AN3408

How to Use Force Sensitive Resistor with 12-bit ADC

Features

- ADC Sample Accumulation up to 1024 Samples per Conversion
- Hardware Averaging using Burst Mode
- ADC Free Running Mode
- ADC Result Transmission to PC Terminal
- ADC Result Transmission over Bluetooth® Communication
- Display Pattern on 4x4 RGB Click board™

Introduction

Author: Rupali Honrao, Microchip Technology Inc.

This application note describes how to use the Analog-to-Digital Converter (ADC) on tinyAVR® 2 family microcontrollers to measure a Force Sensitive Resistor (FSR). In the example application, the ADC result will be sent to an Android™/iOS ® app over Bluetooth communication using the RN4870 Click board. The ADC result will also be sent to a serial terminal and a 4x4 RGB Click board is used to illuminate different LEDs, corresponding to the applied force on the force sensor of the Force Click board. The ADC supports sampling in bursts where a configurable number of conversion results are accumulated into a single ADC result (sample accumulation). This feature is used in the example application to accumulate 1024 samples and perform averaging.

For demonstration, the ATtiny1627 Curiosity Nano board with Curiosity Nano Adapter is used. The example code for replicating the results described in this application note is available from Atmel START:

- Force Sensitive Resistor with tinyAVR Family ADC
  - start.atmel.com/#example/Atmel%3AApplication_AVR_Examples%3A1.0.0%3A%3AApplication%3AForce_Sensitive_Resistor_with_12_bit_ADC%3A

The bare metal code example (without using Atmel START drivers) is available here :

View Code Examples on GitHub
Click to browse repositories

More information about the application is described in Section 2. Demo Operation and Section 6.2 Demo Implementation.

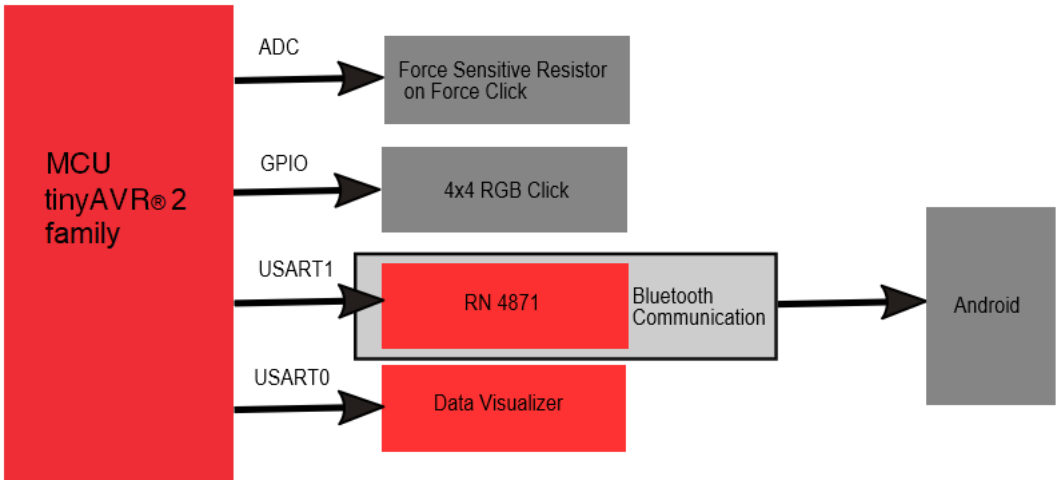
Additional details on ADC performance and general configuration are available in the device data sheet.

Table of Contents

1. Block Diagram

The figure below illustrates the block diagram of the application.

Figure 1-1. Block Diagram



2. Demo Operation

In this demo, ADC measurements are done using an FSR on the Force Click board. When force is applied to the FSR on the Force Click board, an ADC result is read which is proportional to the applied force.

Note: In test setup, V_{DD} = 3.3V, ADC reference is V_{DD}. When maximum force is applied on Force sensor, the voltage on ADC pin is 3.247V which is 100% strength. It may vary from setup to setup.

The strength percentage is calculated and sent to an Android or iOS app over Bluetooth communication using the RN4870 Click board. The ADC result is sent also to *Data Visualizer* (or PC serial terminal) and a 4x4 RGB Click board is used to illuminate different LEDs corresponding to the applied force on the FSR. The number of LEDs illuminated and the brightness of LEDs are proportional to the applied force.

