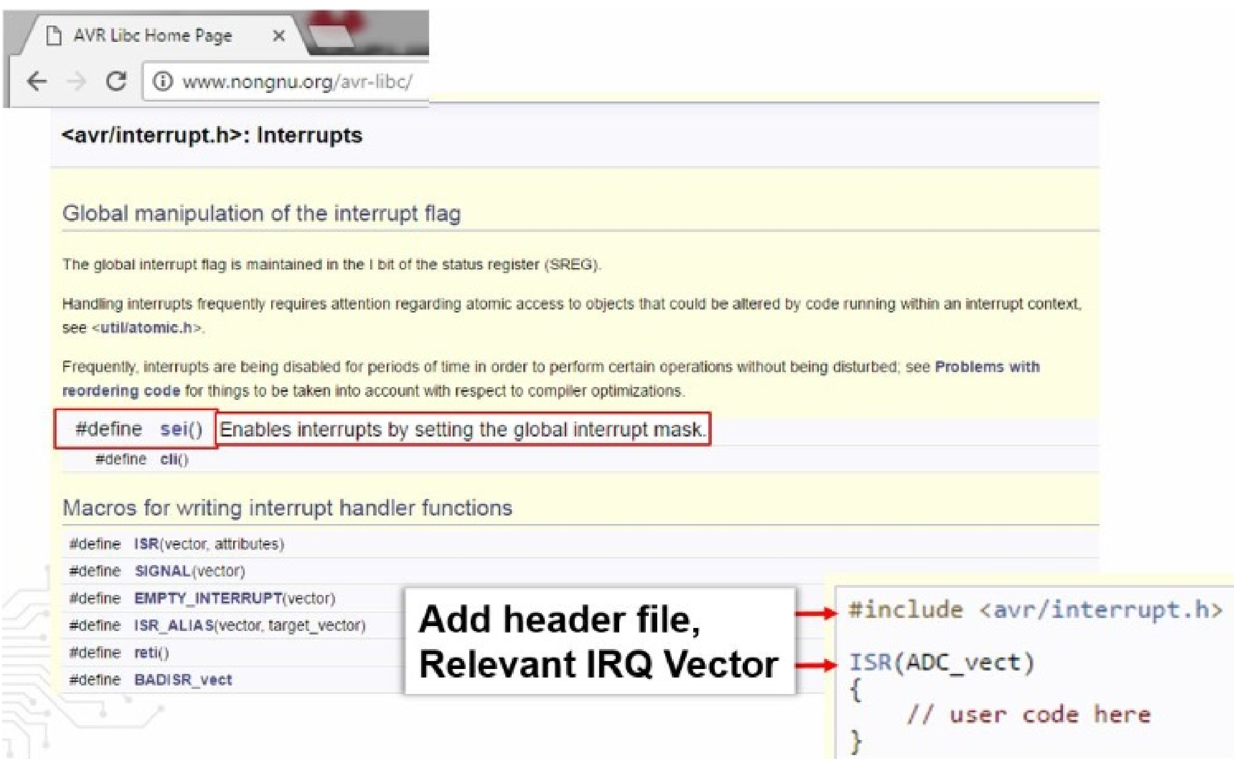


Figure 1-26. Using Interrupts with AVR® Libc



Atmel START

Atmel START is a web-based software configuration tool, for various software frameworks, which helps you getting started with MCU development. Starting from either a new project or an example project, Atmel START allows you to select and configure software components (from **ASF4** and **AVR Code**), such as drivers and middleware to tailor your embedded application in a usable and optimized manner. Once an optimized software configuration is done, you can download the generated code project and open it in the IDE of your choice, including Microchip Studio, MPLAB X, IAR Embedded Workbench, Keil µVision, or simply generate a make-file.

Although Atmel START is a tool for MCU and software configuration, it can still be useful even in bare-metal development, i.e., writing code from scratch using the list of programming references described in this section. Creating a new project for the kit you are using, can be a useful alternative to the board schematic, using the PINMUX view. In addition, the CLOCKS view can be useful to check the default clocks of a device. Furthermore, viewing the configuration code, useful pieces can be pasted back into your project. For example, the AVR Libc delay functions require that the clock frequency is defined, as shown in Figure 1-29. For the ATtiny817 this default value would be: #define F_CPU 3333333.

Figure 1-27. Using START to Creating a New Project for a Relevant Board

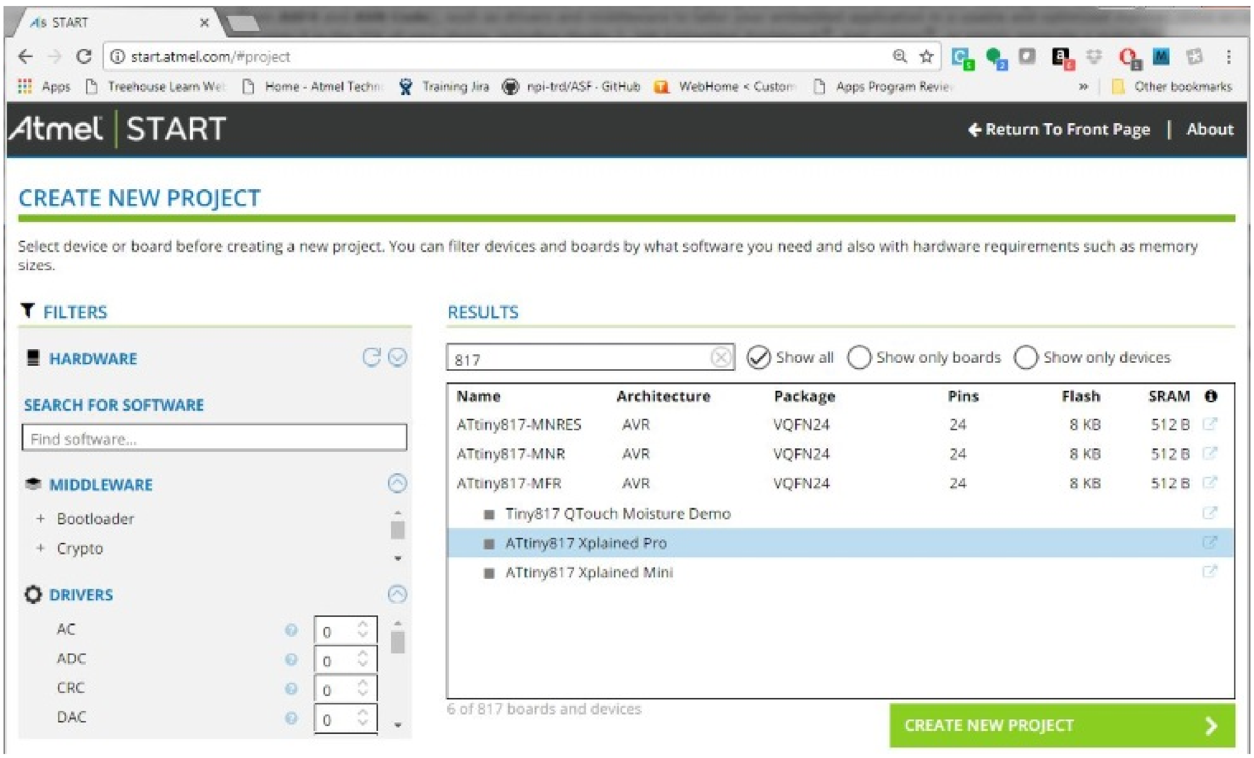


Figure 1-28. Showing Board Labels in START as an Alternative to the Kit Schematic

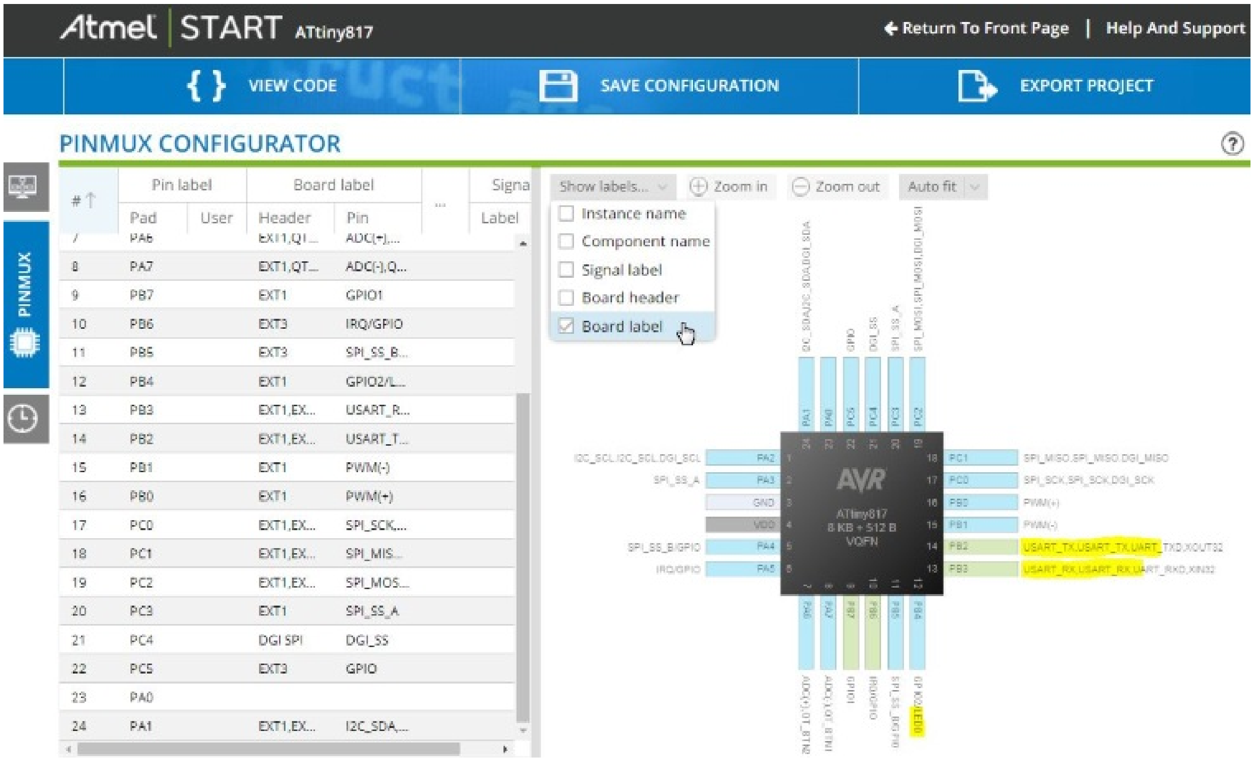
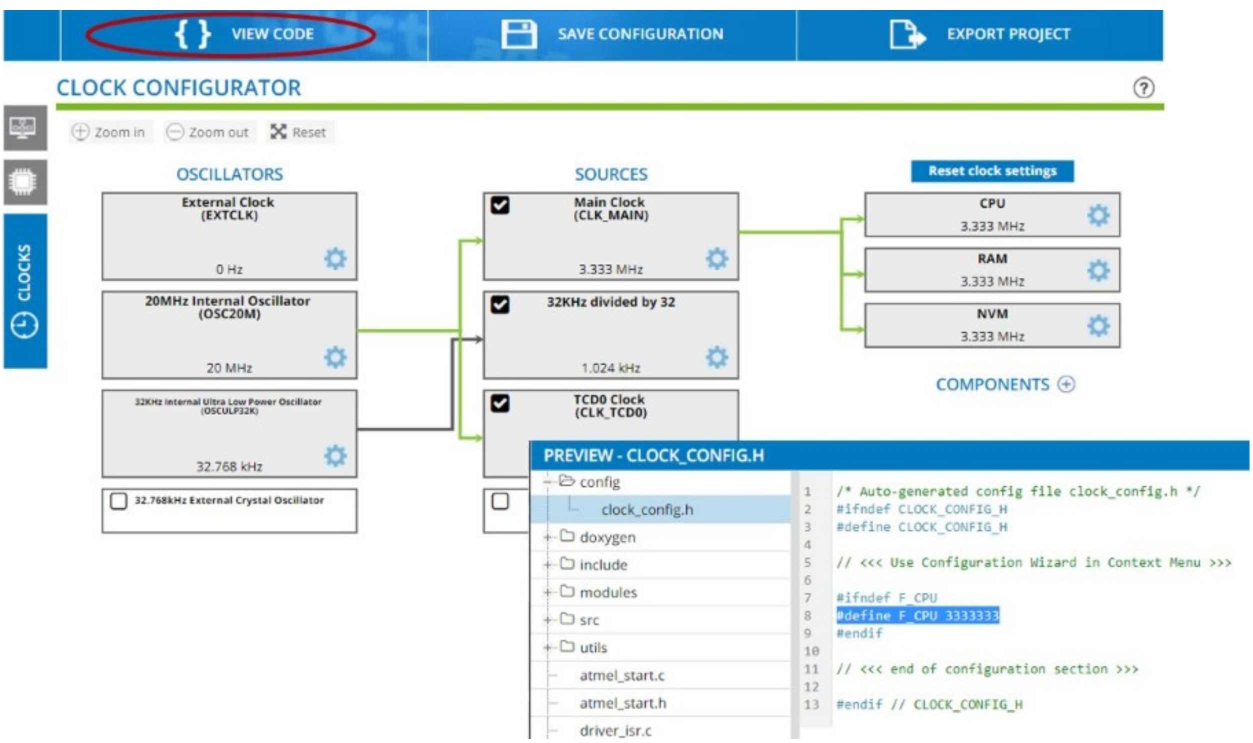


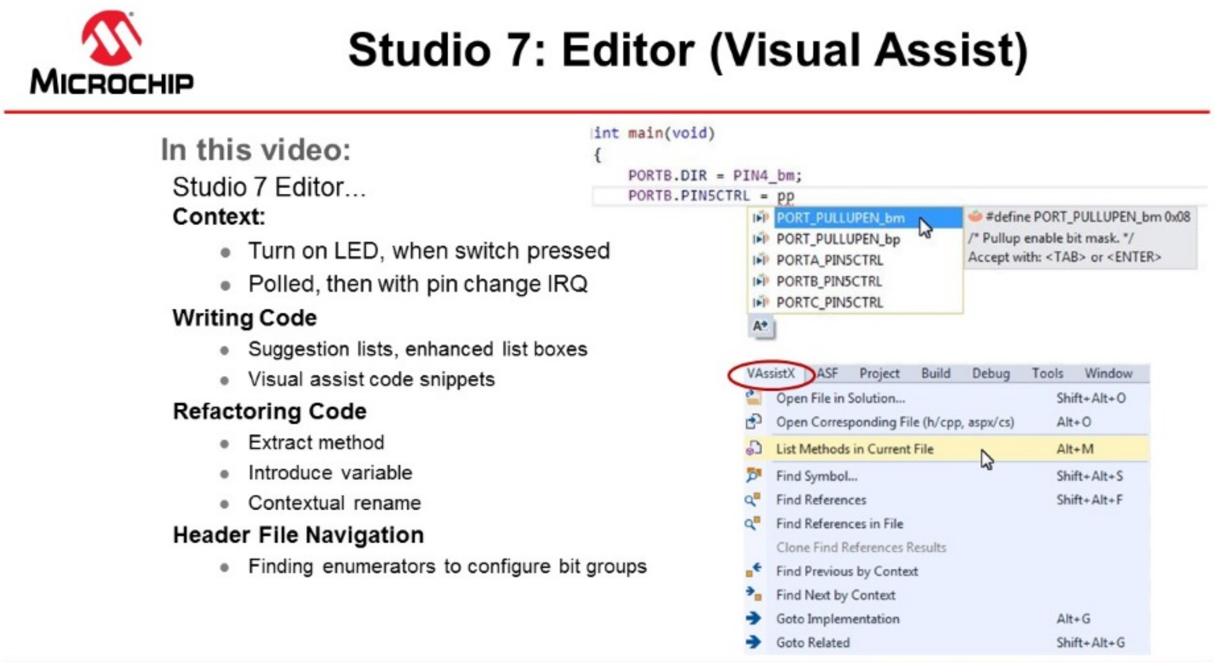
Figure 1-29. Checking Default Clock Configuration and Using VIEW CODE to Find F_CPU Define



1.11 Editor: Writing and Re-Factoring Code (Visual Assist)

The Microchip Studio Editor is powered by an extension called *Visual Assist*, a productivity tool for re-factoring, reading, writing, and navigating C and C++ code.

