

# PIC® and AVR® IoT

# PIC® and AVR® IoT – Transceiving Data with AWS User Guide

#### Introduction

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**Important:** This user guide is a part of a series of tutorials originally published in the Microchip IoT Developer Guides repository on GitHub. The repository has more tutorials and information about using a PIC® or AVR® IoT Board with AWS.

In this tutorial, it will be showcased how the AVR-IoT and PIC-IoT Development Boards can be configured to communicate with the cloud using Amazon Web Services® (AWS) and the MQTT messaging protocol.

It will be demonstrated how a an example application can be developed where a network of IoT devices are configured to blink their LEDs whenever a button is pressed on any of them. Detailed step-by-step instructions will be provided and relevant concepts will also be covered when needed.

The primary goal of this tutorial is for the reader to experience how to develop their own applications with the AVR-IoT and PIC-IoT Development Boards.

#### **Prerequisites**

It is assumed that the reader has already provisioned their PIC-IoT and/or AVR-IoT Development Board(s) to communicate with their own AWS account, as described in the previous tutorial: Connect the Board to your AWS Account

Before starting this tutorial, make sure that IoT device(s) are successfully sending sensor data to AWS IoT Core. It is also assumed that the reader has installed the MPLAB® X IDE and the XC8 (AVR-IoT) or XC16 (PIC-IoT) compiler.

Links to software and other useful tools and guides are provided in the Resources section at the end of this tutorial.



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#### 1. A Brief Introduction to the Firmware of the IoT Boards

The firmware that is pre-loaded onto the PIC-IoT and AVR-IoT Development Boards is available on GitHub and will form the starting point for the example application that will be designed in this tutorial. The MPLAB X projects for the different microcontroller families can be found here:

- GitHub repository for the PIC-IoT Development Boards
- GitHub repository for the AVR-IoT Development Boards

The PICIOT.X and AVRIOT.X projects contain many different files that handle cryptography, Wi-Fi connectivity, MQTT communication, and so on. The main focus of this tutorial will be application\_manager.c, which is located under Source Files -> MCC Generated Files in MPLAB X. This file contains a lot of useful high-level functions that make it easy to develop an AWS application.

Here is a summary of some important functions in application manager.c that is relevant for this tutorial:

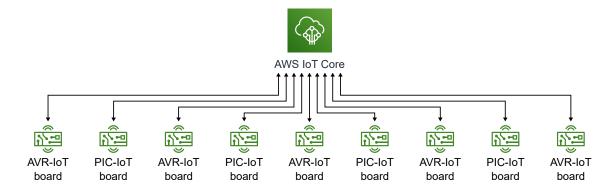
- subscribeToCloud
  - Defines which MQTT topics the IoT board should be subscribed to and which functions should be run when
    messages are received to these topics. In the unmodified PICIOT.X and AVRIOT.X projects, the board is
    only subscribed to its device shadow update MQTT topic, and receivedFromCloud is the function
    specified to handle these updates.
- receivedFromCloud
  - Runs when an MQTT shadow update message is received in the unmodified PICIOT.X or AVRIOT.X
    projects. This function analyzes the message and performs some action based on its contents. It then calls
    the updateDeviceShadow function to acknowledge that the shadow update has been received.
- sendToCloud
  - Called every second to send sensor data to the cloud as MQTT messages. This function is a good template
    to learn how to send custom MQTT messages to custom MQTT topics using the IoT boards.

The reader is encouraged to take a quick look at application\_manager.c, and in particular, at these functions to get an overview of the existing functionality.

# 2. Implementing the Example Application

In this example, it will be demonstrated how devices can be configured to send and receive messages over custom MQTT topics. An example application will be implemented where button presses on any of the configured devices will cause all devices to flash their LEDs. All communication will be sent between the IoT boards and AWS IoT Core, as illustrated in the schematic below. No direct device-to-device communication will be used.

Figure 2-1. Flowchart showing how information flows



#### 2.1 Step 1: Start With an Unmodified Version of the Github Project

The starting point for this example is an unmodified copy of the GitHub project that is compatible with the microcontroller family of the device that will be used:

- · GitHub repository for the PIC-IOT Development Boards
- · GitHub repository for the AVR-IOT Development Boards

Download the correct repository and open the PICIoT.X and/or AVRIoT.X project in MPLAB X.

