AN2447

Measure VCC/Battery Voltage Without Using I/O Pin on tinyAVR and megaAVR

Introduction

This application note describes a low-power solution to measure the V_{CC}/Battery voltage without using any I/O pins or external components.

The core idea is to let the internal reference voltage V_{bg} act as ADC input, and the target V_{CC} act as ADC reference.

This solution helps the users setting up applications with low power consumption, low MCU pin count, and/or few BOM parts.

For better resolution, this solution should be optimized due to its non-linearity. In general voltage/battery monitoring, the solution is quite attractive.

Features

- V_{CC} or battery voltage measurement
- No I/O pin occupying
- No external components
- Low power consumption

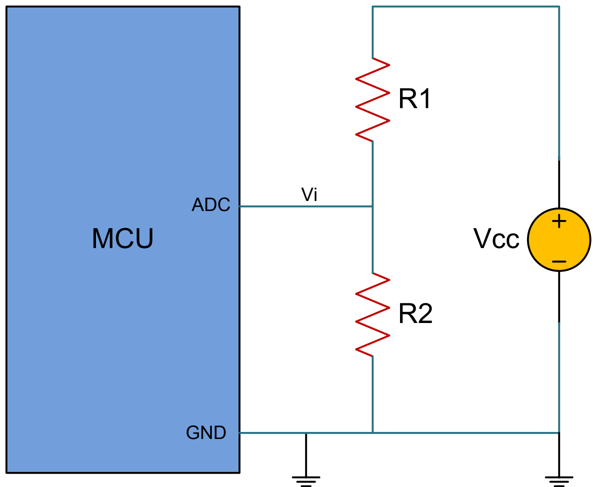
Table of Contents

1. Background

Voltage measurement of the battery or system power is critical to monitor the system performance and stability, especially in applications like IoT, Wearable Devices, Automotive, Power metering, etc.

A simple measurement is to use the ADC to measure the V_{CC} value based on the circuitry, as shown in the figure below.

Figure 1-1. General Voltage Measurement



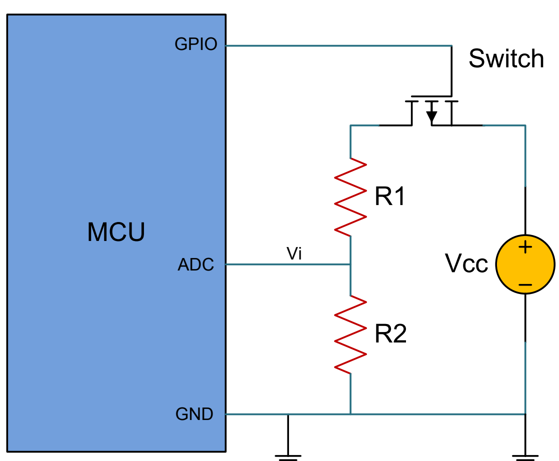
Once V_{IN} is determined, the V_{CC} can be calculated by the formula:

$$V_{cc} = V_{IN} \times (R1 + R2)/R2$$

However, ignoring the influence of a temperature drift to the resistances, there is one significant disadvantage in this approach: it will constantly consume power. In some low power applications with battery, obviously this is not acceptable.

Another improved approach is to add a switch to the circuitry. As shown in the figure below, once a measurement is needed, the switch is programmed to switch ON. If the measurement is finished, the switch is set to OFF status. The circuitry will not work and consume power when the switch is in the OFF status.

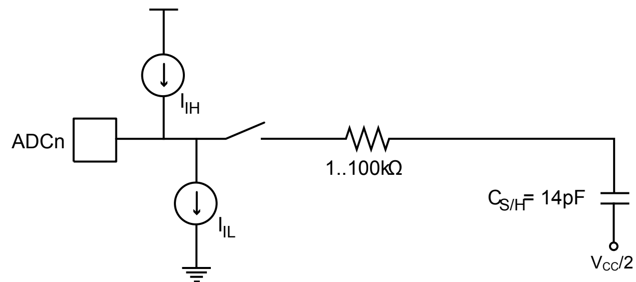
Figure 1-2. Voltage Measurement with Switch



Although this improvement will decrease the power consumption from the external resistors, the MCU I/O resources have to be occupied, and still this is not acceptable in some MCU low pin count applications.

Sometimes the measuring accuracy becomes low as the resistance will drift due to temperature changes. Besides, the response from the switch ON command to be ready for accurate test is quite slow due to the internal capacitor charging of the ADC peripheral, as shown in the figure below.

Figure 1-3. Internal Analog Input Circuitry of the ADC



The question is, will there be any other approach with very low power consumption, quick response, and few external components? The answer is - YES.

This application note describes a quick voltage measurement without any I/O resources or external components.