Getting Started Topics



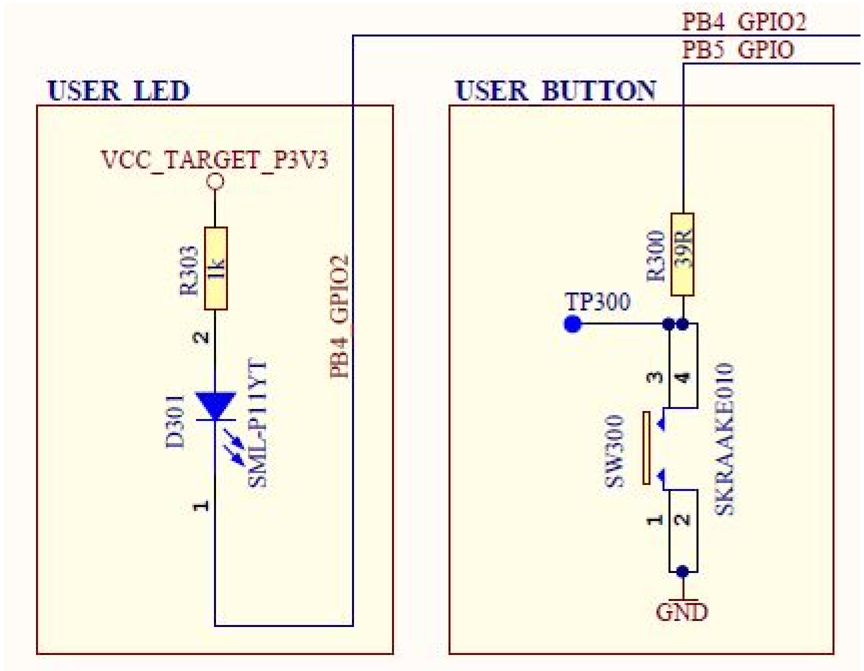
Video: Microchip Studio Editor (Visual Assist)

1. Starting with the basic functionality from 1.10 I/O View and Other Bare-Metal Programming References , main.c has the following code:

```
#include <avr/io.h>

int main(void)
{
    PORTB.DIR = PIN4_bm;

    while (1)
    {
    }
}
```

The ATtiny817 Xplained Pro design documentation schematic shows the connections for the LED and button, as in the figure below.

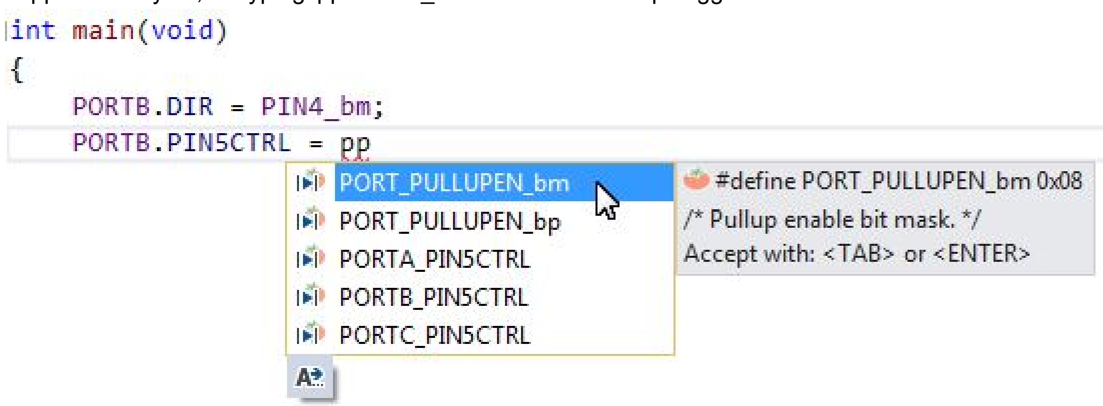
Figure 1-30. ATtiny827 Xplained Pro GPIO Connection Schematics



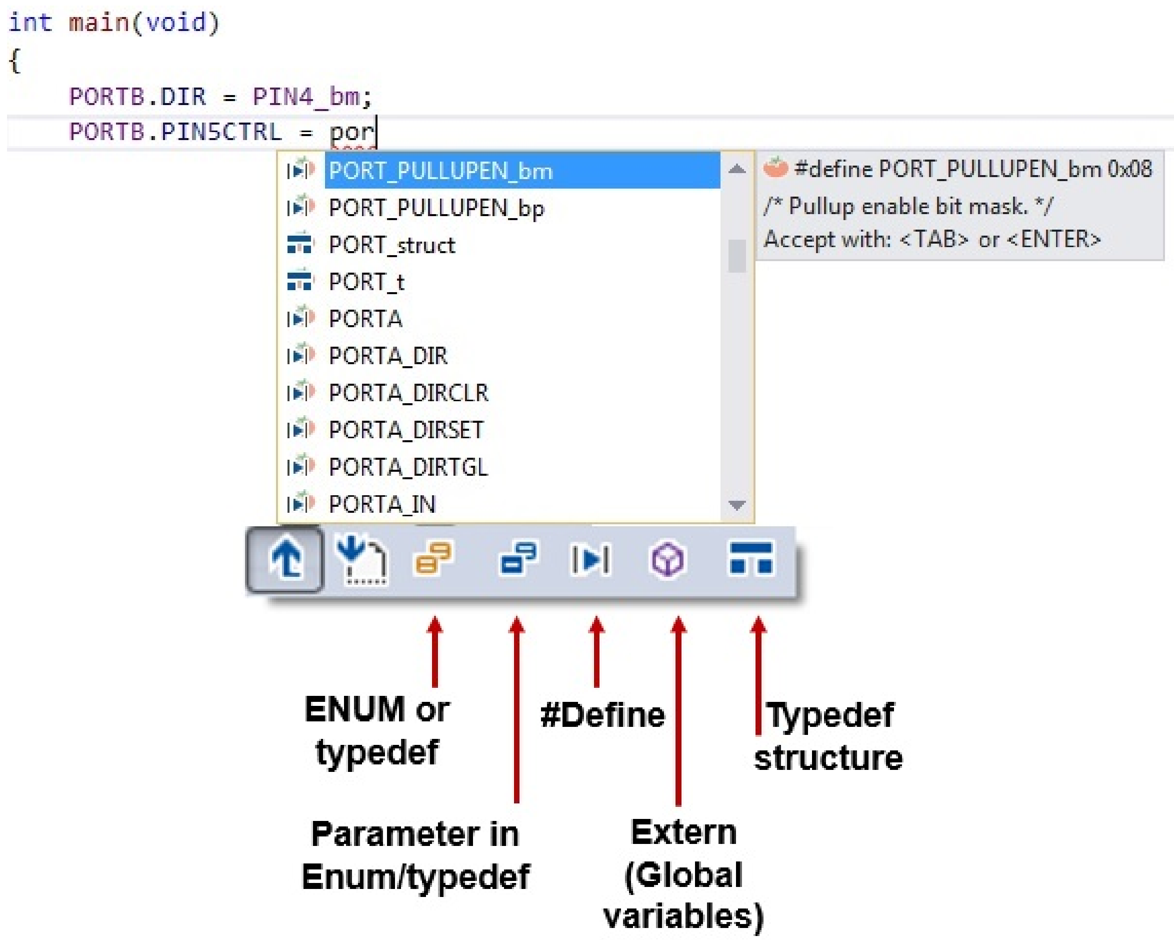
From the schematics, it is concluded that:

- The LED can be turned ON by driving PB4 low.
- SW0 is connected directly to GND and to PB5 through a current limiting resistor.
- SW0 does not have an external pull-up resistor.
- SW0 will be read as '0' when pushed and as '1' when released, if the ATtiny817 internal pull-up is enabled.

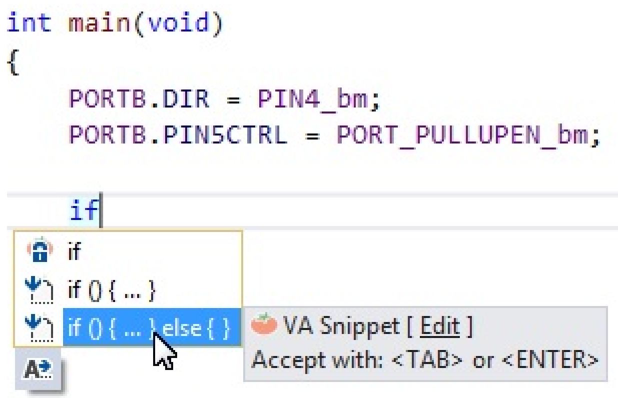
1. Enable the pull-up on PORTB5, **using suggestion list** and **enhanced list box**. Note that suggestion lists support acronyms, so typing 'pp' PORT_PULLUPEN is the top suggestion.

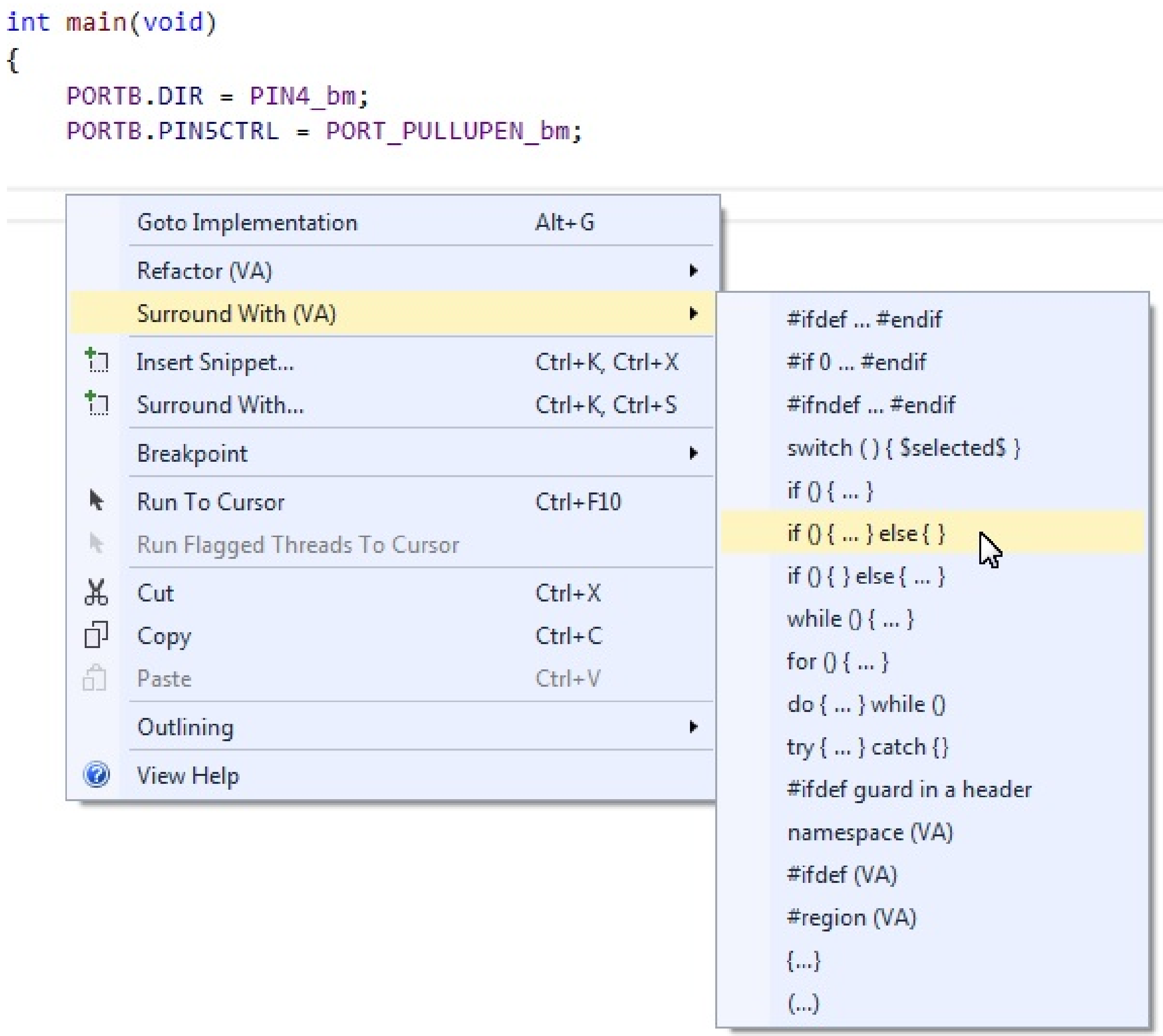


2. However, before hitting enter, first type 'POR', then hit CTRL+SPACE. This will bring up the Enhanced Listbox with all possible options.
   Now it is possible to filter suggestions by type, as indicated in the picture below.



3. Test if SW0 is pressed, using **if( ){...}else{...} visual assist code snippet.**
   Simply typing 'if' will bring up the option. Or, you could *R-click* and choose **Surround With (VA)**, which gives a full list of snippets. This is an editable list, so you can add your own snippets.





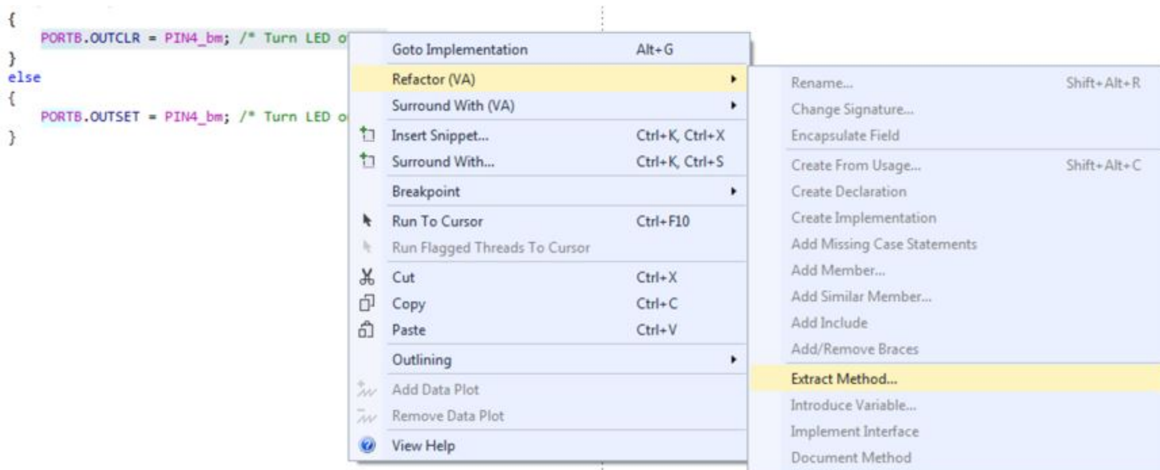
4. Test if the switch is pressed, as the **if( ){...}else{...}** condition, turn the LED ON if pressed and OFF if not. *main.c* should now look as follows:

```
#include<avr/io.h>

int main(void)
{
    PORTB.DIRSET   = PIN4_bm;            /* Configure LED Pin as output */
    PORTB.PIN5CTRL = PORT_PULLUPEN_bm; /* Enable pull-up for SW0 pin  */
```

```
        while(1)
        {
            if (!(PORTB.IN & PIN5_bm)) /* Check switch state */
            {
                PORTB.OUTCLR = PIN4_bm; /* Turn LED off */
            }
            else
            {
                PORTB.OUTSET = PIN4_bm; /* Turn LED on  */
            }
        }
    }
```

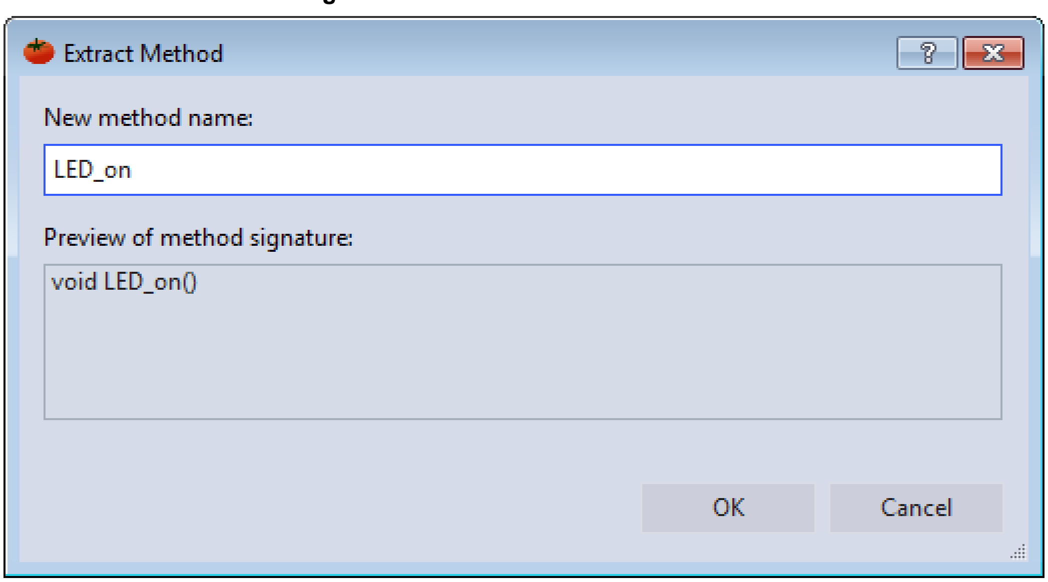
5. **Verify that LED0 lights up when pushing SW0**. Run the code by clicking *Start Without Debugging* (Ctrl +Alt+F5), to verify that LED0 lights up when pushing SW0 on the ATtiny817 Xplained Pro kit.
   Now that the basic functionality is in place, let's refactor the code to make it more readable.
6. **Create functions LED_on( ) and LED_off( ) using Refactor → Extract Method** The line of code to turn the LED ON is executed when SW0 is pressed. Highlight this line of code, right-click and go to it, as indicated in the figure below.