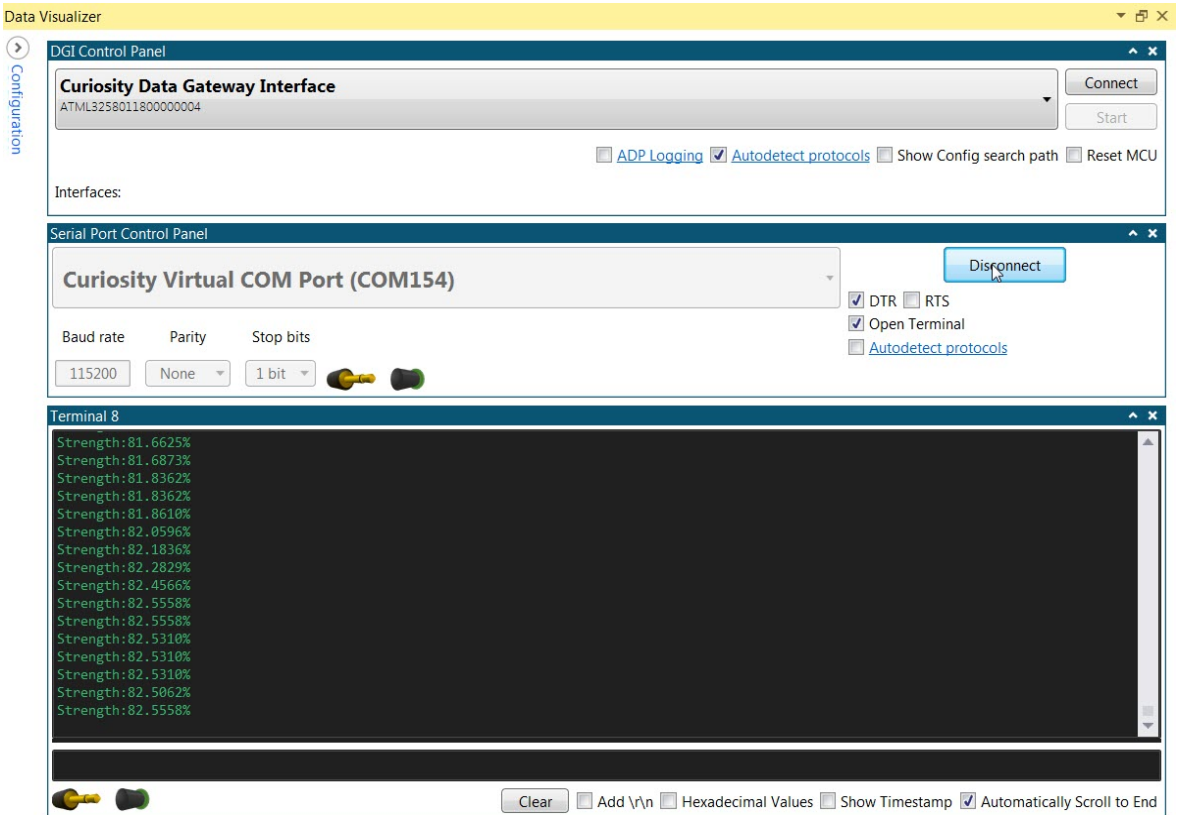
Hardware and Software Setup

1. Connect the boards as mentioned in Section 5. Hardware Setup.
2. Download and install the Android or iOS app referred to in Section 4. Software Prerequisites.
3. Download the application (refer to Section 7. Get Code Examples from Atmel START or Section 8. Get Code Examples from GitHub) and program the ATtiny1627 Curiosity Nano.

4x4 RGB Click, Force Click, Data Visualizer

1. Observe that upon power-up, the 4x4 RGB Click board is illuminated with different color patterns. It displays colors in sequence: Red, Green, White, and then it turns blank.
2. Press the FSR on the Force Click board and observe the LEDs.
   Note: LEDs in blue colors will be illuminated. The number of LEDs illuminated and the brightness of the LEDs are proportional to the applied force.
3. Increase the force on the FSR and observe an increased brightness level and increased number of LEDs illuminated.
4. Open *Data Visualizer* or any other serial terminal on PC.
5. Connect the nEDBG COM Port and configure baud rate to 115200.

Figure 2-1. Data Visualizer



6. Press the FSR on the Force Click board and observe the applied force in percentage.
   Note: When 100% force has been applied on FSR, all the LEDs on the 4x4 RGB Click board will keep flashing with different colors. Colors flashed are red, green, blue, magenta, yellow, cyan, and white.