2. Theory

Normally the voltage measurement can be calculated based on the formula shown below, supposing that ADC is 10-bit.

$$RES_{adc} = 1024 \times V_{IN}/V_{ref}$$

where RES_{adc} is the value in the ADC result register, V_{in} is the input to the ADC, and V_{ref} is the voltage reference for the ADC.

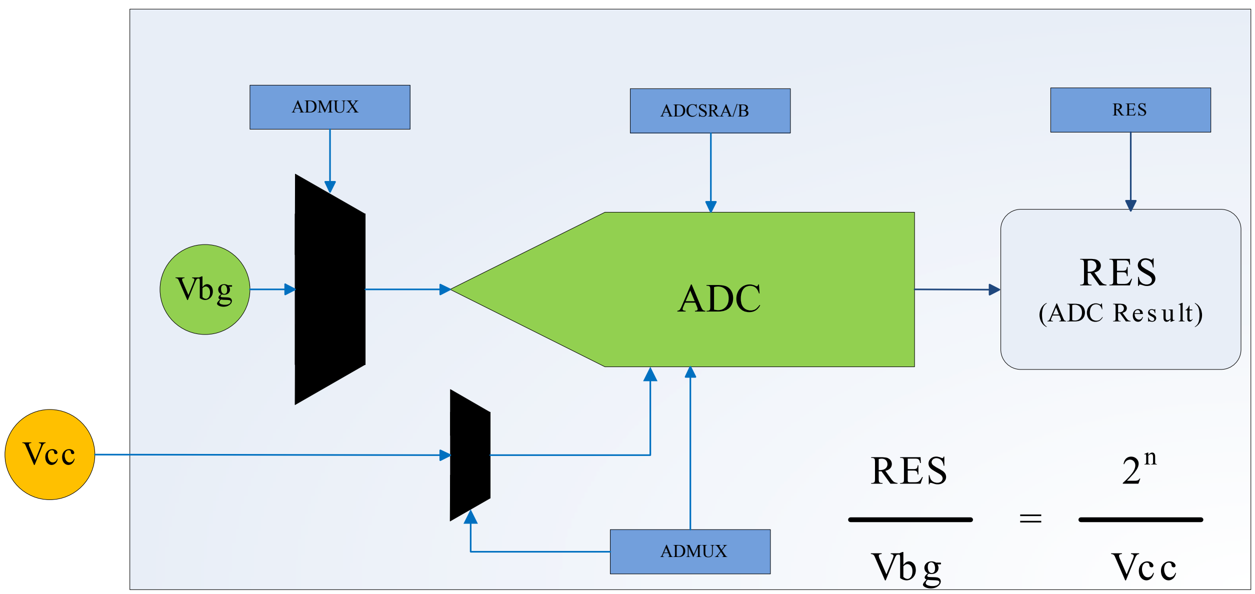
A general way to measure the voltage, is to select external input voltage as *ADC* V_{in}, and select internal V_{CC} or V_{bg} as the *ADC* V_{ref}. This solution is just to the contrary, namely to select V_{bg} as V_{in}, and to select V_{CC} as V_{ref}. The formula can be updated to:

$$RES_{adc} = 1024 \times V_{bg}/V_{CC}$$

Then the V_{CC} value can be determined by the RES_{adc} result and the known V_{bg}, as shown in the formula:

$$V_{CC} = 1024 \times V_{bg}/RES_{adc}$$

Figure 2-1. V_{CC} Measurement Block Diagram



This solution helps to measure the V_{CC} without any external components or I/O pins. But, as every coin has two sides, there are two main limitations to this solution.

1. Non-linearity.
   In this design, the formula is **y = m/x**, where *m = (1024*Vbg)*, *x* stands for the *ADC result register* value, and *y* stands for the *target* V_{CC} value. To avoid measuring accuracy influence from the non-linearity, the users can make a piecewise fitting in algorithm for further research.
2. Not all AVR® parts are suitable.
   The user's MCU to apply this method must fully support the core idea:
   – Internal reference voltage can be the ADC input
   – The V_{CC} can be the ADC reference

   Check the list about tinyAVR® and megaAVR® in the Appendix to see if the MCU is suitable.

Note: This solution is not necessary to be applied in AVR XMEGA® devices, as these devices have dedicated functions to monitor the voltage.

3. Examples

Two examples will be used to show this solution. One is a typical megaAVR device (ATmega328PB) and the other is a newly released tinyAVR device (ATtiny817).

3.1 Preparation

The preparation shown in the list below is recommended.

1. Install Atmel Studio 7.0

Atmel Studio 7 is an integrated development platform (IDP) for developing and debugging the Microchip® SMART ARM®-based applications and the AVR microcontroller (MCU) applications. Studio 7 supports all AVR and Microchip SMART MCUs.

The Atmel Studio 7 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 Microchip debuggers and development kits.

The users are highly recommended to install the Atmel Studio 7.0, which support the ATtiny817. The download link can be found here: http://www.microchip.com/development-tools/atmel-studio-7.