Figure 1-31. Extract Method



A **Extract Method** dialog will appear. Name the function 'LED_on', as indicated in the following figure.

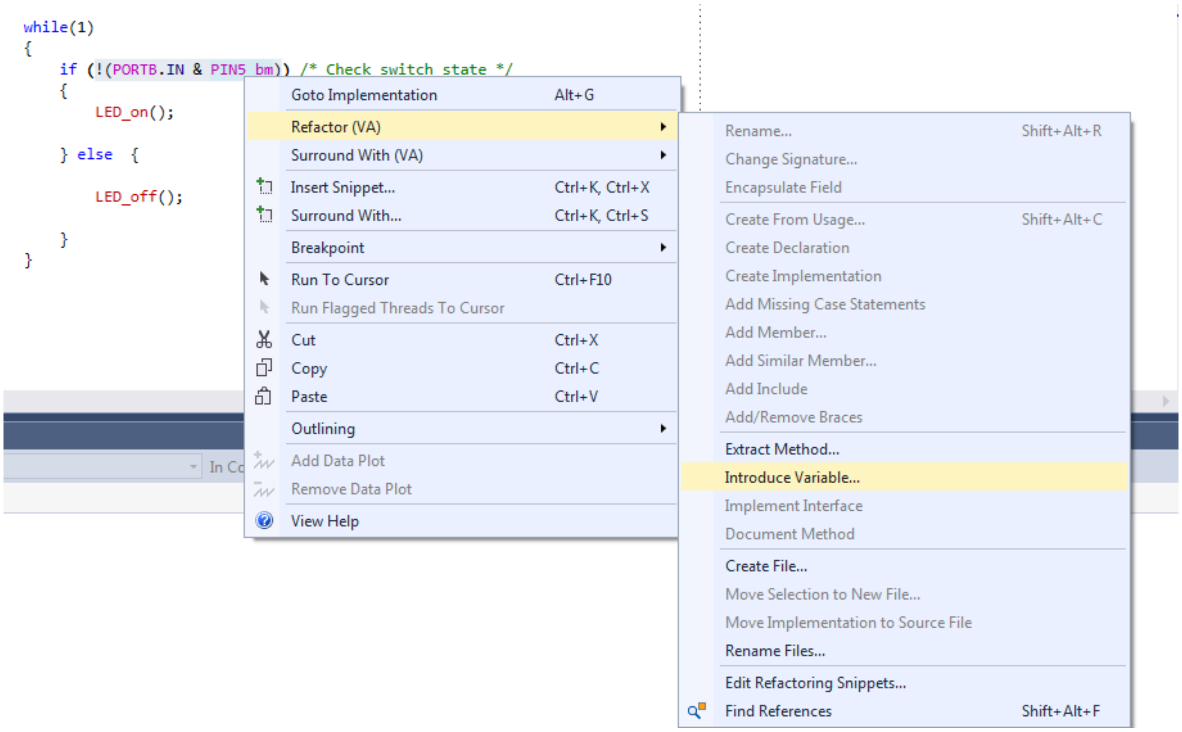
Figure 1-32. Extract Method Dialog



Click **OK**, and the code should change. A new function called `LED_on()` should appear at the top of the file, with a function call where the line of code used to be. Use the same method to implement `LED_off()`.

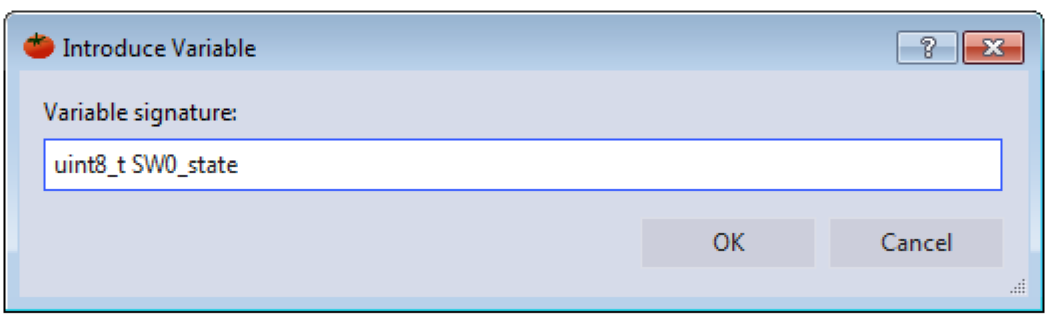
7. **Create a variable for SW0 state, using Refactor → Introduce Variable**. Next, it is necessary to create a variable for the SW0 state. Highlight the condition inside the `if()` in the `main()` `while(1)` loop. Right-click and go to it, as indicated in the figure below.

Figure 1-33. Introduce Variable



The **Introduce Variable** dialog will appear, as depicted in Figure 1-34. Name the variable 'uint8_t SW0_state'.

Figure 1-34. Introduce Variable Dialog



Tip: Change the automatically generated `bool` return value to `uint8_t` to avoid having to include an extra header to deal with Boolean values.

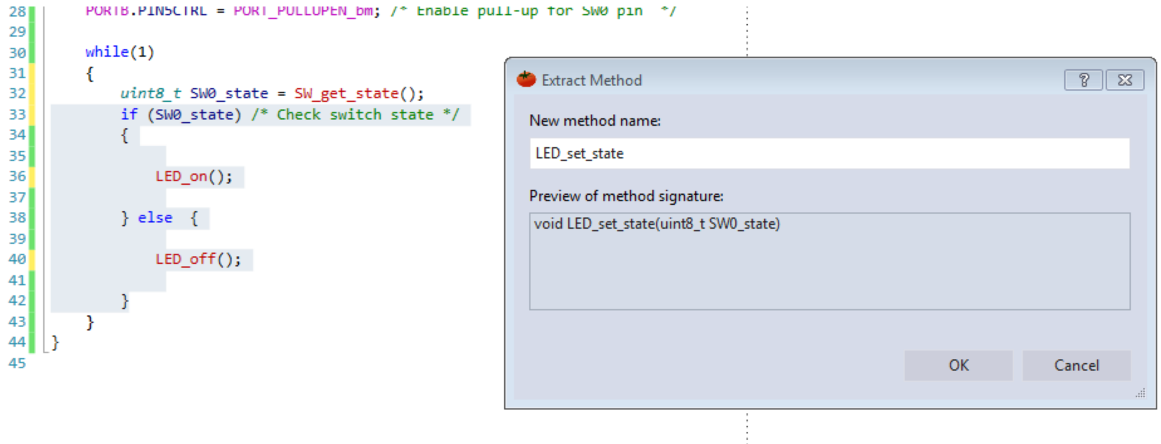
Click **OK** and the code should change. The condition inside the `if()` statement should now reference a variable assigned to the variable on the line above it, as shown in the code block below.

```
while (1)
{
uint8_t SW0_state = !(PORTB.IN & PIN5_bm);
    if (SW0_state)
    {
        LED_on();
    }
    else
    {
```

```
            LED_off();
        }
    }
```

8. **Create a function `SW_get_state`, using Refactor → Extract Method.** Select the right side of the `SW0_state` assignment and extract a method for `SW_get_state`.
9. **Implement a function `void LED_set_state(uint8_t state)`**. Extract the method. Microchip Studio will detect the argument `SW0_state`, as indicated in Figure 1-35.

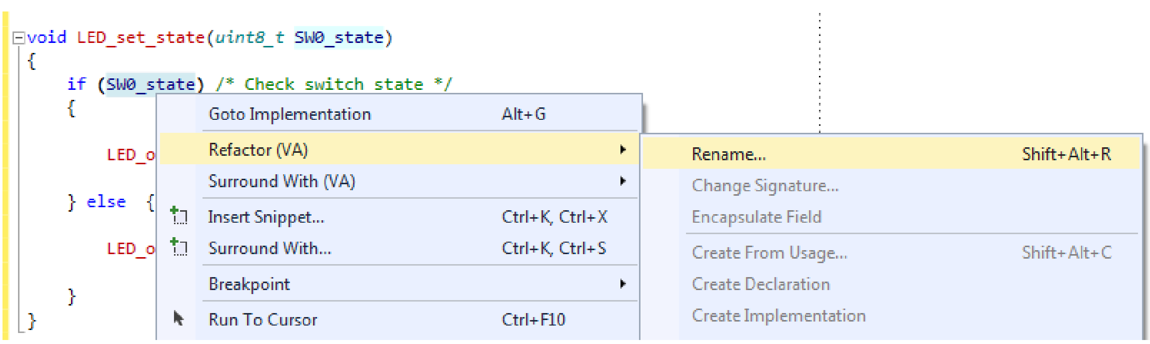
Figure 1-35. Extract Method with Argument



Click **OK** and the code should change. Now, there is a separate method for setting the LED state.

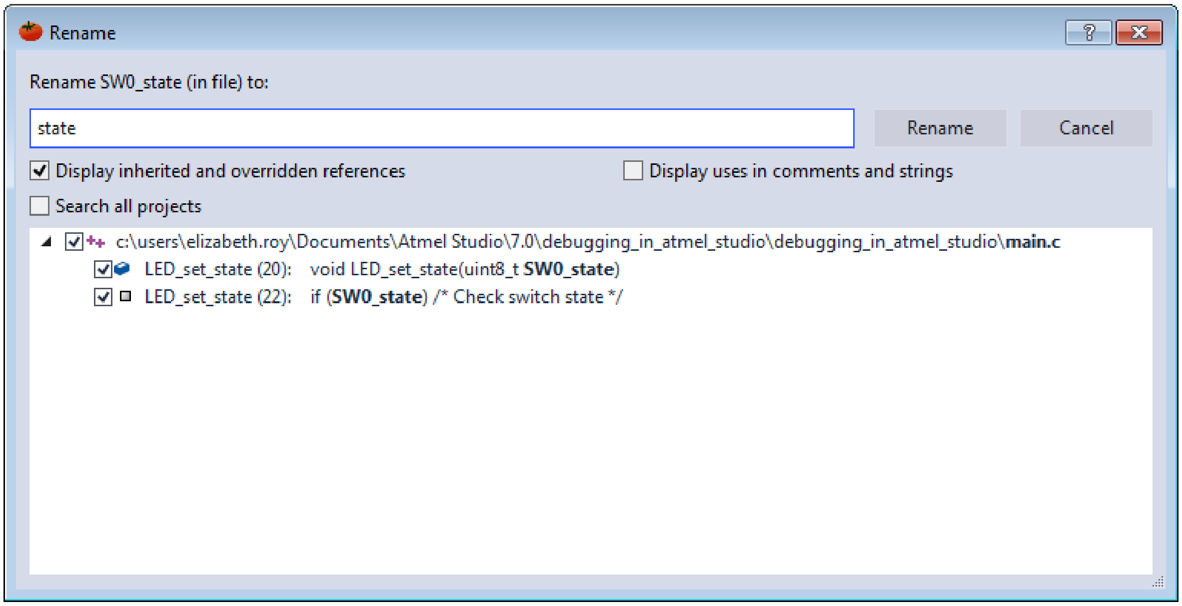
10. **In function *void LED_set_state(uint8_t state)* rename SW0_state to state using Refactor → Rename**. In a larger application, this function may be used for setting the LED state in a context that is irrelevant to the SW0 state. Microchip Studio is capable of contextual renaming, so this feature can be used to easily rename the argument and avoid confusion. Inside the `LED_set_state()` function, right-click on the `SW0_state` variable and go to **Refactor → Rename**, as indicated in Figure 1-36.

Figure 1-36. Contextual Rename



The **Rename** dialog will appear, as depicted in Figure 1-37. Rename the `SW0_state` variable to 'state'. Microchip Studio will detect all occurrences of the variable with the same context as the one which has been selected, and which are presented in a list and able to be individually selected or deselected.

Figure 1-37. Contextual Renaming Dialog



Click **Rename** and the code should change. Observe that the argument of `LED_set_state()` and all of its references inside the function have been renamed, but the references to `SW0_state` in `main()` have remained the same.

11. Create function definitions, moving created functions below `main()`.
main.c should now look as follows:

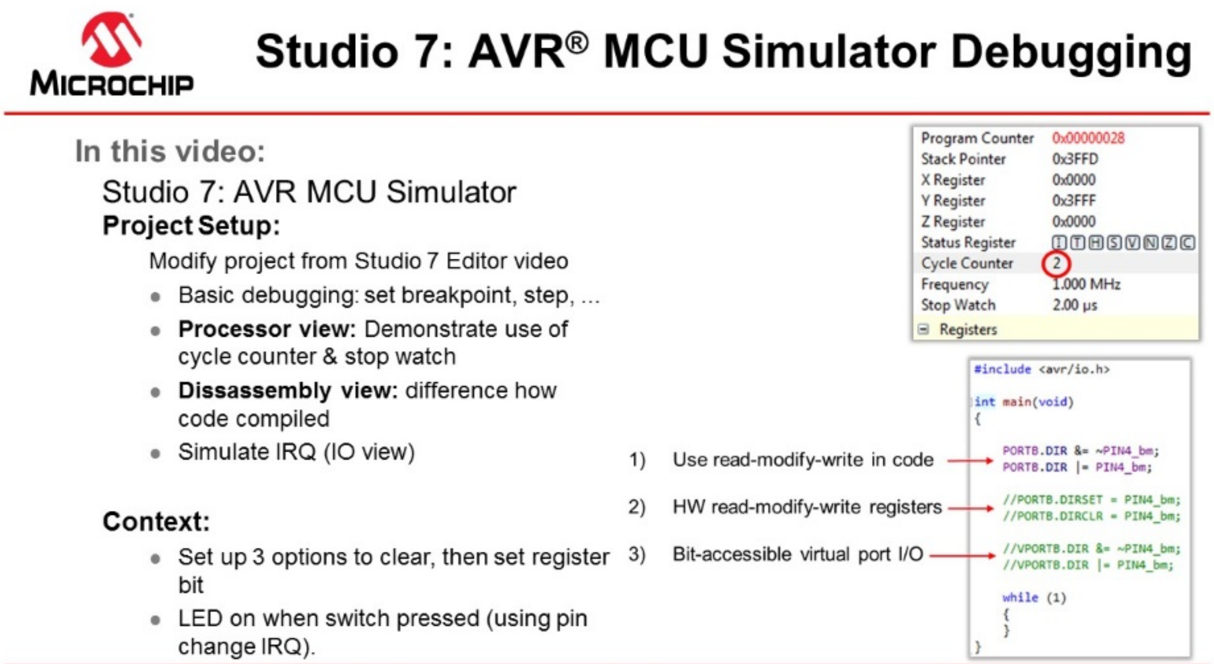
```
#include <avr/io.h>

void LED_on(void);
void LED_off(void);
void LED_set_state(uint8_t state);
uint8_t SW_get_state(void);


int main(void)
{
    PORTB.DIRSET    = PIN4_bm;           /* Configure LED Pin as output */
    PORTB.PIN5CTRL = PORT_PULLUPEN_bm; /* Enable pull-up for SW0 pin   */

    while(1)
    {
        uint8_t SW0_state = SW_get_state(); /* Read switch state */
        LED_set_state(SW0_state);           /* Set LED state     */
    }
}

uint8_t SW_get_state(void)
{
    return !(PORTB.IN & PIN5_bm); /* Read switch state */
}

void LED_off(void)
{
    PORTB.OUTSET = PIN4_bm; /* Turn LED off  */
}

void LED_on(void)
{
    PORTB.OUTCLR = PIN4_bm; /* Turn LED on */
}

void LED_set_state(uint8_t state)
{
    if (state)
    {
```

```
            LED_on();
        }
        else
        {
            LED_off();
        }
}
```

1.12 AVR® Simulator Debugging

This section will demonstrate the use of the AVR Simulator key features, such as: Cycle Counter, Stopwatch (only available in the simulator), and basic debugging (setting breakpoints and stepping through code). We will also show how to simulate interrupts.