Bluetooth Communication

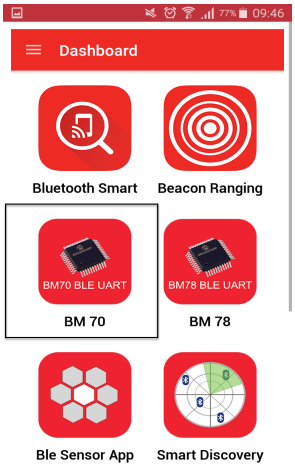
Note: This section shows the interface using the Microchip Bluetooth Data android app. Steps are almost similar for iOS app.

1. Install and open the app *Microchip Bluetooth Data*.

   Figure 2-2. Microchip Bluetooth Data

2. Click on *BM70 BLE UART*.

Figure 2-3. BM70 BLE UART

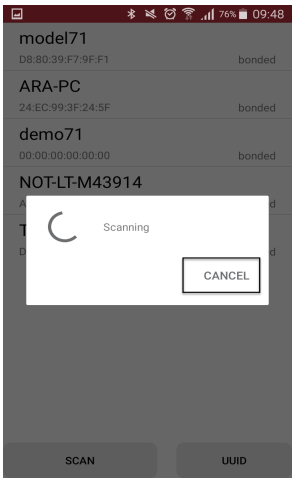


3. Click on **Scan**. If a pop-up message appears to turn on Bluetooth, click *Yes* and then click **Scan** again.
4. Click the **Scan** tab to list the devices.

Figure 2-4. SCAN

5. Wait for the scan for 4-5 seconds, and then click **Cancel** to cancel the scan.

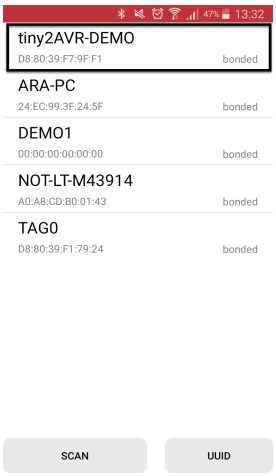
Figure 2-5. Cancel Scan



Note: After canceling the scan, the Bluetooth module name, *tiny2AVR-DEMO*, should be listed on the screen. If the name is not listed, go to Step:Click on *BM70 BLE UART* and repeat the scan.

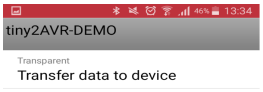
6. Click on *tiny2AVR-DEMO*.

Figure 2-6. Bluetooth Module Name: tiny2AVR-DEMO



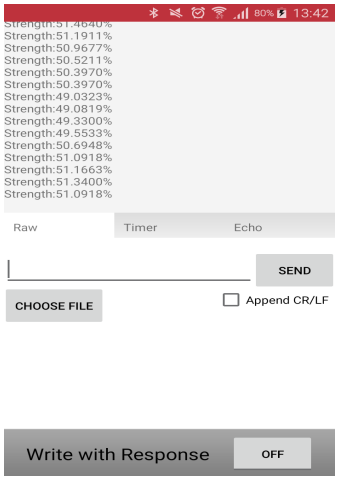
7. Wait for connection.
8. Click on *Transfer data to device*.

Figure 2-7. Transfer Data to device



9. Press the FSR on the Force Click board and observe the applied force in percentage in the app.

Figure 2-8. Data in the App



Note: If iOS app is used, enable the checkmark *Display data* to visualize the data in the app.

3. Hardware Prerequisites

- ATtiny1627 Curiosity Nano: www.microchip.com/developmenttools/ProductDetails/DM080104
- Curiosity Nano Adapter: www.microchip.com/DevelopmentTools/ProductDetails/AC164162
- RN4870 Click: www.mikroe.com/rn4870-click
  - **Note:** RN4871 Click board can also be used because it is code compatible – www.mikroe.com/rn4871-click
- Force Click: www.mikroe.com/force-click
- 4x4 RGB Click board (optional): www.mikroe.com/4x4-rgb-click

4. Software Prerequisites

- Atmel Studio 7 (Version 7.0.1931)
- Android or iOS app *Microchip Bluetooth Data*:
  - Android
    - https://play.google.com/store/apps/details?id=com.microchip.bluetooth.data&hl=en
  - iOS
    - itunes.apple.com/us/app/microchip-bluetooth-data/id1319166097?mt=8

5. Hardware Setup

This section provides information on the hardware setup and pin configuration as shown in the figure and table below.