2. Get the target evaluate kit or device.

3.2 Example for ATmega328PB

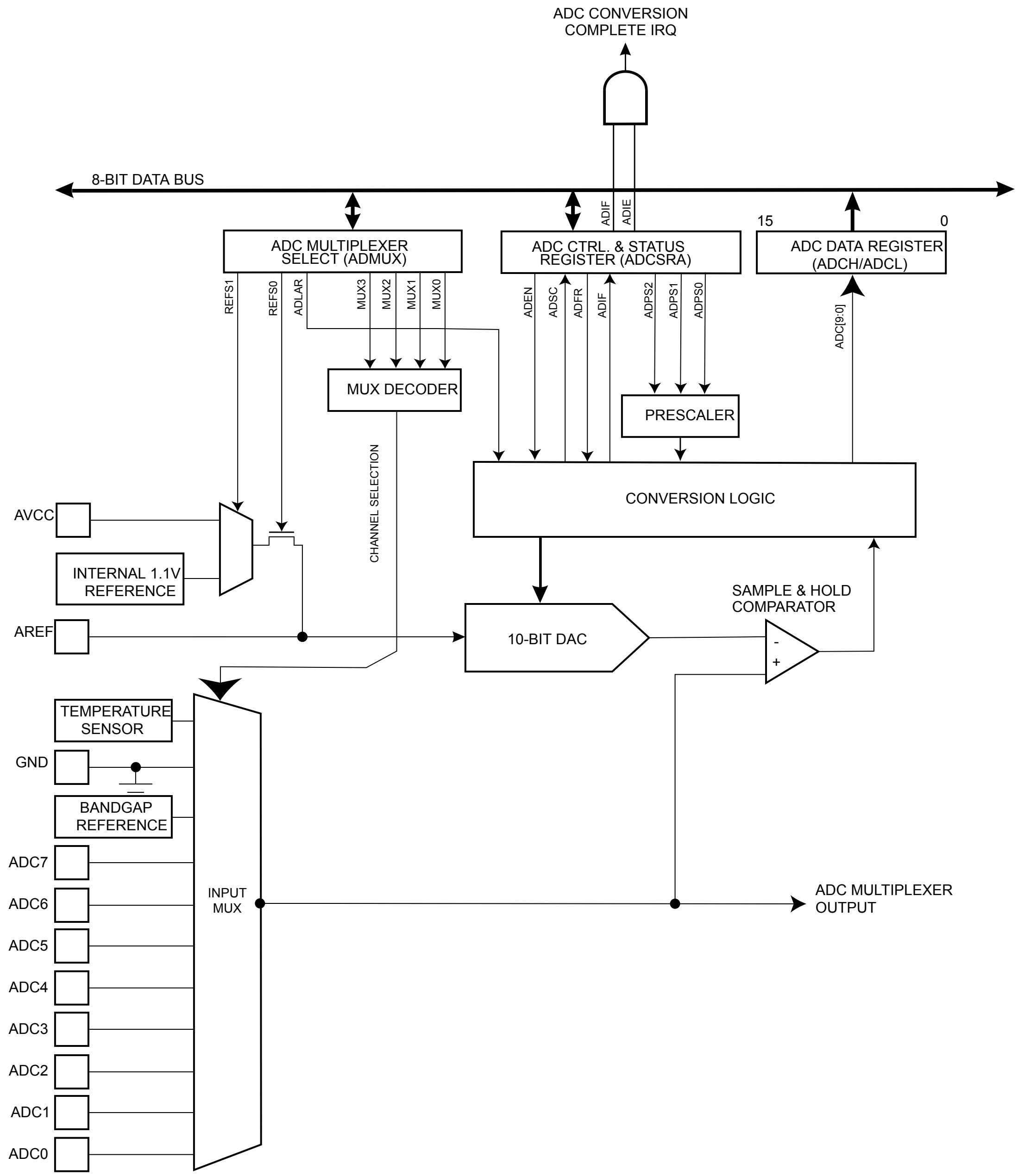
The high performance ATmega328PB is selected in this example.

ATmega328PB is a megaAVR 8-bit RISC-based microcontroller with picoPower® technology. It combines an 8-channel 10-bit A/D converter and operates between 1.8 and 5.5 volts.

Also, ATmega328PB is the first AVR 8-bit MCU to feature the QTouch® Peripheral Touch Controller (PTC), which acquires signals in order to detect touch on either self- or mutual-capacitance sensors. It provides a faster and less complex capacitive touch implementation in any application, saving BOM cost.

By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching 1 MIPS/MHz, balancing power consumption, and processing speed.