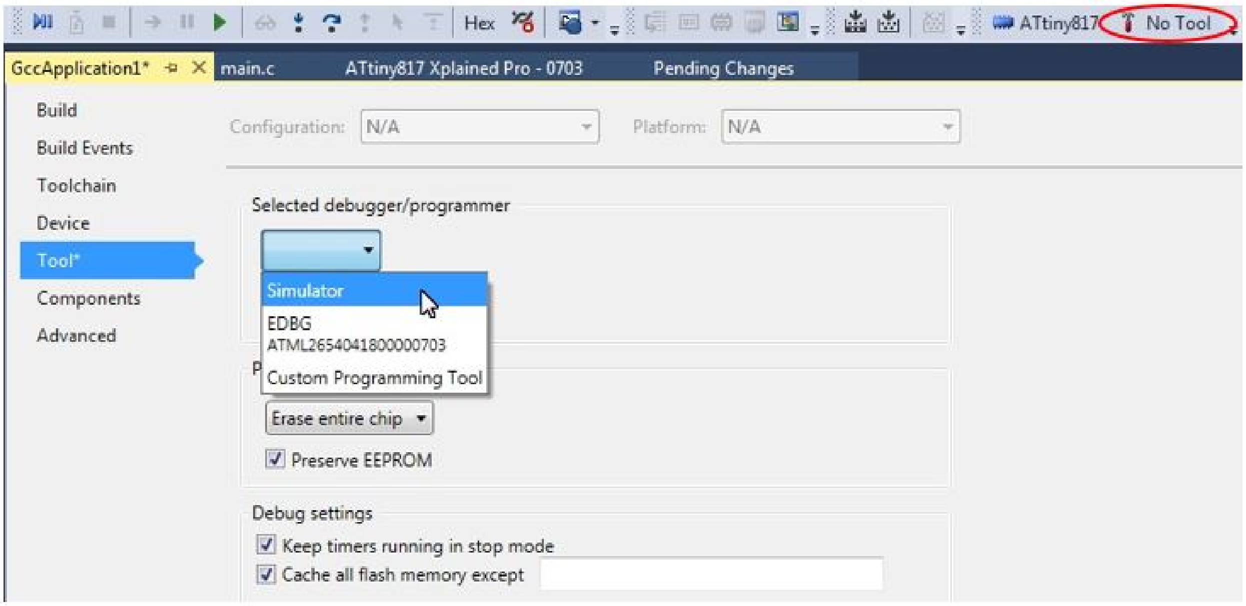
Getting Started Topics



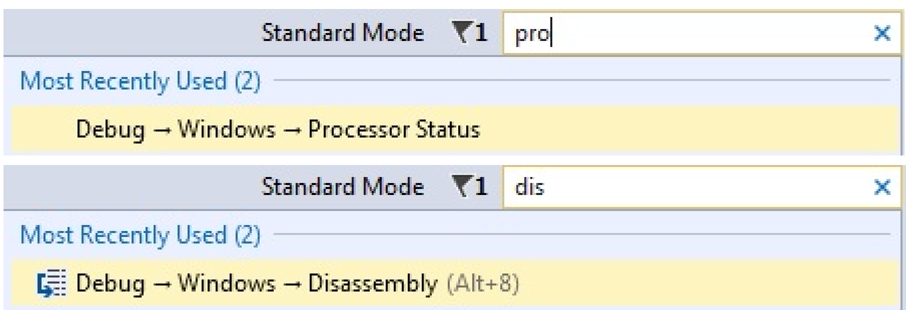
Video: AVR Simulator Debugging

The code used in the video above was written in the video: 1.11 Editor: Writing and Re-Factoring Code (Visual Assist).

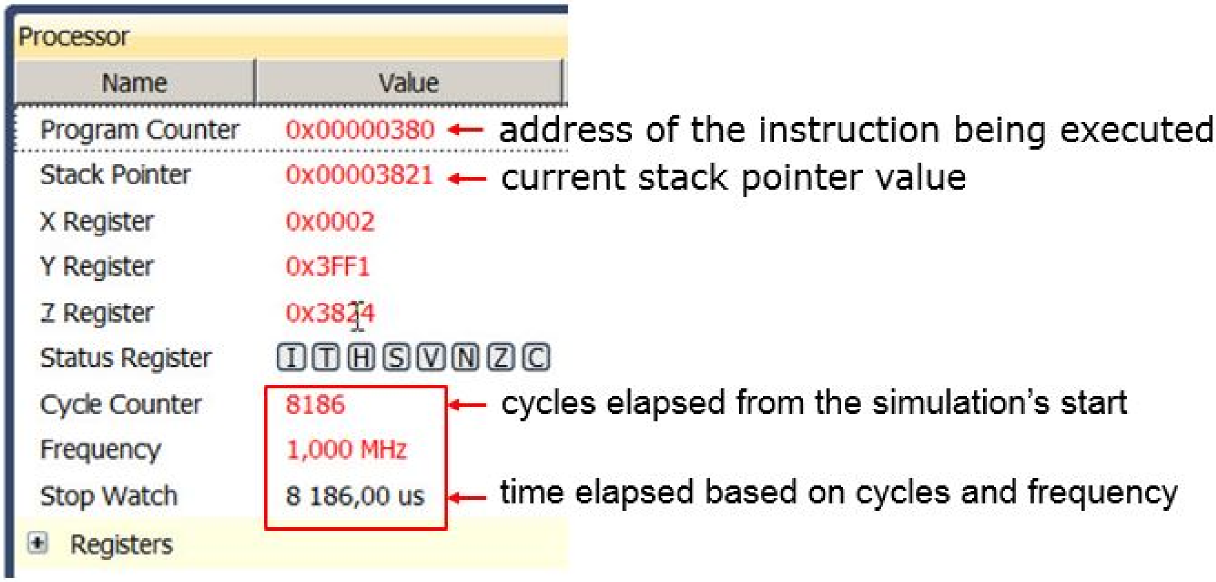
To associate the simulator with the project, click on the Tool icon , then select Simulator.



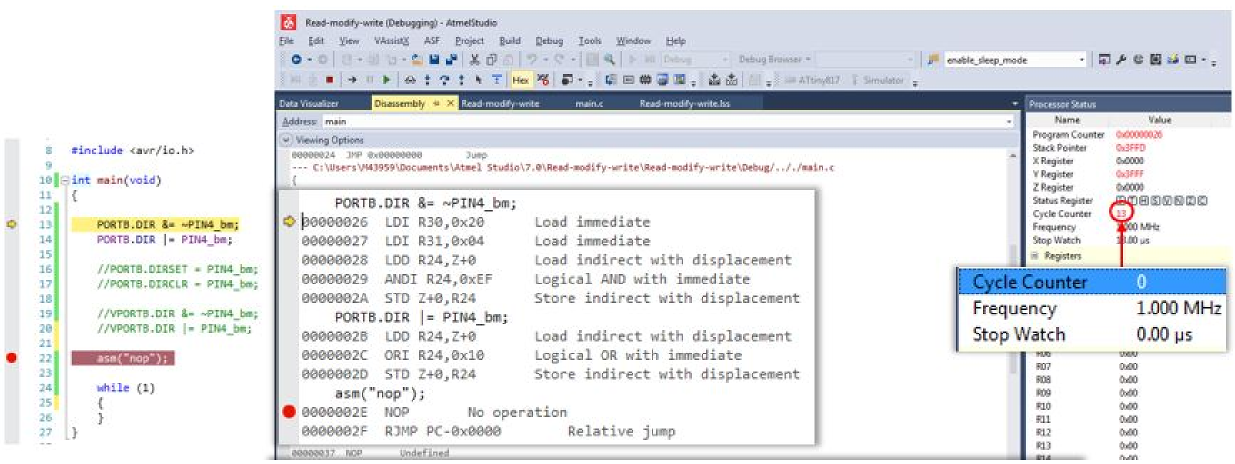
The **Cycle Counter** and **Stopwatch** is only available with the simulator. To use these, first, click *Start Debugging and Break* to start a debug session and then open the **Processor Status** window by typing 'Processor' into the quick-launch bar and hitting enter (or this can be found under Debug > Windows > Processor Status). Similarly, the **Disassembly** window can also be opened.



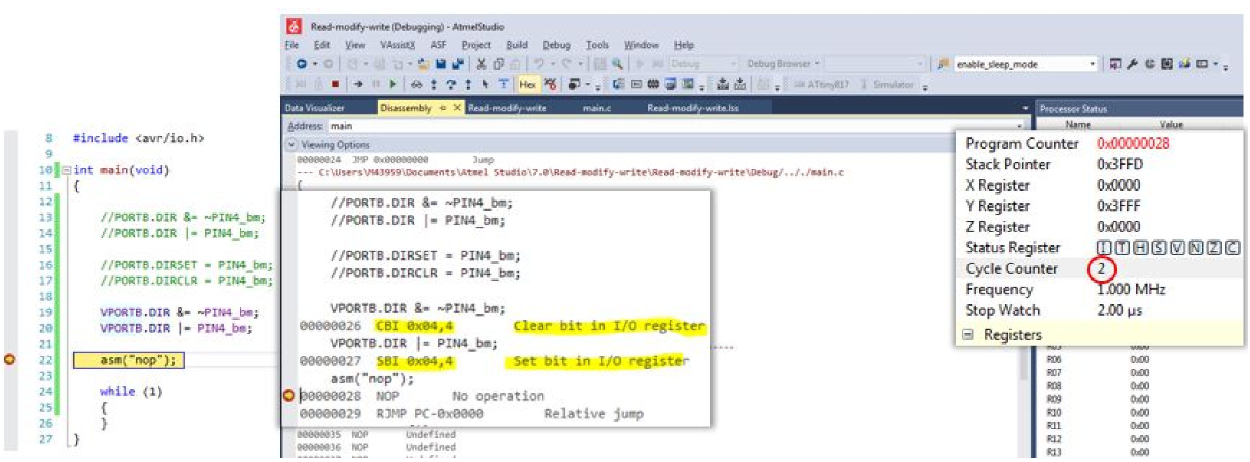
The AVR Simulator is using models based on the same RTL code used to make the real device. This makes the **Cycle Counter** both bug and delay accurately. Note that the **Stop Watch** is related to the **Frequency**, which you can set by double-clicking on the value and entering the clock frequency you would like to use.



The **Cycle Counter** can be reset by clicking on the value and entering 0. Values in the Processor Status window are updated every time the program breaks, similar to the I/O view. Then running to a breakpoint.



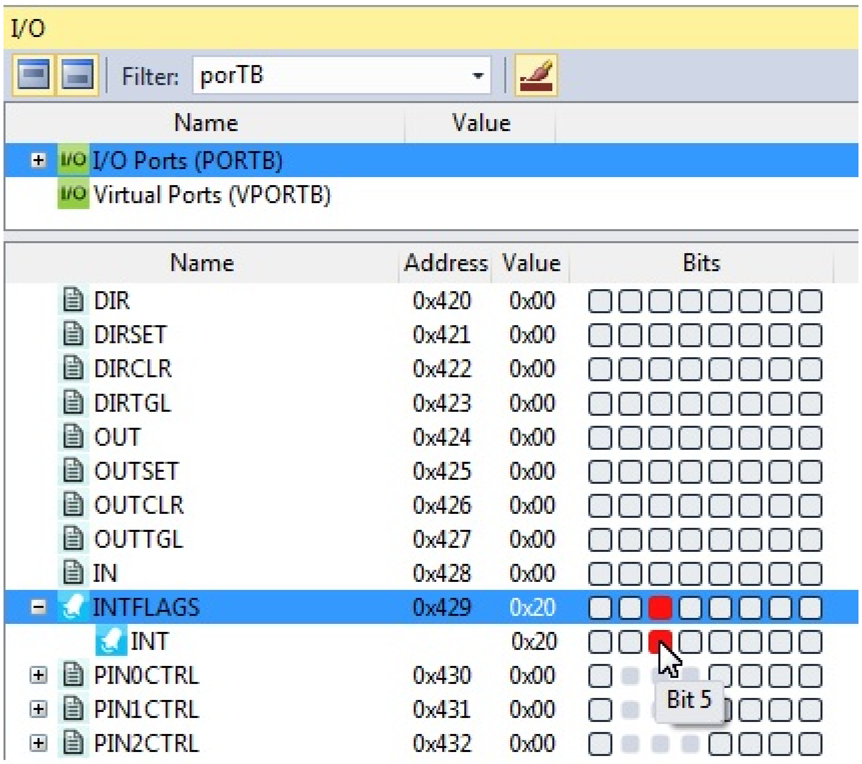
Note the difference in generated assembly code between the SW read-modify-write (above) and the virtual port registers (see below).



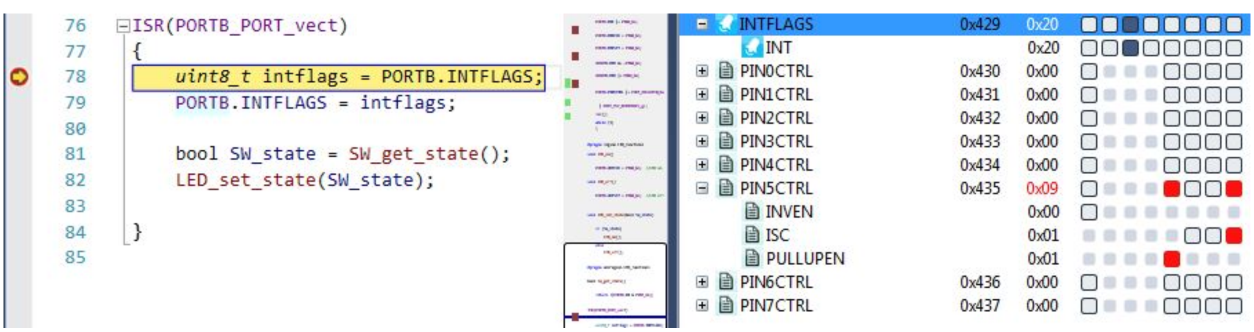
The result of comparing these three methods are summarized in the table below:

Method	Cycles	Comments
SW read-modify-write	10	
HW read-modify-write reg.	5	Atomic instruction (IRQ safe)
Bit-accessible virtual port I/O	2	Atomic instruction (IRQ safe), really fast

Next, we would like to simulate a pin change IRQ. We can do this by setting the relevant IRQ flag in the I/O view when debugging.



As shown below the ISR is hit. Note that the INTERRUPT still needs to be enabled, as shown in the write to PORTB.PIN5CTRL in the code below.



The pin change IRQ could also have been triggered by writing to the Port Input register in the I/O view. Writing a bit in the Port Input register is the same as applying that value to the physical pin of the device package. The internal Port logic will then trigger the interrupt if it is configured accordingly.