Figure 5-1. Visual Representation of HW Setup

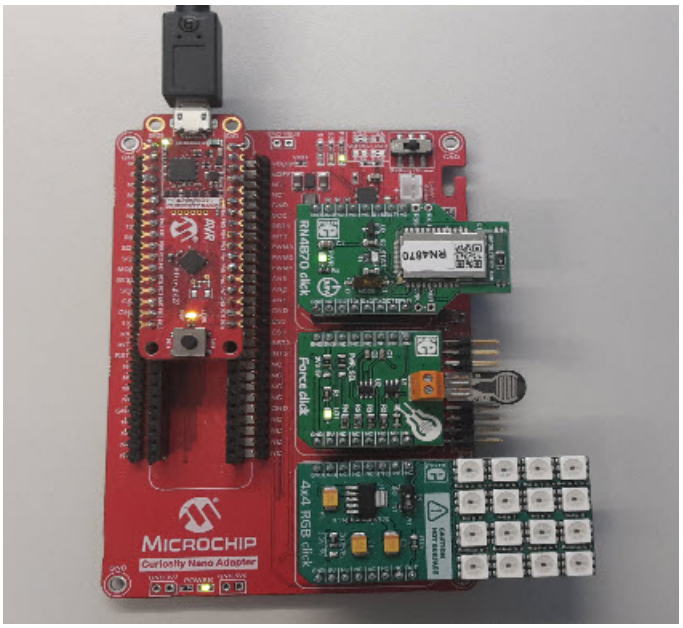


Table 5-1. Pin Configuration and Click Board

Curiosity Nano Adapter Slot	Click Board	Curiosity Nano Adapter Pin Name	MCU Pin Name
Slot 1	RN4870 Click / RN4871 Click	RST1(HW Reset)	PB6
		RX1	PA2
		TX1	PA1
Slot 2	Force Click	AN2	PA6
Slot 3	4x4 RGB Click	CS3 (Switch position IN2 on Click board)	PC5

6. Source Code Overview

The following is the overview of the source code using the ATtiny1627:

- CPU clock: 10 MHz
- Peripherals used:
  - ADC
    - ADC input channel is AIN6: pin PA6
    - ADC reference voltage: V_{DD}
    - ADC clock: 2.5 MHz (F_{CPU}/4)
  - USART1
    - TXD: PA1
    - RXD: PA2
    - Baud rate: 115200, ADC result is sent over to Bluetooth Communication
  - USART0
    - TXD: PB2
    - RXD: PB3
    - Baud rate: 115200, ADC result is sent to serial terminal
  - GPIO
    - Pin PC5: 4x4 RGB Click board input
    - Pin PB6: RN4870/71 Click HW Reset