Figure 3-1. Analog to Digital Converter Block Schematic Operation



As shown in the figure above, the ADC converts an analog input voltage to a 10-bit digital value through successive approximation. The minimum value represents GND and the maximum value represents the voltage on the AREF pin minus 1 LSB. Optionally, the AVCC or an internal 1.1V reference voltage may be connected to the AREF pin by writing to the REFSn bits in the ADMUX Register. The internal voltage reference must be decoupled by an external capacitor at the AREF pin to improve the noise immunity.

The analog input channel is selected by writing to the MUX bits in the ADC Multiplexer Selection register ADMUX.MUX[3:0]. Any of the ADC input pins, as well as GND and a fixed bandgap voltage reference, can be selected as single ended inputs to the ADC.

The ADC generates a 10-bit result, which is presented in the ADC Data Registers, ADCH, and ADCL. By default, the result is presented right adjusted, but can optionally be presented left adjusted by setting the ADC Left Adjust Result bit ADMUX.ADLAR.

3.2.1 ADC Input Selection

V_{bg} (V_{REF}) can be selected as the ADC input per the table below, from the ADMUX registers of the ADC at ATmega328PB.

Table 3-1. ADC Input Selected

REFS[1:0]	Voltage reference selection
0	AREF, internal V_{REF} turned OFF
1	AVCC with external capacitor at AREF pin
10	Reserved
11	**Internal 1.1V voltage reference with external capacitor at AREF pin**

3.2.2 ADC Reference Selection

The reference selection for the ATmega328PB ADC is shown in the table below. It can be configured in the ADMUX register.

Table 3-2. Input Channel Selection

MUX[3:0]	Single ended input
0	ADC0
1	ADC1
10	ADC2
11	ADC3
100	ADC4
101	ADC5
110	ADC6
111	ADC7
1000	Temperature sensor
1001	Reserved
1010	Reserved
1011	Reserved
1100	Reserved
1101	Reserved
1110	1.1V (VBG)
1111	0V (GND)

3.2.3 Code Example for ATmega328PB

To quickly implement the method into a real project, generating an Atmel START Project based on the ATmega328PB is recommended.

- Connect an ATmega328PB XPRO Mini board to the computer via a Mini-USB cable
- Open Atmel Studio 7.0 and click File → New → Atmel START Example Project

- Type "ATmega328PB", then select the "ATmega328PB Xplained Mini", and click "CREATE NEW PROJECT" in the window
- Select AV_{CC} as ADC reference and 1.1V internal reference voltage as ADC input, then click "GENERATE PROJECT"
- Type "Battery Voltage Measurement without using I/O pin on ATmega328PB" as the project name
- Wait for the completion of the project generation to be finished and then locate the main.c file

The simplest way is to check or update three items based on the generated project:

1. Let V_{bg} act as ADC input.
2. Let V_{CC} act as ADC reference.

```
ADMUX = (0x01 << REFS0)    /* AVCC with external capacitor at AREF pin */
        | (0 << ADLAR)        /* Left Adjust Result: disabled
*/
        | (0x0e << MUX0)    /* Internal Reference (VBG) */;
```

3. Start the ADC and calculate the result in the main while(1).

```
float Vcc_value = 0 /* measured Vcc value */;
uint16_t ADC_RES_L = 0;
uint16_t ADC_RES_H = 0;

while(1) {
    if (ADCSRA & (0x01 << ADIF))    /* check if ADC conversion complete */
    {
        ADC_RES_L = ADCL;
        ADC_RES_H = ADCH;
        Vcc_value = ( 0x400 * 1.1 ) / (ADC_RES_L + ADC_RES_H * 0x100)    /* calculate
the Vcc value */;
    }
         }
```

3.2.4 Result Validation

By setting a break-point at the calculation code and adding the V_{CC} value in the watch window, the V_{CC} value can be viewed in the watch window.

To verify if the measured V_{CC} value (5.006222V) is correct, the users can use a multimeter to measure the V_{CC} of the XPRO Mini board. In this example, the real V_{CC} value of the board, measured by a multimeter, is V_{CC} = 4.96V.