Most of the standard debugging features of **Microchip Studio** are available when using the simulator, and those features will also be available on devices that lack on-chip debugging capabilities and cannot be debugged using hardware debuggers. See the debugging sections of this Getting Started guide.

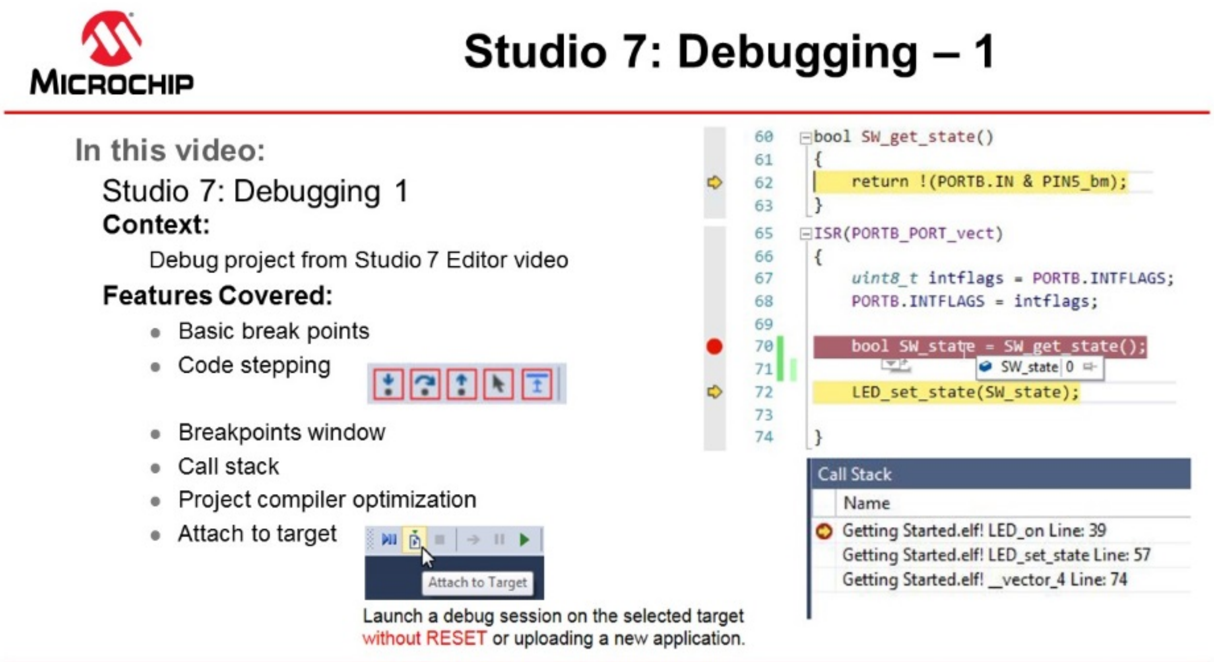
Code Used to Demonstrate AVR® Simulator (Written for ATtiny187)

```
#include <avr/io.h>
#include <stdbool.h>
#include <avr/interrupt.h>

void LED_on();
void LED_off();
bool SW_get_state();
void LED_set_state(bool SW_state);

int main(void)
{
    PORTB.DIR &= ~PIN4_bm;
    PORTB.DIR |= PIN4_bm;

    PORTB.DIRCLR = PIN4_bm;
       PORTB.DIRSET = PIN4_bm;

       VPORTB.DIR &= ~PIN4_bm;
       VPORTB.DIR |= PIN4_bm;

    PORTB.PIN5CTRL |= PORT_PULLUPEN_bm | PORT_ISC_BOTHEDGES_gc;
    sei();

    while (1)
    {
    }
}

#pragma region LED_functions
void LED_on()
{
    PORTB.OUTCLR = PIN4_bm;  //LED on
}

void LED_off()
{
    PORTB.OUTSET = PIN4_bm;  //LED off
}

void LED_set_state(bool SW_state)
{
    if (SW_state)
    {
        LED_on();

    }
    else
    {
        LED_off();

    }
}
#pragma endregion LED_functions

bool SW_get_state()
{
    return !(PORTB.IN & PIN5_bm);
}

ISR(PORTB_PORT_vect)
{
    uint8_t intflags = PORTB.INTFLAGS;
    PORTB.INTFLAGS = intflags;

    bool SW_state = SW_get_state();
    LED_set_state(SW_state);

}
```

1.13 Debugging 1: Break Points, Stepping, and Call Stack

This section will introduce the debugging capabilities of Microchip Studio, both as video (linked below) and hands-on document. The main topics are breakpoints, basic code stepping using the Breakpoint, and Callstack-Windows, as well as adjusting project compiler optimization settings.

Getting Started Topics



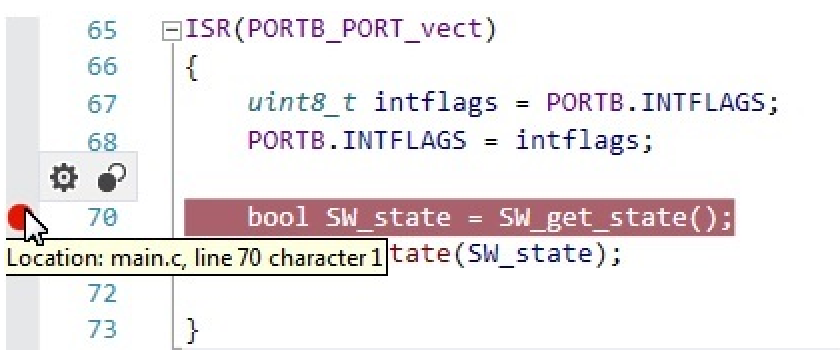
Video: Microchip Studio Debugging-1

The same code as the one created in section 1.11 Editor: Writing and Re-Factoring Code (Visual Assist), is used.

To do: Place a breakpoint and inspect a list of all breakpoints in the project.

1. Set a breakpoint on the line getting the switch state, as indicated in Figure 1-38.

Figure 1-38. Placing a Breakpoint



Info: A breakpoint can be placed at a line of code by:

- Clicking the gray bar on the left edge of the editor window.
- In the top menu bar, go to **Debug** → **Toggle Breakpoint**.
- By pressing F9 on the keyboard.

2. Launch a debug session . The breakpoint will be hit when the switch (SW0) on the Xplained Pro kit is pressed. Observe that execution is halted when the breakpoint is hit, and the execution arrow indicates that the line of code where the breakpoint is placed is about to execute. See Figure 1-39.

Figure 1-39. Execution Halting when a Breakpoint is Hit

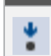
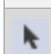
```
ISR(PORTB_PORT_vect)
{
    uint8_t intflags = PORTB.INTFLAGS;
    PORTB.INTFLAGS = intflags;

    bool SW_state = SW_get_state();
    LED_set_state(SW_state);

}
```

Tip: If a breakpoint is hit in a file that is not currently open, Microchip Studio will open the file in a temporary pane. A file containing a breakpoint that is hit in a debug session will always be brought to focus.

3. Since most of the logic of the program is handled only when an ISR is processed, it is now possible to check the logical flow of the program. If the switch is pressed and then released when the ISR is hit - what will be the state of the switch that the function returns? The assumption is that since pressing the switch triggered the interrupt, that switch will be set as *pressed*, and the LED will thus be turned ON.
Code stepping can be used to check this assumption. The key buttons used for code stepping are illustrated in the table below, found in the top menu bar or in the **Debug** menu. The corresponding functionality and keyboard shortcuts are outlined in the figure below.

Figure 1-40. Microchip Studio Buttons for Code Stepping

Table 1-4. Microchip Studio Button Functionality (Code Stepping)

Button	Functionality	Keyboard Shortcut
	Step Into Function Call	F11
	Step Over	F10
	Step Out of Function Call	Shift + F11
	Run to Cursor	Ctrl + F10
	Issue System Reset	

To do: Find out what state is returned if the switch is pressed and then released when the ISR is hit. Is our assumption correct that since pressing the switch triggered the interrupt, it will be set as *pressed*, and the LED will thus be turned ON?

The *Step Into Function Call* can be used first. To go into the SW_get_state( ) function, the *Step Out of Function Call* can be used to move to the next line after returning from the function. Pressing *Step Over* from the breakpoint would land us at this same point directly. Note that we could step further into the function *LED_set_state(SW_state)* to determine if the LED is turned ON or not. However, we could simply hover the mouse pointer over the *SW_state* variable to see that it is now set to 0, i.e. the LED will be turned OFF. Verify this by stepping further.

Figure 1-41. Checking Value of *SW_state* Using Mouse Hover

Info: Although the breakpoint was triggered by the falling edge by pressing the switch, only when calling the *SW_get_state( )* function the switch state is recorded. Verify that *SW_state* will read 1 if the switch is held down when stepping over this line.

1. A window or view to keep track of the breakpoints in a program is needed. The Quick Launch bar performs a search of the Microchip Studio user interface menus. This is demonstrated below, by comparing the two figures Figure 1-42 and Figure 1-43. Note that each of the hits in the Quick Launch bar is from '*break*' related entries in the *Debug* menu.

Figure 1-42. 'Break' Search in the Quick Launch Bar

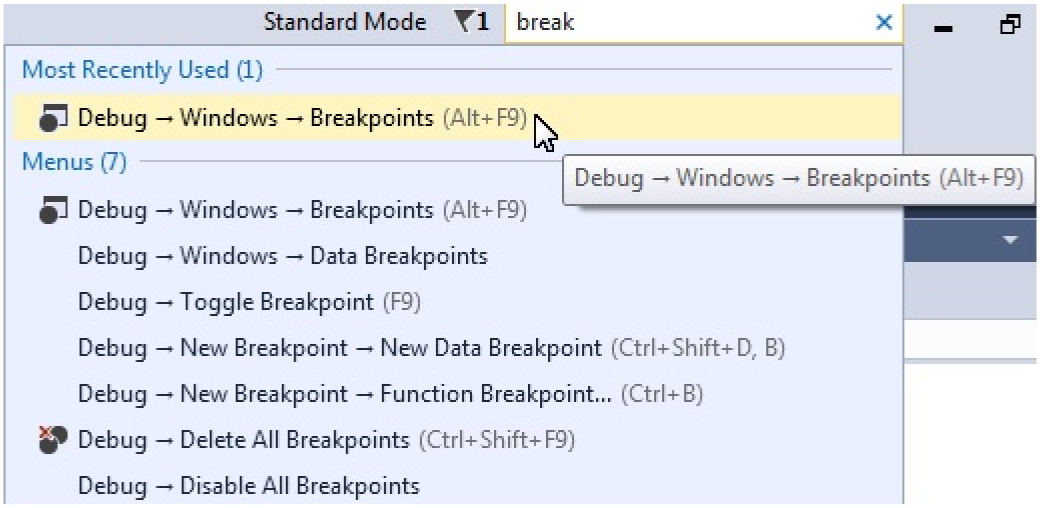
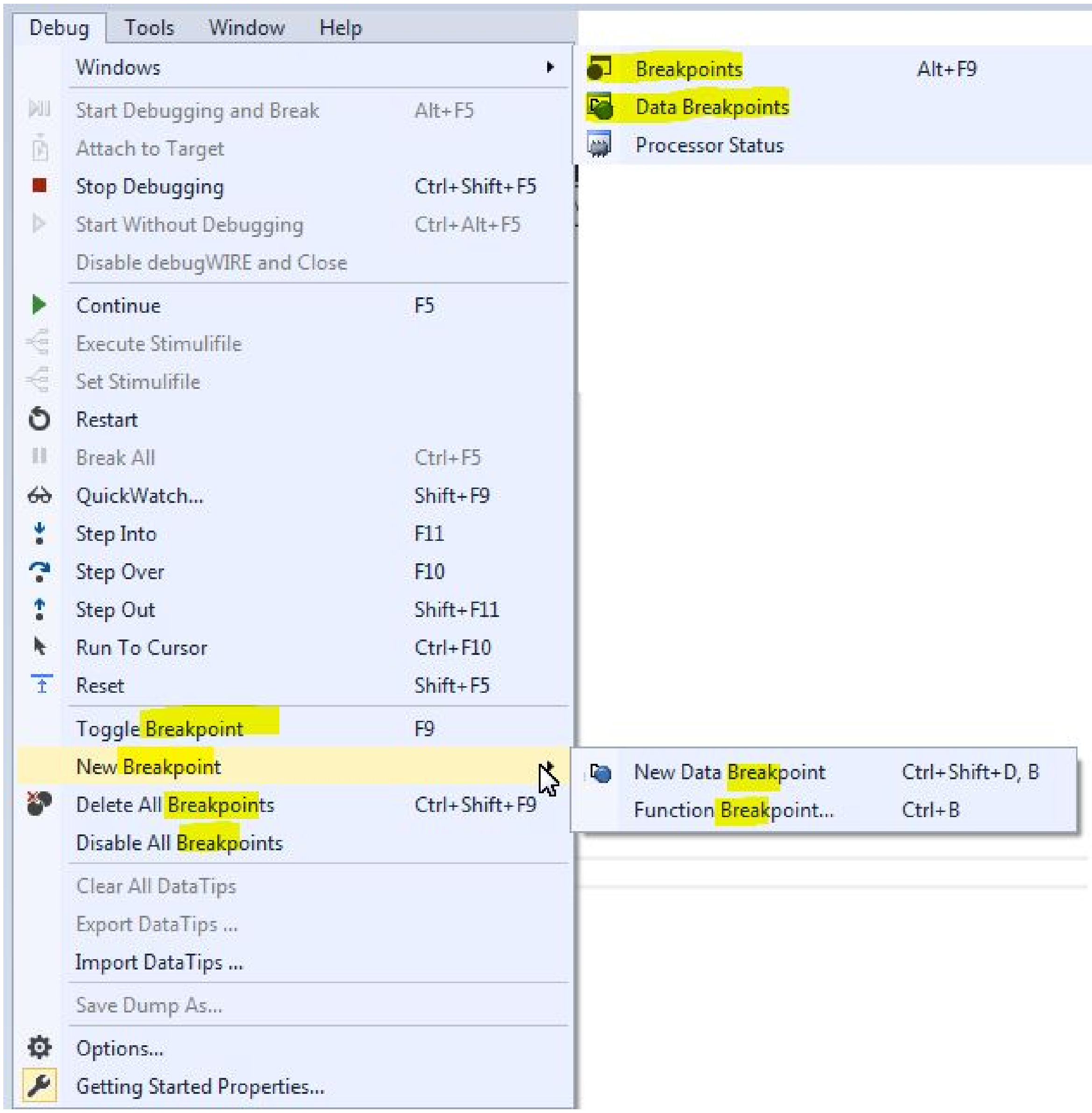


Figure 1-43. 'Break' Hits in Debug Menu



Open the Breakpoints Window by clicking on the top result (**Debug** → **Windows** → **Breakpoints**). The Breakpoints Window lists all the breakpoints in the project, along with the current hit count, as depicted in Figure 1-44.

Tip: A breakpoint can temporarily be disabled by unchecking the checkbox next to a breakpoint in the list.

Tip: The Disassembly view can be conveniently displayed alongside the source code, as demonstrated in the Figure 1-45 section.