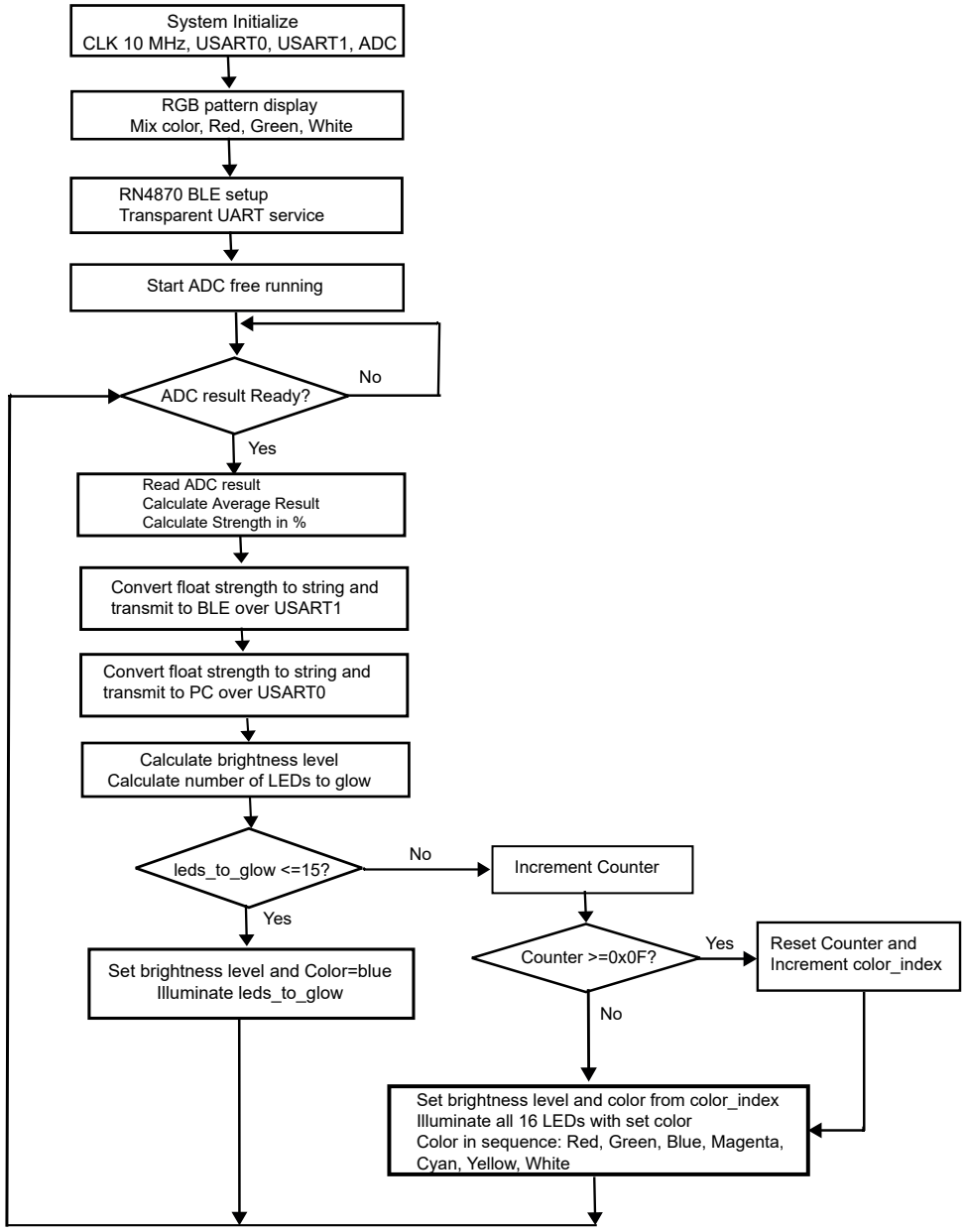
The project configured in Atmel START generates peripheral driver functions and files, as well as a '`main()`' function that initializes all drivers.

- Driver header and source files are in the *src* and *include* folder
- In `atmel_start.c` file, the function '`atmel_start_init()`' initializes MCU, drivers, and middleware in the project

6.1 Flow Chart

The flow chart below illustrates the application.

Figure 6-1. Flow Chart



6.2 Demo Implementation

RGB LED display

- Upon power-up, 4x4 RGB Click board will be illuminated with different color patterns. It displays Red, Green, and White, and then it turns blank.
  - `rgb_pattern_MixColor()` illuminates RGB LEDs with mixed colors
  - `rgb_pattern_Red_Green_White()` illuminates Red, Green, White in sequence

ADC

- An FSR sensor on the Force Click board is measured using the ADC.
- The FSR changes the resistance when a force, pressure, or mechanical stress is applied. When an FSR is pressed, the gap between two membranes gets closed. This process shorts the two membranes together, with a resistance that is proportional to applied force and thus, the voltage on an analog pin is the measure of applied force.
- In the example application, the ADC is initialized in `ADC_0_init()` in *adc_basic.c* under the *src* folder.

  The ADC is configured with Burst mode to accumulate 1024 samples.

  In Burst mode, a burst of *n* conversions accumulated as fast as possible after a single trigger and the conversion results are accumulated into a single ADC result.

  The Free Running mode, which continuously repeats ADC conversion cycles, is enabled by writing a '1' to the FREERUN bit in the Control F register (ADCn.CTRLF) before starting the first conversion.

```
ADC0.CTRLF |= 1 << ADC_FREERUN_bp; /* ADC Freerun mode: enabled */
```

  Conversion is started by running following before `while(1)` in `main.c`:

```
ADC0.COMMAND |= ADC_START_IMMEDIATE_gc; /*Start Conversion Free running*/
```

  By enabling the Free Running mode, a new ADC conversion will be started immediately after the results are available in the Sample Register ADCn.SAMPLE.