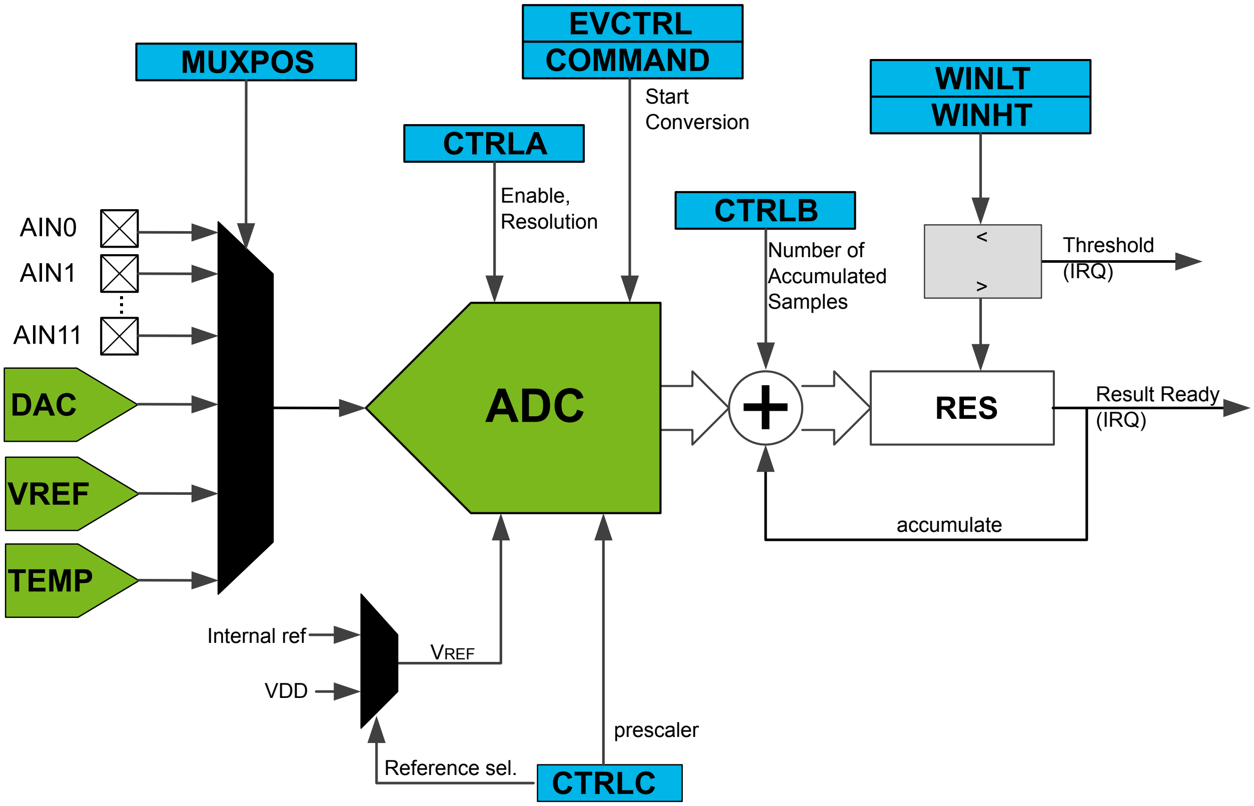
3.3 Example for ATtiny817

The selected ATtiny817 uses the latest technology from Microchip with a flexible and low-power architecture including Event System and SleepWalking, accurate analog features, and advanced peripherals. Capacitive touch interfaces with driven shields are supported with the integrated QTouch peripheral touch controller.

The Analog-to-Digital Converter (ADC) peripheral in ATtiny817 features a 10-bit successive approximation ADC, and is capable of a sampling rate of up to 150ksps. The ADC is connected to a 12-channel Analog Multiplexer, which allows twelve single-ended voltage inputs. The single-ended voltage inputs refer to 0V (GND). The input values can be either internal (e.g., a voltage reference) or external (connected I/O pins).

The ADC block diagram from the latest data sheet of the ATtiny817 is shown in the figure below.

Figure 3-2. ADC Block Diagram of the ATtiny817



The ADC contains a sample-and-hold circuit, which ensures that the input voltage to the ADC is held at a constant level during conversion.

Any of the ADC input pins, as well as GND and an internal voltage reference (programmable) can be selected as single ended inputs to the ADC. The ADC generates a 10-bit result, which is presented in the Result Register (ADC.RES). The result is presented right adjusted. The minimum value represents GND and the maximum value represents the reference voltage.

3.3.1 ADC Input Selection

V_{bg} (V_{REF}) can be selected as the ADC input per the table below from the MUXPOS registers of the ADC at ATtiny817.

Table 3-3. ADC Input Selected

Value	Description
0x0	AIN0
0x1	AIN1
0x2	AIN2
0x3	AIN3
0x4	AIN4
0x5	AIN5
0x6	AIN6
0x7	AIN7

Value	Description
0x8	AIN8
0x9	AIN9
0x10	AIN10
0x11	AIN11
0x1C	DAC0
0x1D	**Internal reference (from VREF peripheral)**
0x1E	Temperature sensor
0x1F	0V (GND)
Other	Reserved

The value of the V_{bg} (V_{REF}) can be selected per the table below from CTRLA register of the V_{REF} at ATtiny817.

Table 3-4. Vbg Reference Value selected

Value	Description
0x0	0.55V
0x1	**1.1V**
0x2	2.5V
0x3	4.3V
0x4	1.5V
other	Reserved

In this design, V_{bg} (1.1V) is selected as the input of the ADC for easier calculation.

3.3.2 ADC Reference Selection

The reference selection for the ATtiny817 ADC is shown in the table below. It can be configured in the ADMUX register of the ADC.