Figure 1-44. Breakpoints Window

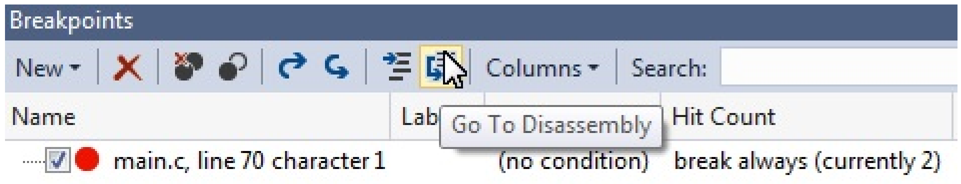
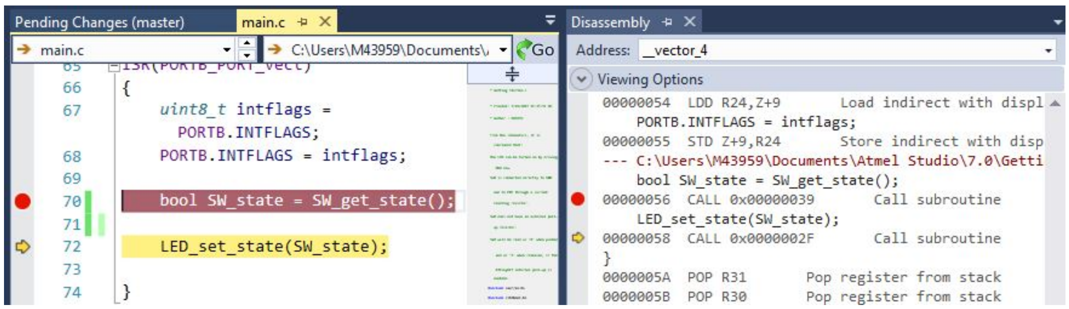


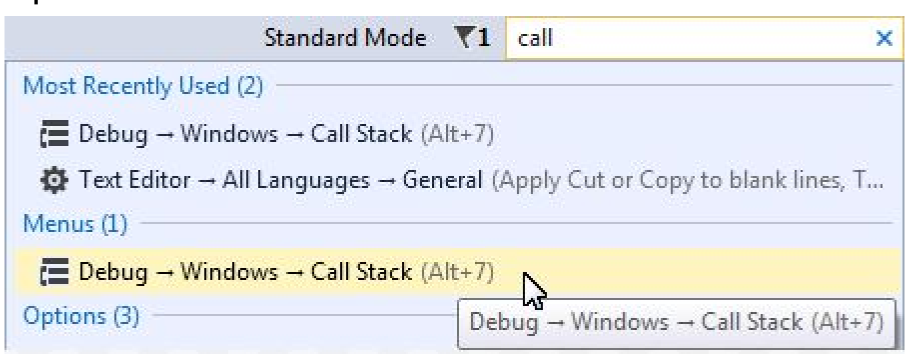
Figure 1-45. Disassembly View



ToDo: Examine the Call Stack and the effect on it when optimizations are disabled.

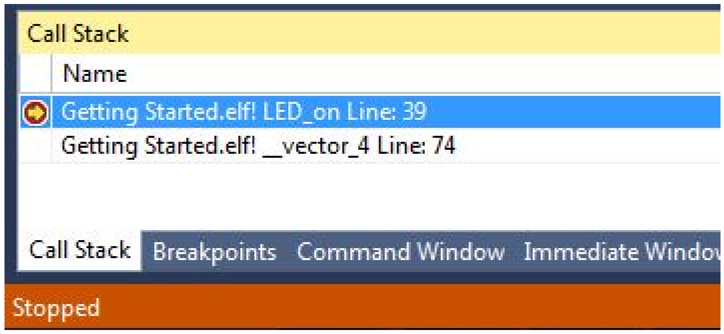
1. Following from the previous section, set a breakpoint on the `LED_on()` function, then trigger the breakpoint so that it is hit.
2. Open the Call Stack window by typing 'Call' in the Quick Launch bar, selecting **Debug** → **Windows** → **Call Stack**, as represented in Figure 1-46.
   Note: A debug session needs to be active to open this window.

   Figure 1-46. Open the Call Stack Window

3. It would be expected that the Call Stack shows `LED_set_state()` as the caller of `LED_on()`, since that's how the code is written. However, in the Call Stack window, *_vector_4* is listed as the caller (as in Figure 1-47); this is because of compiler optimization.

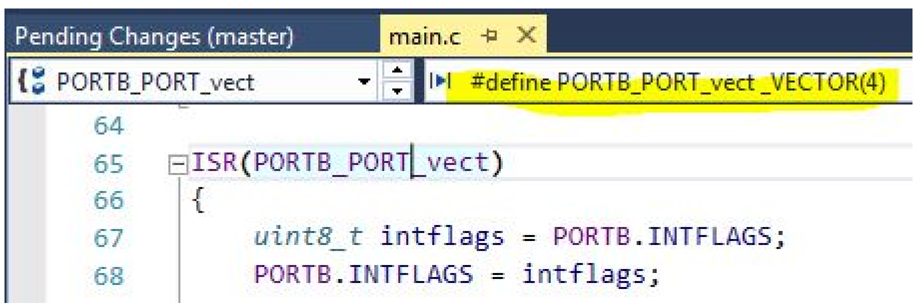
Figure 1-47. Call Stack with Optimization



Info: The call order is different because of the compiler optimization. This code is relatively simple to follow and it is possible to understand what is going on even though the compiler has optimized and made subtle changes to what is expected. In a more complex project, it can sometimes be helpful to disable the compiler optimization to track down a bug.

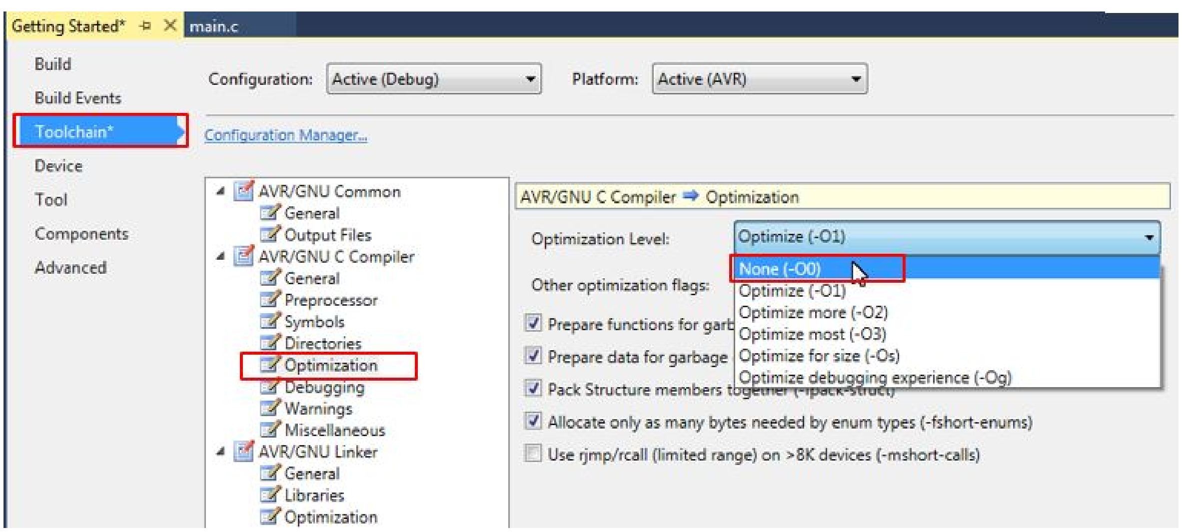
Note: To see why the Call Stack shows that it comes from *_vector_4* initially, click on *PORTB_PORT_vect* and look in the context field for the definition, as shown in Figure 1-48.

Figure 1-48. __vector_4 Is the PORTB ISR Vector



4. Stop debugging by clicking the Stop Debugging button  or pressing Shift + F5.
5. Open the project settings by going to **Project** → ***<project_name>* properties** or pressing Alt + F7. Go to the **Toolchain** tab on the left menu, as in Figure 1-49.
6. Under **AVR/GNU C Compiler** → **Optimization**, set the **Optimization Level** to **None (-O0)** using the drop-down menu.

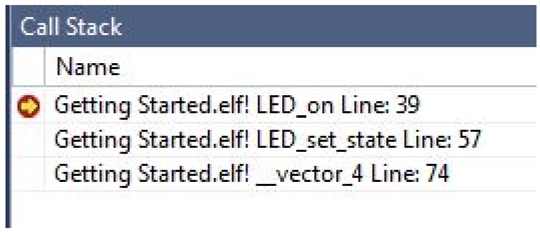
Figure 1-49. Disabling Compiler Optimizations



⚠WARNING Disabling compiler optimization will result in increased memory consumption and can result in changes in execution timing. This can be important to consider when debugging time is a critical code.

7. Launch a new debug session and break code execution inside `LED_on()`.
8. Observe the Call Stack. It should now adhere to how the code is actually written and list `LED_set_state()` as the caller of `LED_on()`, as shown in Figure 1-50.

Figure 1-50. Call Stack Without Optimization



Tip: Microchip Studio will try to link the compiled code to the source-code as best it can, but the compiler optimization can make this challenging. Disabling compiler optimization can help if breakpoints seem to be ignored during debugging, or if the execution flow is hard to follow during code stepping.

Result: The call stack has now been examined both with and without optimization enabled.

Code Used for Debugging 1

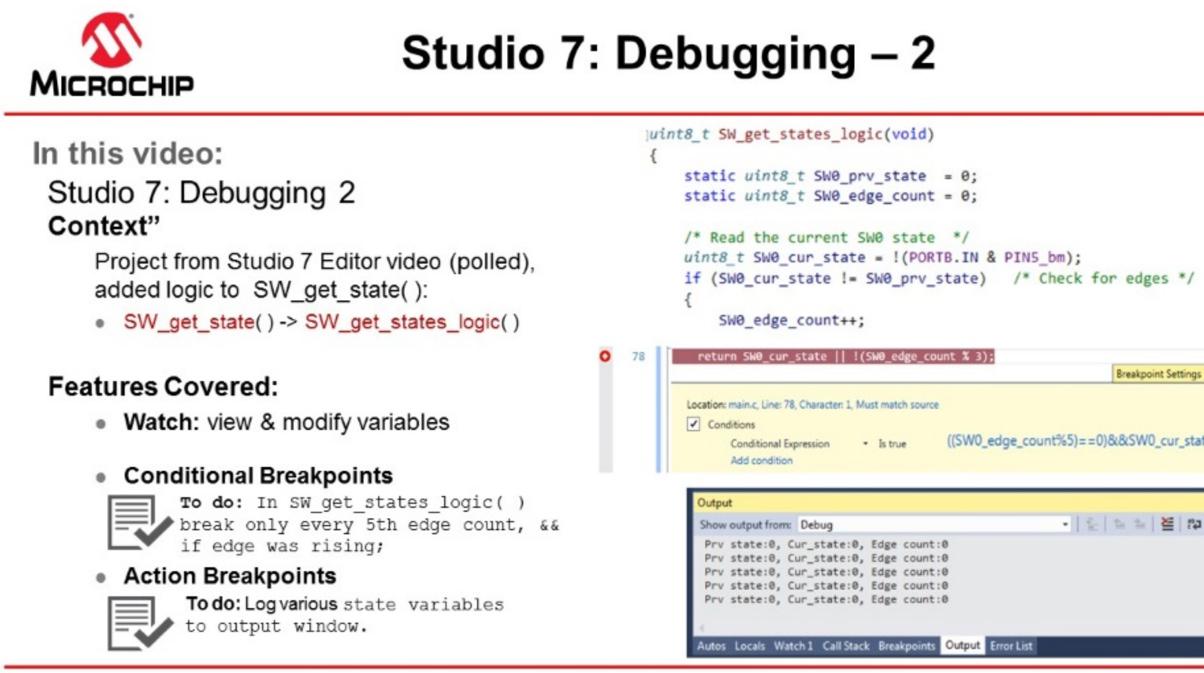
```
/*
 LED is turned on when switch is pressed, LED is turned on (via a pin change interrupt).
 MY_mistake() written to demonstrate Attach to Target, is commented out, to avoid hanging
 project unintentionally.

 From the schematics, it is concluded that:
 The LED can be turned on by driving PB4 low.
 SW0 is connected directly to GND and to PB5 through a current limiting resistor.
 SW0 does not have an external pull-up resistor.
 SW0 will be read as '0' when pushed and as '1' when released, if the ATtiny817 internal pull-
up is enabled.
*/

#include <avr/io.h>
#include <stdbool.h>
#include <avr/interrupt.h>

void LED_on();
void LED_off();
bool SW_get_state();
void LED_set_state(bool SW_state);

int main(void)
{
    PORTB.DIRSET = PIN4_bm;
    PORTB.OUTSET = PIN4_bm;
     PORTB.PIN5CTRL |= PORT_PULLUPEN_bm | PORT_ISC_BOTHEDGES_gc;
    sei();

    while (1)
    {
    }
}
```

```
#pragma region LED_functions
void LED_on()
{
    PORTB.OUTCLR = PIN4_bm;  //LED on
}

void LED_off()
{
    PORTB.OUTSET = PIN4_bm;  //LED off
}

void LED_set_state(bool SW_state)
{
    if (SW_state)
    {
        LED_on();
    }
    else
    {
        LED_off();
    }
}
#pragma endregion LED_functions

bool SW_get_state()
{
    return !(PORTB.IN & PIN5_bm);
}

/*
void My_mistake()
{
    while(1)
    {
        asm("nop");
    }
}
*/

ISR(PORTB_PORT_vect)
{
    uint8_t intflags = PORTB.INTFLAGS;
    PORTB.INTFLAGS = intflags;
    //My_mistake();

    bool SW_state = SW_get_state();

    LED_set_state(SW_state);

}
```

1.14 Debugging 2: Conditional- and Action-Breakpoints

This section covers more advanced debugging topics with Microchip Studio both as video (linked below) and hands-on document. The main topics are how to modify variables in the code, conditional- and action-breakpoints, as well as memory view.

Getting Started Topics



Video: Debugging - 2

ToDo: Use Microchip Studio to inspect and modify the contents of variables in the code.

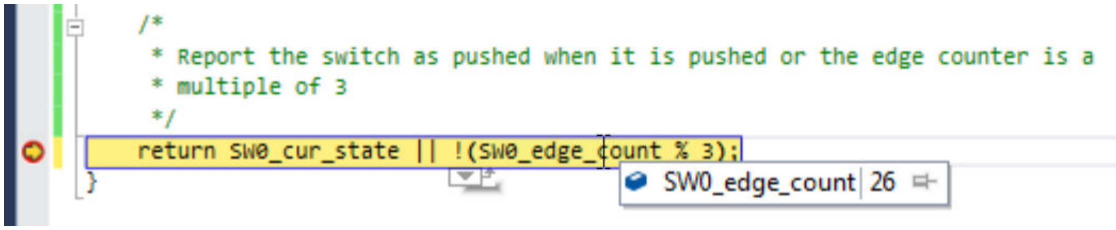
1. The code (see below) used is the same as the one developed in section 1.11 Editor: Writing and Re-Factoring Code (Visual Assist). The `SW_get_state()` function has just been replaced with the following code (note also the change in return value type):

```
uint8_t SW_get_state(void)
{
    static uint8_t SW0_prv_state  = 0;
    static uint8_t SW0_edge_count = 0;

    uint8_t SW0_cur_state = !(PORTB.IN & PIN5_bm); /* Read the current SW0 state  */
    if (SW0_cur_state != SW0_prv_state)            /* Check for edges             */
    {
        SW0_edge_count++;
    }
    SW0_prv_state = SW0_cur_state;                /* Keep track of previous state */

    /*
     * Report the switch as pushed when it is pushed or the edge counter is a
     * multiple of 3
     */
    return SW0_cur_state || !(SW0_edge_count % 3);
}
```

   Info: This code will count how many times the SW0 push button has been pressed or released. The return statement has also been modified to always report the button as pushed if the `SW0_edge_count` variable is a multiple of three.

2. Go to **Debug** → **Disable All Breakpoints** to disable all breakpoints. This should be reflected by all the checkboxes becoming unchecked in the Breakpoints window.
3. Launch a new debug session by clicking the Start Debugging button .
4. Push SW0 on the kit several times and observe how the changes to the code have affected the LED's behavior.
5. Break execution by placing a breakpoint at the return line of the `SW_get_state` function.
6. Hover over the `SW0_edge_count` variable to observe the current value, as indicated in Figure 1-51.