  The total conversion time for a Burst Accumulation to accumulate *SAMPNUM* samples is calculated by:

$$\text{Total Conversion Time} = \text{Initialization} + \frac{(\text{SAMPDUR} + 13.5) \times \text{SAMPNUM} + 2}{f_{\text{CLK\_ADC}}}$$

  Here,

  SAMPNUM =1024, SAMPDUR=20, f_{CLK_ADC} =2.5 MHz, Initialization = 60 us.

$$\text{Total Conversion Time} = 60\ \text{us} + \frac{((20 + 13.5) \times 1024) + 2}{2.5\ \text{MHz}}$$

  So total Conversion time = 0.0137s. This means that the Sampling Burst rate is 72 Hz.

  Sampling Burst rate can be increased by decreasing the number of samples to be accumulated, *SAMPNUM*.

  The conversion rate (f_{conv}) for samples within a single burst is calculated by:

$f_{\text{conv}} = \frac{f_{\text{CLK\_ADC}}}{\text{SAMPDUR}+13.5}$ = Here it is 74 kHz.

  Result Ready and Sample Ready Interrupt Flags (RESRDY and SAMPRDY) in the Interrupt Flags register (ADCn.INTFLAGS) are set when accumulated result and single sample are ready, respectively.

  RESRDY is set when 1024 samples are accumulated and result is available in the ADCn.RESULT register.

  SAMPRDY flag is set when each sample is available in the ADCn.SAMPLE register.

  In the example code, the ADC result is read in the `adc_get_result()` function when RESRDY flag is set and the average result is calculated by dividing the accumulated ADC result by 1024, number of samples, or by right shifting the ADC result by 10. It is illustrated in code below in bold:

```
while (1)
{
    if(ADC_0_is_conversion_done())
    {
      adc_t.adc_result = ADC_0_get_conversion_result();
      adc_t.adc_average_result = adc_t.adc_result>>SAMPLES;
      strength_percentage  = (float)(adc_t.adc_average_result * MAX_FORCE_PERCENT) /
ADC_MAX_VALUE_for_FORCE_CLICK;
      transmit_to_BLE(strength_percentage);
      trasmit_to_terminal(strength_percentage);
      rgb_display_pattern_per_force();
    }
}
```

Bluetooth and USART

- Bluetooth is configured with transparent UART service in `RN4871_Setup_Transparant_UART_service()`. The Bluetooth module name is also configured in this function.
- Using the measured ADC result, strength percentage is calculated and sent to the Android/iOS app over Bluetooth communication using the RN4870 Click board over USART1 in function `transmit_to_BLE()` shown in the above code block.
- In test setup, V_{DD} = 3.3V , ADC reference is V_{DD}. 12 bit ADC count is 0x0FFF at 3.3V. When maximum force is applied on Force sensor of the Force Click board, the voltage on ADC pin is 3.261V, which gives ADC count ~0x0FCF and strength percentage is 100%. It may vary from setup to setup.
- Percentage strength is sent to a serial terminal over USART0 in function `transmit_to_terminal()`.

RGB LED display

- The 4x4 RGB Click board is used to illuminate different LEDs corresponding to the applied force on the FSR on the Force Click board in function `rgb_display_pattern_per_force()`.
- The number of LEDs illuminated and brightness level of LEDs are proportional to applied force.
- When applied force is less than 100%, RGB LEDS will be illuminated in blue color and brightness level is also proportional to applied force. As force is increased, the number of LEDs to be illuminated and brightness level gradually increases.
- When 100% force has been applied on the FSR, all the LEDs on the 4x4 RGB Click board will be kept flashing with different colors. Colors in sequence red, green, blue, magenta, yellow, cyan, and white are flashed.

7. Get Code Examples from Atmel START

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

The Atmel START webpage: http://start.atmel.com/.

Code Examples

- Force Sensitive Resistor with tinyAVR Family ADC
  - start.atmel.com/#example/Atmel%3AApplication_AVR_Examples%3A1.0.0%3A%3AApplication%3AForce_Sensitive_Resistor_with_12_bit_ADC%3A

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

Atmel Studio

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

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

MPLAB® X

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

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

IAR Embedded Workbench®

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

8. Get Code Examples from GitHub

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

The GitHub webpage: GitHub.

Code Examples

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

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

9. Revision History

Revision	Date	Description
A	09/2020	Initial document release

The Microchip Website

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

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

Product Change Notification Service

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

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

Customer Support

Users of Microchip products can receive assistance through several channels:

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

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

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

Microchip Devices Code Protection Feature

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

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Legal Notice

Trademarks

ISBN: 978-1-5224-6713-7

Quality Management System

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

Worldwide Sales and Service

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