Table 3-5. ADC Reference Selection

Value	Description
0x0	Internal reference
0x1	**VDD**
Other	Reserved.

As the core idea is to let V_{CC} act as the reference of the ADC, the VDD is selected as the ADC reference in this example.

3.3.3 Code Example for ATtiny817

To quickly implement the method into a real project, generating an Atmel START Project based on the ATtiny817 is recommended.

- Connect the ATtiny817 XPRO Mini board to the computer via a Mini-USB cable
- Open Atmel Studio 7.0 and click File → New → Atmel START Example Project
- Type "ATtiny817" then select the "ATtiny817 Xplained Mini", and click "CREATE NEW PROJECT" in the window
- Select AVCC as ADC reference and 1.1V internal reference voltage as ADC input, and then click "GENERATE PROJECT"
- Type "Battery Voltage Measurement without using I/O pin on ATtiny817" as the project name
- Wait for the completion of the project generation to be finished and then locate the main.c file

The simplest way is to check or update three items based on the generated project.

1. Let V_{bg} act as ADC input.

```
ADC0.MUXPOS = ADC_MUXPOS_INTREF_gc  /* ADC internal reference, the Vbg*/;
```

2. Let V_{CC} act as ADC reference.

```
ADC0.CTRLC = ADC_PRESC_DIV2_gc /* CLK_PER divided by 2 */
            | ADC_REFSEL_VDDREF_gc /* Vdd (Vcc) be ADC reference */
            | 0 << ADC_SAMPCAP_bp /* Sample Capacitance Selection: disabled */;
```

3. Start the ADC and calculate the result.

```
float Vcc_value = 0 /* measured Vcc value */;
ADC0.CTRLA = 1 << ADC_ENABLE_bp /* ADC Enable: enabled */
        | 1 << ADC_FREERUN_bp /* ADC Free run mode: enabled */
        | ADC_RESSEL_10BIT_gc /* 10-bit mode */;
ADC0.COMMAND |= 1; // start running ADC
while(1) {
        if (ADC0.INTFLAGS)
        {
            Vcc_value = ( 0x400 * 1.1 ) / ADC0.RES /* calculate the Vcc value */;
        }
    }
```

3.3.4 Result Validation

By setting a break-point at the calculation code and adding the V_{CC} value in the watch window, the V_{CC} value can be viewed in the watch window.

To verify if the measured result V_{CC}_value (5.006222V) is correct, the users can use a multimeter to measure the V_{CC} of the XPRO Mini board. In this example, the real V_{CC} value of the board, measured by a multimeter, is V_{CC} = 4.96V.

4. Appendix

In this chapter, the users will find an overview of tinyAVR and megaAVR devices showing whether they can support this method or not.

Table 4-1. tinyAVR Device List

ATtiny devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATtiny4	No	n/a	n/a	Not available
ATtiny5	Yes	n/a	Yes	Not available
ATtiny9	No	n/a	n/a	Not available
ATtiny10	Yes	No	Yes	Not available
ATtiny416	Yes	Yes, 1.1V	Yes	OK
ATtiny816	Yes	Yes, 1.1V	Yes	OK
ATtiny417	Yes	Yes, 1.1V	Yes	OK
ATtiny817	Yes	Yes, 1.1V	Yes	OK
ATtiny814	Yes	Yes, 1.1V	Yes	OK
ATtiny102	Yes	n/a	Yes	Not available
ATtiny104	Yes	n/a	Yes	Not available
ATtiny13	Yes	n/a	Yes	Not available
ATtiny13V	Yes	n/a	Yes	Not available
ATtiny13A	Yes	n/a	Yes	Not available
ATtiny20	Yes	Yes, 1.1V	Yes	OK
ATtiny24	Yes	Yes, 1.1V	Yes	OK
ATtiny44	Yes	Yes, 1.1V	Yes	OK
ATtiny84	Yes	Yes, 1.1V	Yes	OK
ATtiny24A	Yes	Yes, 1.1V	Yes	OK
ATtiny44A	Yes	Yes, 1.1V	Yes	OK
ATtiny84A	Yes	Yes, 1.1V	Yes	OK
ATtiny25	Yes	Yes, 1.1V	Yes	OK
ATtiny45	Yes	Yes, 1.1V	Yes	OK
ATtiny85	Yes	Yes, 1.1V	Yes	OK
ATtiny26	Yes	Yes, 1.18V	Yes	OK
ATtiny28L	No	n/a	n/a	Not available
ATtiny28V	No	n/a	n/a	Not available
ATtiny40	Yes	Yes, 1.1V	Yes	OK