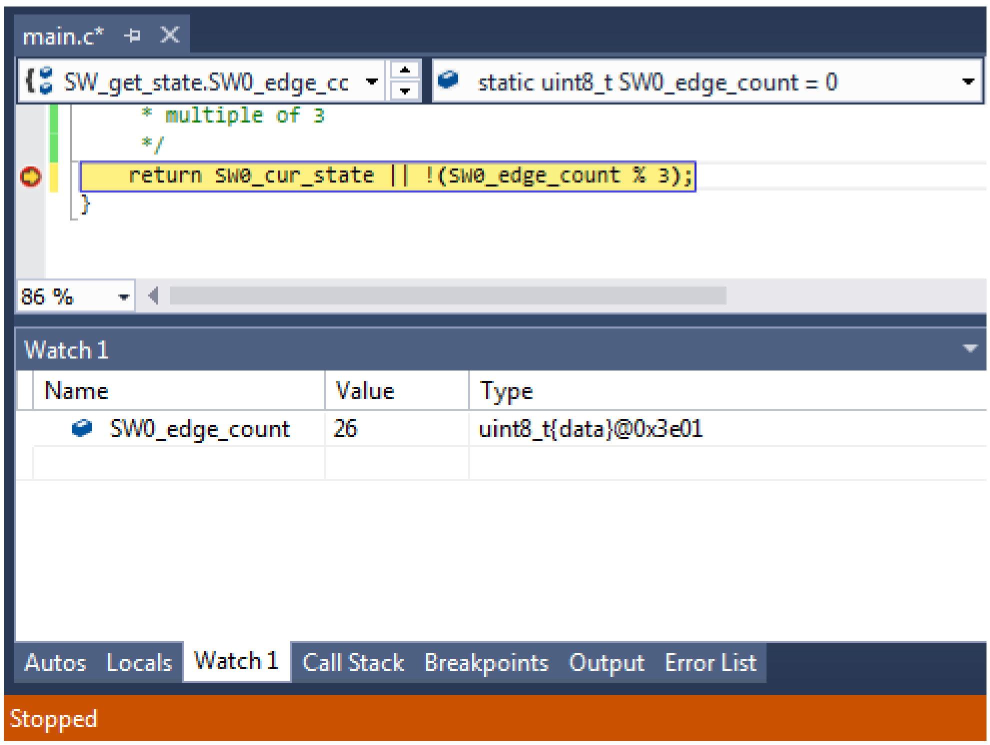
Figure 1-51. Hover Over Variable to See Current Value



Info: When the cursor hovers over a variable that is in scope at the point where execution is halted, Microchip Studio will present the content of the variable in a pop-up.

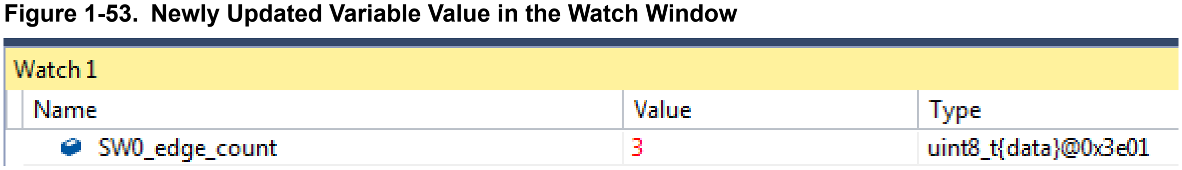
7. Right-click the `SW0_edge_count` variable and select **Add Watch** from the context menu to add the variable to the data Watch window. The Watch window should appear, with the `SW0_edge_count` variable listed, with the variable value, data type, and memory address, as in Figure 1-52.

Figure 1-52. Add Variable to Watch Window



8. Modify the contents of a **Watch Window** variable, using the process described below. Assign the value '3' to the `SW0_edge_count` variable. The value will reflect as updated by turning red, as indicated in Figure 1-53.
   – Double-click a variable value in the Watch window
   – Type in the desired new value of the variable
   – Press Enter to confirm

Figure 1-53. Newly Updated Variable Value in the Watch Window



Info: The Value column in the Watch window can be displayed in hex by right-clicking in the Watch window and selecting **Hexadecimal Display** from the context menu.

9. To have the device evaluate the new value of `SW0_edge_count`, disable all breakpoints and continue the debug session by clicking ▶ or pressing F5. Observe how the LED stays ON as a result of the change made to `SW0_edge_count`.

Info:
A variable can also be added to the Watch window by clicking on an empty field name and typing the variable name. This way, it is even possible to cast a variable to a different data type for better readability in the Watch window. This is especially useful if it is required to look at an array that is passed to a function as a pointer.

For example, if an array is passed to a function, it will be passed to the function as a pointer. This makes it impossible for Microchip Studio to know the length of the array. If the length of the array is known, and it needs to be examined in the Watch window, the pointer can be cast to an array using the following cast:

```
*(uint8_t (*)[<n>])<name_of_array_pointer>
```

Where <n> is the number of elements in the array and <name_of_array_pointer> is the name of the array to be examined.

This can be tested on the `SW0_edge_count` variable by entering the following in an empty name field in the Watch window:

```
*(uint8_t (*)[5])&SW0_edge_count
```

Note that the '`&`' symbol must be used in this case to obtain a pointer to the variable.

Result: Microchip Studio has now been used to inspect and modify the contents of variables in the code.

1.14.1 Conditional Breakpoints

This section is a guide to using Microchip Studio to place conditional breakpoints.

Conditional breakpoints are those which will only halt code execution if a specified condition is met, and can be useful if it is required to break if certain variables have given values. Conditional breakpoints can also be used to halt code execution according to the number of times a breakpoint has been hit.
ToDo: Place a conditional breakpoint inside `SW_get_state()` to halt execution for debugging at every 5th edge count, but only if the edge was rising, and check its functionality.

1. Clear all breakpoints from the project using the Breakpoints window.
2. Place a breakpoint at the return line of `SW_get_state()`, as in Figure 1-54.
3. Right-click the breakpoint and select **Conditions...** from the context menu.
4. Enter the following in the condition textbox:

```
((SW0_edge_count % 5) == 0) && SW0_cur_state
```

Figure 1-54. Conditional Breakpoint Expression Example

5. Press Enter to confirm the break condition.
6. Continue/Start a new debug session by clicking the ▶ button or pressing F5.
7. Push SW0 on the kit several times and observe how code execution is halted when the condition is fulfilled.
8. Verify that the condition is met by double-checking the variable values in the Watch window.

⚠WARNING Even though code execution is completely halted only if the specified break condition is met, Microchip Studio temporarily breaks code execution each time the breakpoint is hit to read the variable content and determine if the break condition is met. Conditional breakpoints will, therefore, have an impact on execution timing, even if the actual break condition is never met.

Tip: Use the **Hit Count** condition if execution needs to break based on how many times a breakpoint has been hit.

Result: Microchip Studio has been used to halt execution when the specified break condition is satisfied.

1.14.2 Action Breakpoints

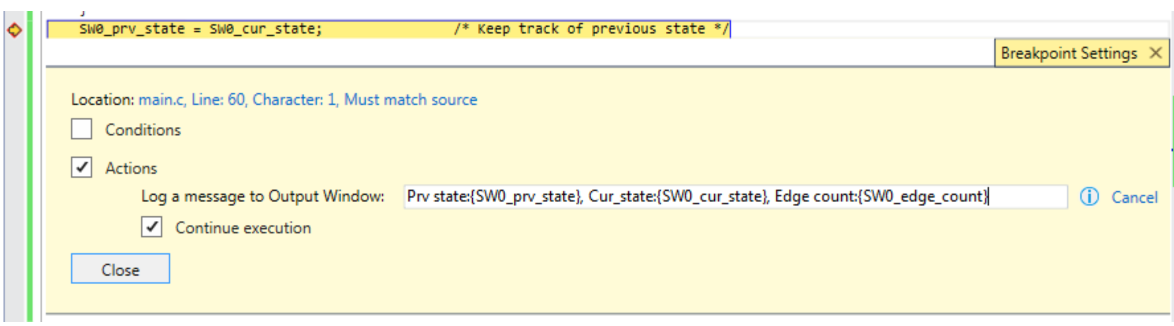
This section is a guide to using Microchip Studio to place action breakpoints.

Action breakpoints can be useful if variable contents or execution flow needs to be logged without having to halt code execution and manually record the required data.
ToDo: Place an action breakpoint to log `SW0_cur_state`, `SW0_prv_state` and `SW0_edge_count`, and check the output for the relevant variable states.

1. Stop the ongoing debug session and clear all the breakpoints from the Breakpoints window.
2. Place a breakpoint at the `SW0_prv_state = SW0_cur_state;` line, as in Figure 1-55.
3. Right-click the breakpoint and select **Actions...** from the context menu.
4. Enter the following in the output message text box:

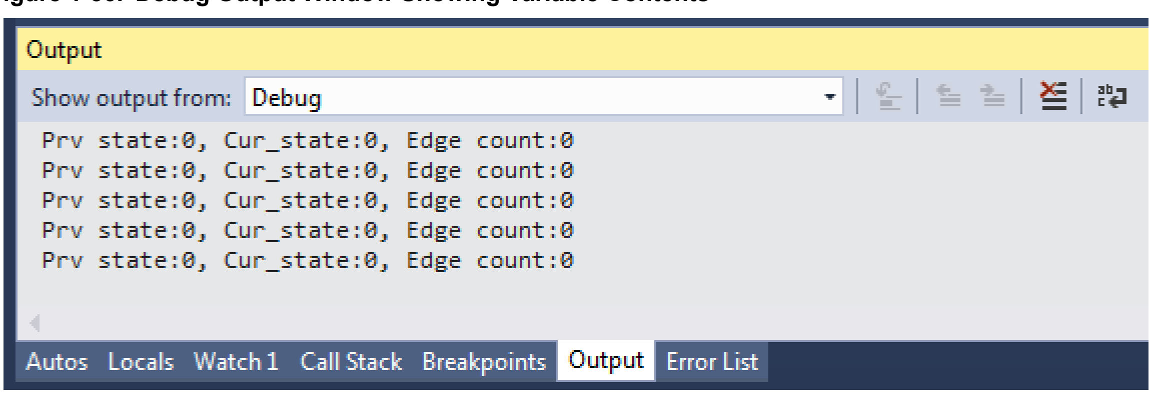
```
Prv state:{SW0_prv_state}, Cur_state:{SW0_cur_state}, Edge count:{SW0_edge_count}
```

Figure 1-55. Action Breakpoint Example



5. Press Enter to confirm.
6. Start a debug session.
7. Open the Debug Output window by going to **Debug** → **Windows** → **Output**. It should list the variable contents as in Figure 1-56. If SW0 is pushed on the kit, the content is updated.

Figure 1-56. Debug Output Window Showing Variable Contents



⚠WARNING When using action breakpoints, Microchip Studio will temporarily halt code execution to read out variable content. As a result, execution timing will be affected. A less intrusive approach would be to place the action breakpoint at the `SW0_edge_count++` line, which is only executed upon SW0 edge detection. This will cause a temporary halt only when SW0 is pressed, but will also cause the debug window output to be delayed by one line of code.

Tip: Action and Conditional breakpoints can be used together to log data only if a condition is satisfied.

Result: Microchip Studio has been used to log variable data using an action breakpoint.

1.14.3 Code Used (for ATtiny817 Xplained Pro)

Code used for conditional- and action-breakpoints.

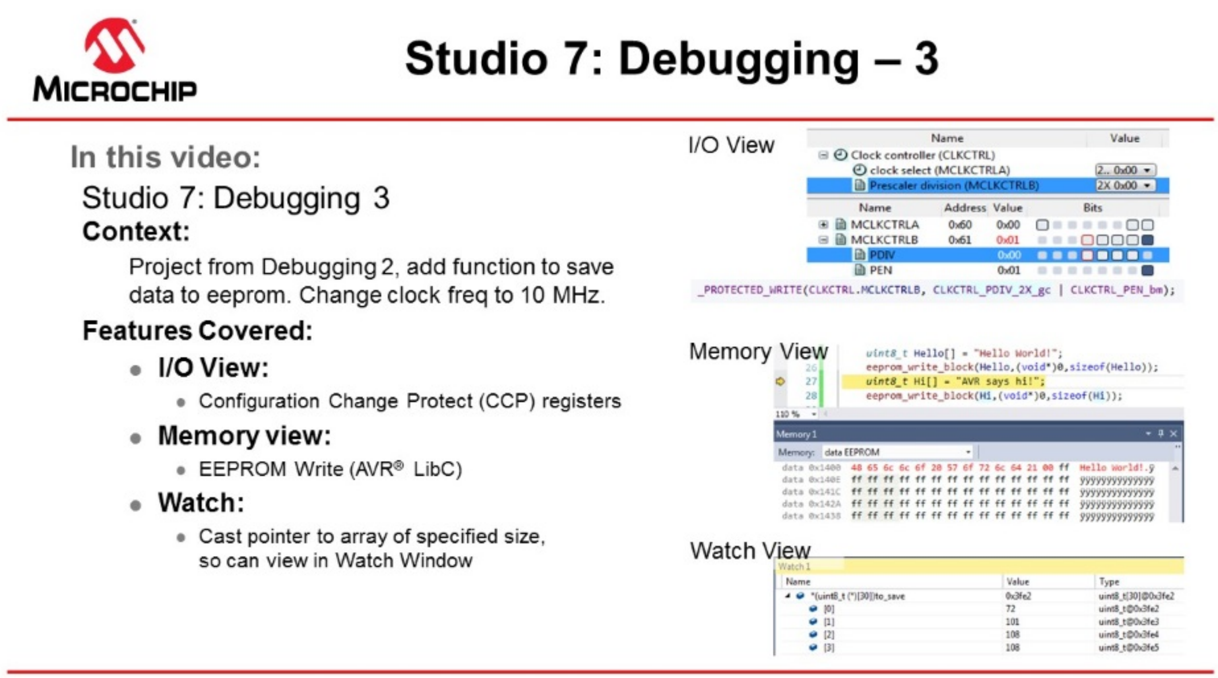
```
#include <avr/io.h>
#include <avr/interrupt.h>

void LED_on();
void LED_off();
uint8_t SW_get_state();
void LED_set_state(uint8_t SW_state);

int main(void)
{
    PORTB.DIRSET = PIN4_bm;
    PORTB.OUTSET = PIN4_bm;
     PORTB.PIN5CTRL |= PORT_PULLUPEN_bm | PORT_ISC_BOTHEDGES_gc;
    sei();

    while (1)
    {
    }
}

#pragma region LED_functions
void LED_on()
{
    PORTB.OUTCLR = PIN4_bm;  //LED on
}

void LED_off()
{
    PORTB.OUTSET = PIN4_bm;  //LED off
}

void LED_set_state(uint8_t SW_state)
{
    if (SW_state)
    {
        LED_on();
    }
    else
    {
        LED_off();
    }
}
#pragma endregion LED_functions


uint8_t SW_get_state(void)
{
    static uint8_t SW0_prv_state  = 0;
    static uint8_t SW0_edge_count = 0;

    uint8_t SW0_cur_state = !(PORTB.IN & PIN5_bm); /* Read the current SW0 state   */
    if (SW0_cur_state != SW0_prv_state)            /* Check for edges              */
    {
```

```
        SW0_edge_count++;
    }
    SW0_prv_state = SW0_cur_state;                /* Keep track of previous state */

    /*
     * Report the switch as pushed when it is pushed or the edge counter is a
     * multiple of 3
     */
    return SW0_cur_state || !(SW0_edge_count % 3);
}

ISR(PORTB_PORT_vect)
{
    uint8_t intflags = PORTB.INTFLAGS;
    PORTB.INTFLAGS = intflags;

    uint8_t SW_state = SW_get_state();

    LED_set_state(SW_state);
}
```

1.15 Debugging 3: I/O View Memory View and Watch

This section covers more advanced debugging topics with Microchip Studio both as video (linked below) and hands-on document. The main topics are using I/O View to work with Configuration Change Protected (CCP) registers, Memory View to validate EEPROM writes, as well as using the Watch window to cast pointers as an array.