ATtiny devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATtiny43U	Yes	Yes, 1.1V	Yes	OK
ATtiny48	Yes	Yes, 1.1V	Yes	OK
ATtiny88	Yes	Yes, 1.1V	Yes	OK
ATtiny87	Yes	Yes, 1.1V	Yes	OK
ATtiny167	Yes	Yes, 1.1V	Yes	OK
ATtiny261A	Yes	Yes, 1.1V	Yes	OK
ATtiny461A	Yes	Yes, 1.1V	Yes	OK
ATtiny861A	Yes	Yes, 1.1V	Yes	OK
ATtiny261	Yes	Yes, 1.1V	Yes	OK
ATtiny461	Yes	Yes, 1.1V	Yes	OK
ATtiny861	Yes	Yes, 1.1V	Yes	OK
ATtiny828	Yes	Yes, 1.1V	Yes	OK
ATtiny441	Yes	Yes, 1.1V	Yes	OK
ATtiny841	Yes	Yes, 1.1V	Yes	OK
ATtiny2313	No	n/a	n/a	Not available
ATtiny2313A	No	n/a	n/a	Not available
ATtiny4313	No	n/a	n/a	Not available
ATtiny1634	Yes	Yes, 1.1V	Yes	OK

Table 4-2. megaAVR Device List

ATmega devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATmega48PB	Yes	Yes, 1.1V	Yes	OK
ATmega88PB	Yes	Yes, 1.1V	Yes	OK
ATmega168PB	Yes	Yes, 1.1V	Yes	OK
ATmega48	Yes	Yes, 1.1V	Yes	OK
ATmega88	Yes	Yes, 1.1V	Yes	OK
ATmega168	Yes	Yes, 1.1V	Yes	OK
ATmega48A	Yes	Yes, 1.1V	Yes	OK
ATmega88A	Yes	Yes, 1.1V	Yes	OK
ATmega168A	Yes	Yes, 1.1V	Yes	OK
ATmega48P	Yes	Yes, 1.1V	Yes	OK
ATmega88P	Yes	Yes, 1.1V	Yes	OK
ATmega168P	Yes	Yes, 1.1V	Yes	OK

ATmega devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATmega48PA	Yes	Yes, 1.1V	Yes	OK
ATmega88PA	Yes	Yes, 1.1V	Yes	OK
ATmega168PA	Yes	Yes, 1.1V	Yes	OK
ATmega8	Yes	Yes, 1.3V	Yes	OK
ATmega8515	No	n/a	n/a	Not available
ATmega8535	Yes	Yes, 1.22V	Yes	OK
ATmega324PB	Yes	Yes, 1.1V	Yes	OK
ATmega8A	Yes	Yes, 1.3V	Yes	OK
ATmega16	Yes	Yes, 1.22V	Yes	OK
ATmega16A	Yes	Yes, 1.22V	Yes	OK
ATmega162	No	n/a	n/a	Not available
ATmega164A	Yes	Yes, 1.1V	Yes	OK
ATmega164P	Yes	Yes, 1.1V	Yes	OK
ATmega164PA	Yes	Yes, 1.1V	Yes	OK
ATmega165P	Yes	Yes, 1.1V	Yes	OK
ATmega165A	Yes	Yes, 1.1V	Yes	OK
ATmega165PA	Yes	Yes, 1.1V	Yes	OK
ATmega325A	Yes	Yes, 1.1V	Yes	OK
ATmega325PA	Yes	Yes, 1.1V	Yes	OK
ATmega3250A	Yes	Yes, 1.1V	Yes	OK
ATmega3250PA	Yes	Yes, 1.1V	Yes	OK
ATmega645A	Yes	Yes, 1.1V	Yes	OK
ATmega645P	Yes	Yes, 1.1V	Yes	OK
ATmega6450A	Yes	Yes, 1.1V	Yes	OK
ATmega6450P	Yes	Yes, 1.1V	Yes	OK
ATmega32	Yes	Yes, 1.22V	Yes	OK
ATmega325	Yes	Yes, 1.1V	Yes	OK
ATmega3250	Yes	Yes, 1.1V	Yes	OK
ATmega645	Yes	Yes, 1.1V	Yes	OK
ATmega6450	Yes	Yes, 1.1V	Yes	OK
ATmega324P	Yes	Yes, 1.1V	Yes	OK
ATmega324A	Yes	Yes, 1.1V	Yes	OK