Getting Started Topics



Video: Debugging - 3

1.15.1 I/O View

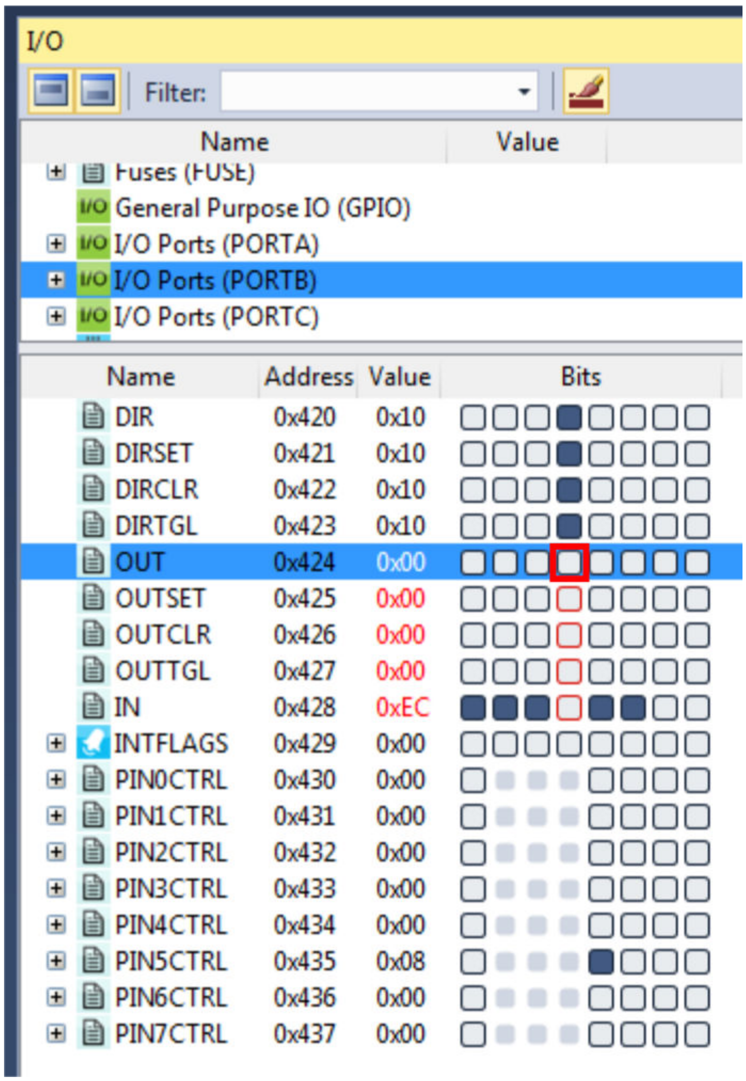
The I/O view provides a graphical view of the I/O memory map of the device associated with the active project. This debug tool will display the actual register content when debugging, allowing verification of peripheral configurations. It can also be used to modify the content of a register without having to recompile.

ToDo: Use I/O view to:

- Get an overview of the device memory map.
- Check current peripheral configurations.
- Modify peripheral configurations.
- Validate configuration changes.

1. Remove all breakpoints and start a new debug session.
2. Break code execution by pressing the Break All button .
3. Open the I/O view from the top menu bar by going to **Debug** → **Windows** → **I/O**.
4. Scroll through the list of peripherals and select **I/O Ports (PORTB)**. Find the **OUT** register and click on **Bit 4** in the **Bits** column, so the corresponding square changes color, as depicted in Figure 1-57. Observe that clicking Bit 4 in the PORTB.OUT register toggles the output level on GPIO pin PB4, which controls the LED on the ATtiny817 Xplained Pro.

Figure 1-57. Manipulate Bit Value in Register Using I/O View



Info: The I/O view is refreshed after any register has been modified, and all detected changes are highlighted in red.

Tip: Multiple bits can be modified simultaneously by double-clicking the value field and typing in the desired value to be assigned to the register.

5. Expand the Clock controller (CLKCTRL) in the I/O view, and answer the following questions:
   – What is the currently selected clock source (Clock select)?
   – What is the configured prescaler value (Prescaler division)?
   – Is the main clock prescaler enabled (MCLKCTRLB.PEN)?

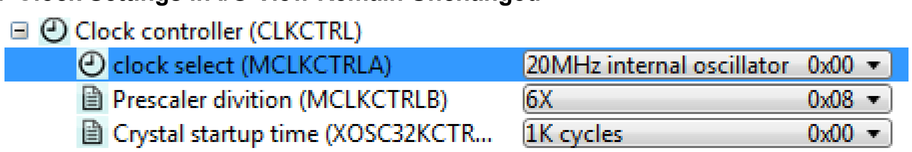
   Result: The Clock controller should be configured with the ATtiny817 default clock settings; the main clock is running from the internal RC oscillator with prescaler enabled and a division factor of six.

   Info: The default clock configuration ensure that the device will execute code reliably over the entire supported operating voltage range, 1.8V to 5.5V. The Xplained Pro kit powers the ATtiny817 at 3.3V. According to the 'General Operating Ratings' section in the device data sheet, the device can be safely run at 10 MHz with a 3.3V supply.
6. The code will now be changed to run the ATtiny817 at 10 MHz. Modify the start of `main()` as below:

```
int main(void)
{
    /*
     * Set the Main clock division factor to 2X,
     * and keep the Main clock prescaler enabled.
     */
    CLKCTRL.MCLKCTRLB = CLKCTRL_PDIV_2X_gc | CLKCTRL_PEN_bm;
```

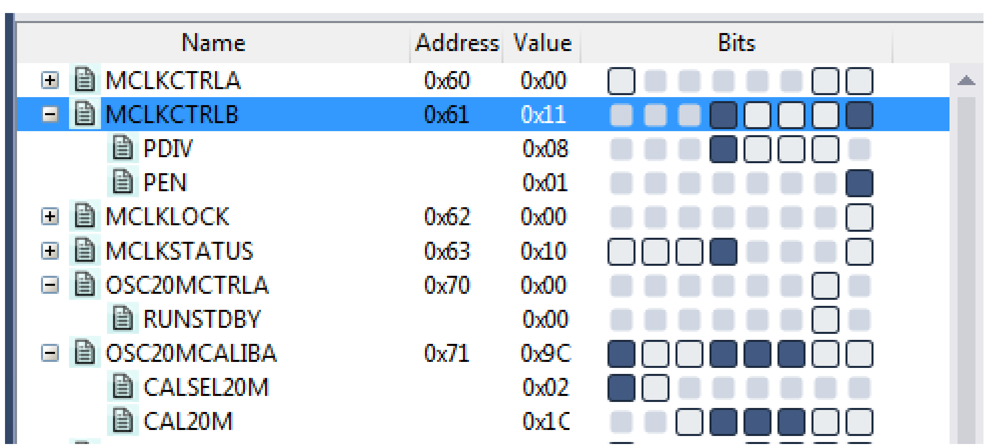
7. Start a new debug session to recompile the project and program the device.
8. Halt code execution by clicking . Examine the clock settings in I/O view, depicted in Figure 1-58.

   Figure 1-58. Clock Settings in I/O View Remain Unchanged



   Result: There is a problem! The prescaler remains unchanged.
9. Select the **MCLKCTRLB** register in I/O view, as indicated in Figure 1-59.

   Figure 1-59. Select MCLKCTRLB in I/O View



10. Push F1 on the keyboard to bring up a web-based register description.
    Info: Internet access is required to use the web-based register description. Refer to an offline version of the ATtiny817 data sheet if internet access is not available.
11. Find out if any access restrictions apply to the MCLKCTRLB register.

Result: The register is protected by the **Configuration Change Protection (CCP)** mechanism. Critical registers are configuration change protected to prevent unintended changes. These registers can only be modified if the correct unlock sequence is followed, as described in the data sheet.

12. Replace the line of code, which was just added, with the following:

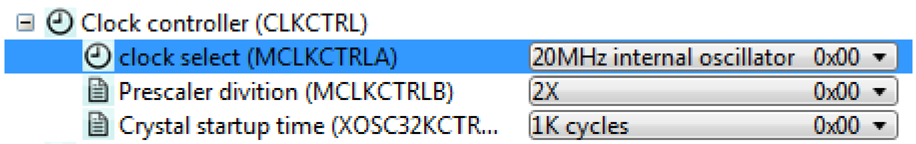
```
_PROTECTED_WRITE(CLKCTRL.MCLKCTRLB, CLKCTRL_PDIV_2X_gc | CLKCTRL_PEN_bm);
```

Info: `_PROTECTED_WRITE()` is an assembly macro that ensure timing requirements for unlocking protected registers are met. It is recommended to use this macro when modifying protected registers.

Tip: Right-click the macro name in the code and select **Goto Implementation** to navigate to the implementation of the macro. This is also possible by placing the cursor at the macro name in the code and pressing Alt+G on the keyboard. The same process can also be used for variable declarations and function implementations.

13. Stop the previous debug session and launch a new session to program the device with the changes.
14. Break code execution and use the I/O view to verify that the prescaler is now successfully set to 2X, as indicated in Figure 1-60.

Figure 1-60. Clock Settings in I/O View Changed Successfully



Tip: The Processor Status window is the register view tool for the AVR Core. This tool can be opened from the top menu bar by going to **Debug** → **Windows** → **Processor Status**. This window will provide a detailed view of the status of the internal AVR Core registers. This view can be used to check if global interrupts are enabled; look for the **I**-bit in the status register.

Result: The capabilities of the I/O view have been used to find and fix a bug in the project.

1.15.2 Memory View

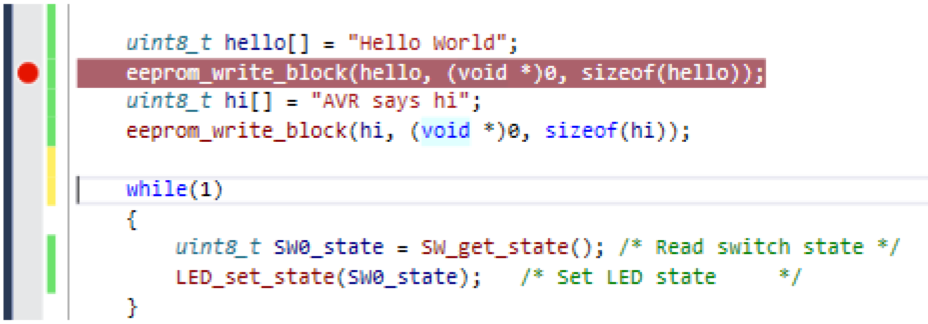
ToDo: Write two strings to the beginning of the ATtiny817 EEPROM and use Memory view to verify the EEPROM contents.

1. Add `#include <avr/eeprom.h>` after the `#include <avr/io.h>` line.
2. Add the following code before the `while(1)` loop in `main()`:

```
    uint8_t hello[] = "Hello World";
    eeprom_write_block(hello, (void *)0, sizeof(hello));
    uint8_t hi[] = "AVR says hi";
    eeprom_write_block(hi, (void *)0, sizeof(hi));
```

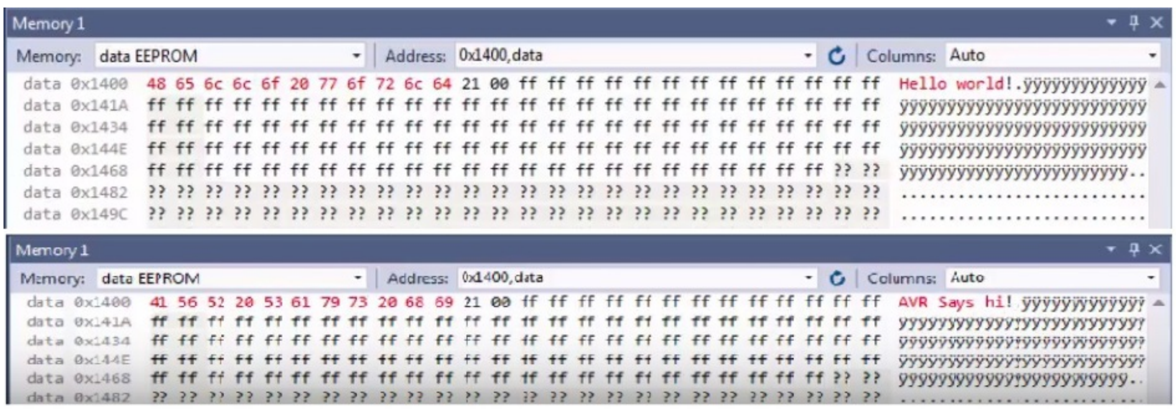
3. Place a breakpoint next to the first call to `eeprom_write_block()` as in Figure 1-61.

Figure 1-61. Breakpoint to Halt for Checking EEPROM



4. Start a new debug session to program the device with the updated code.
5. After the breakpoint has been hit, open the memory window from the top menu bar by going to **Debug** → **Windows** → **Memory** → **Memory 1**. Look at the current content of the EEPROM.
6. Push F10 on the keyboard to step over the `eeprom_write_block()` call and verify the EEPROM write.
7. Allow the ATtiny817 to execute the next EEPROM write before verifying the write using the Memory view. The view should appear as in Figure 1-62 at each interval respectively.

Figure 1-62. Memory View Updating After EEPROM Writes



> **Tip:** The Memory view tool can also be used to investigate the contents of other AVR memory sections, including the program memory. This can be useful when debugging bootloaders.

Result: The content of the EEPROM is updated after each call to `eeprom_write_block()`. The updated content is highlighted in red, and the ASCII interpretation of the EEPROM content matches the written strings. Therefore, the contents of EEPROM after writing to it have been verified using Memory view.

1.15.3 Watch Window

This is covered in more detail in section 1.14 Debugging 2: Conditional- and Action-Breakpoints , however, the note on how to cast pointers as an array in the Watch window is repeated here.

Info: A variable can also be added to the Watch window by clicking on an empty field name and typing the variable name. This way, it is even possible to cast a variable to a different data type for better readability in the Watch window. This is especially useful if it is required to look at an array that is passed to a function as a pointer.
For example, if an array is passed to a function, it will be passed to the function as a pointer. This makes it impossible for Microchip Studio to know the length of the array. If the length of the array is known, and it needs to be examined in the Watch window, the pointer can be cast to an array using the following cast:

```
*(uint8_t (*)[<n>])<name_of_array_pointer>
```

Where <n> is the number of elements in the array and <name_of_array_pointer> is the name of the array to be examined.

This can be tested on the `SW0_edge_count` variable by entering the following in an empty name field in the Watch window:

```
*(uint8_t (*)[5])&SW0_edge_count
```

Note that the '`&`' symbol must be used in this case to obtain a pointer to the variable.

Result: Microchip Studio has now been used to inspect and modify the contents of variables in the code.

Code Used for Debugging 3

```
#include <avr/io.h>
#include <avr/eeprom.h>

void LED_on(void);
void LED_off(void);
void LED_set_state(uint8_t state);
uint8_t SW_get_state(void);
uint8_t SW_get_state_logic(void);

int main(void)
{
    PORTB.DIRSET   = PIN4_bm;           /* Configure LED Pin as output */
    PORTB.PIN5CTRL = PORT_PULLUPEN_bm;  /* Enable pull-up for SW0 pin  */

    _PROTECTED_WRITE(CLKCTRL.MCLKCTRLB, CLKCTRL_PDIV_2X_gc | CLKCTRL_PEN_bm);

    uint8_t Hello[] = "Hello World!";
    save(Hello,sizeof(Hello));
    uint8_t Hi[] = "AVR says hi!";
    save(Hi,sizeof(Hi));

    while(1)
    {
        uint8_t SW0_state = SW_get_state_logic(); /* Read switch state */
        LED_set_state(SW0_state);           /* Set LED state     */
    }
}

void save(const uint8_t* to_save, uint8_t size)
{
    eeprom_write_block(to_save,(void*)0,size);
}

uint8_t SW_get_state()
{
    return !(PORTB.IN & PIN5_bm);
}

uint8_t SW_get_state_logic(void)
{
    static uint8_t SW0_prv_state  = 0;
    static uint8_t SW0_edge_count = 0;

    uint8_t SW0_cur_state = !(PORTB.IN & PIN5_bm); /* Read the current SW0 state   */
    if (SW0_cur_state != SW0_prv_state)            /* Check for edges              */
    {
        SW0_edge_count++;
    }
    SW0_prv_state = SW0_cur_state;                /* Keep track of previous state */
```

```
    /*
     * Report the switch as pushed when it is pushed or the edge counter is a
     * multiple of 3
     */
    return SW0_cur_state || !(SW0_edge_count % 3);
}

void LED_off(void)
{
    PORTB.OUTSET = PIN4_bm; /* Turn LED off  */
}

void LED_on(void)
{
    PORTB.OUTCLR = PIN4_bm; /* Turn LED on */
}

void LED_set_state(uint8_t state)
{
    if (state)
    {
        LED_on();
    }
    else
    {
        LED_off();
    }
}
```

2. Revision History

Doc. Rev.	Date	Comments
B	01/2021	Renaming to Microchip Studio
A	2018	Initial version

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip design partner program member listing
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