ATmega devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATmega324PA	Yes	Yes, 1.1V	Yes	OK
ATmega325P	Yes	Yes, 1.1V	Yes	OK
ATmega3250P	Yes	Yes, 1.1V	Yes	OK
ATmega328	Yes	Yes, 1.1V	Yes	OK
ATmega328P	Yes	Yes, 1.1V	Yes	OK
ATmega328PB	Yes	Yes, 1.1V	Yes	OK
ATmega32A	Yes	Yes, 1.22V	Yes	OK
ATmega64	Yes	Yes, 1.22V	Yes	OK
ATmega640	Yes	Yes, 1.1V	Yes	OK
ATmega1280	Yes	Yes, 1.1V	Yes	OK
ATmega1281	Yes	Yes, 1.1V	Yes	OK
ATmega2560	Yes	Yes, 1.1V	Yes	OK
ATmega2561	Yes	Yes, 1.1V	Yes	OK
ATmega1284	Yes	Yes, 1.1V	Yes	OK
ATmega1284P	Yes	Yes, 1.1V	Yes	OK
ATmega128	Yes	Yes, 1.23V	Yes	OK
ATmega128A	Yes	Yes, 1.22V	Yes	OK
ATmega644	Yes	Yes, 1.1V	Yes	OK
ATmega644A	Yes	Yes, 1.1V	Yes	OK
ATmega644P	Yes	Yes, 1.1V	Yes	OK
ATmega644PA	Yes	Yes, 1.1V	Yes	OK
ATmega64A	Yes	Yes, 1.22V	Yes	OK
AT90CAN128	Yes	Yes, 1.1V	Yes	OK
AT90CAN64	Yes	Yes, 1.1V	Yes	OK
AT90CAN32	Yes	Yes, 1.1V	Yes	OK
ATmega16M1	Yes	Yes, 1.1V	Yes	OK
ATmega32M1	Yes	Yes, 1.1V	Yes	OK
ATmega64M1	Yes	Yes, 1.1V	Yes	OK
AT90PWM1	Yes	Yes, 1.1V	Yes	OK
AT90PWM2B	Yes	Yes, 1.1V	Yes	OK
AT90PWM3B	Yes	Yes, 1.1V	Yes	OK
AT90PWM216	Yes	Yes, 1.1V	Yes	OK

ATmega devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
AT90PWM316	Yes	Yes, 1.1V	Yes	OK
AT90PWM81	Yes	Yes, 1.1V	Yes	OK
AT90PWM161	Yes	Yes, 1.1V	Yes	OK
AT90USB82	No	n/a	n/a	Not available
AT90USB162	No	n/a	n/a	Not available
AT90USB646	Yes	Yes, 1.1V	Yes	OK
AT90USB647	Yes	Yes, 1.1V	Yes	OK
AT90USB1286	Yes	Yes, 1.1V	Yes	OK
AT90USB1287	Yes	Yes, 1.1V	Yes	OK
ATmega16U4	Yes	Yes, 1.1V	Yes	OK
ATmega32U4	Yes	Yes, 1.1V	Yes	OK
ATmega8U2	No	n/a	n/a	Not available
ATmega16U2	No	n/a	n/a	Not available
ATmega32U2	No	n/a	n/a	Not available
ATmega169P	Yes	Yes, 1.1V	Yes	OK
ATmega169PV	Yes	Yes, 1.1V	Yes	OK
ATmega169A	Yes	Yes, 1.1V	Yes	OK
ATmega169PA	Yes	Yes, 1.1V	Yes	OK
ATmega329A	Yes	Yes, 1.1V	Yes	OK
ATmega329PA	Yes	Yes, 1.1V	Yes	OK
ATmega3290A	Yes	Yes, 1.1V	Yes	OK
ATmega3290PA	Yes	Yes, 1.1V	Yes	OK
ATmega649A	Yes	Yes, 1.1V	Yes	OK
ATmega649P	Yes	Yes, 1.1V	Yes	OK
ATmega649PA	Yes	Yes, 1.1V	Yes	OK
ATmega6490A	Yes	Yes, 1.1V	Yes	OK
ATmega6490P	Yes	Yes, 1.1V	Yes	OK
ATmega329	Yes	Yes, 1.1V	Yes	OK
ATmega3290	Yes	Yes, 1.1V	Yes	OK
ATmega649	Yes	Yes, 1.1V	Yes	OK
ATmega6490	Yes	Yes, 1.1V	Yes	OK

ATmega devices	Have ADC	V_{bg} as input	V_{CC} as V_{REF}	Conclusion
ATmega329P	Yes	Yes, 1.1V	Yes	OK
ATmega3290P	Yes	Yes, 1.1V	Yes	OK

5. Revision History

Doc. Rev.	Date	Comments
A	05/2017	Initial document release.

The Microchip Web Site

Microchip provides online support via our web site at http://www.microchip.com/. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **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 (FAQ), technical support requests, online discussion groups, Microchip consultant 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

Customer Change Notification Service

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

To register, access the Microchip web site at http://www.microchip.com/. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or Field Application Engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://www.microchip.com/support

Microchip Devices Code Protection Feature

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

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.

ISBN: 978-1-5224-1761-3

Quality Management System Certified by DNV

ISO/TS 16949

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://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

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-3326-8000
Fax: 86-21-3326-8021

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
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

France - Saint Cloud
Tel: 33-1-30-60-70-00

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

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: 47-7289-7561

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