### 2.2 Step 2: Sending MQTT Messages to the Cloud

The first thing to do is to detect when a button is pressed, which will be done using interrupts. The procedures for this differ somewhat for AVR-IoT and PIC-IoT boards. Follow Procedures for AVR-IoT boards or Procedures for PIC-IoT boards, depending on which board you are using, and then continue with Procedures for both AVR-IoT and PIC-IoT boards.

#### **Procedures for AVR-IoT Boards**

In application\_manager.c, add the following code just after the  ${\tt SYSTEM\_Initialize}$  () call in the application\_init function:

```
SW0_EnableInterruptForFallingEdge();
PORTF_SW0_SetInterruptHandler(sendButtonPressToCloud);
```

The first line enables falling edge interrupt detection for the SWO button on the AVR-IoT boards, and a function handler for this interrupt is then assigned on the second line. The interested reader is encouraged to take a look at the pin manager.c file to see how these functions are implemented.

Skip ahead to Procedures for both AVR-IoT and PIC-IoT boards to complete this step.

#### **Procedures for PIC-IoT Boards**

In pin\_manager.c, perform the following edits:

# Implementing the Example Application

1. In the PIN\_MANAGER\_initialize function, enable interrupts for the SWO button (which is connected to RA7) and clear its interrupt flag by including these two lines:

2. Add another variable below the INT\_InterruptHandler variable to store the interrupt handler for the SWO hardware button:

```
void (*SW0_InterruptHandler)(void) = NULL;
```

Add a function that sets the variable we just created (place it just after the INT\_SetInterruptHandler function):

```
void SW0_SetInterruptHandler(void (* InterruptHandler)(void))
{
    IEC1bits.IOCIE = 0; //Disable IOCI interrupt
    SW0_InterruptHandler = InterruptHandler;
    IEC1bits.IOCIE = 1; //Enable IOCI interrupt
}
```

4. Modify the \_IOCInterrupt interrupt service routine to also handle the SW0 button presses (the interrupt service routine is located near line 155 in pin\_manager.c). The SW0 button is connected to the RA7 pin. The fully modified interrupt service routine is provided below. Either copy and replace \_IOCInterrupt in its entirety or add the second nested if statement to your project.

In pin\_manager.h, add a declaration of the SWO\_SetInterruptHandler function that was just added to make it available in other files, for example after the declaration of the INT\_SetInterruptHandler function:

```
void SW0_SetInterruptHandler(void (* InterruptHandler)(void));
```

In application\_manager.c, set the SWO interrupt handler just after the call to the SYSTEM\_Initialize() in the application init function:

```
// Set interrupt handler for button presses
SWO_SetInterruptHandler(sendButtonPressToCloud);
```

#### Procedures for Both AVR-IoT and PIC-IoT Boards

Now, any time the SWO button is pressed, the <code>sendButtonPressToCloud</code> function will be called. Prior to implementing this function, declare a variable for the MQTT topic that will be used. Add the following declaration to application <code>manager.c</code> (e.g., below the declaration of the <code>mqttSubscribeTopic</code> variable):

```
char tutorialMqttSubscribeTopic[SUBSCRIBE_TOPIC_SIZE];
```

Implement the aforementioned function handler by adding the following code to application manager.c:

```
static void sendButtonPressToCloud(){
    // Ensure that we have a valid cloud connection
    if (shared_networking_params.haveAPConnection)
    {
        static char tutorialPayload[PAYLOAD_SIZE];
        int tutorialLen = 0;

        // Set MQTT topic
        memset((void*)tutorialMqttSubscribeTopic, 0, sizeof(tutorialMqttSubscribeTopic));
        sprintf(tutorialMqttSubscribeTopic, "buttonPresses");

        // Construct payload
        tutorialLen = sprintf(tutorialPayload,"{\"thing_name\":\"%s\"}", cid);

        // Publish data to cloud
        CLOUD_publishData((uint8_t*)tutorialMqttSubscribeTopic, (uint8_t*)tutorialPayload,
        tutorialLen);
    }
}
```

This function closely resembles the <code>sendToCloud</code> function that was mentioned earlier and will publish an MQTT message to the <code>buttonPresses</code> topic. The content of the message will be a JSON object that contains the name of the thing/device that sent the message.

Build the modified project and program it onto the device using MPLAB X. This is done by clicking on the **Make and Program Device Main Project** button on the MPLAB X toolbar (see the image below).

#### Figure 2-2. How to make and program device in MPLAB X



If you are unfamiliar with the MPLAB X integrated developer environment (IDE), check out the following guide: Get Started with MPLAB® X IDE and Microchip Tools

#### Verify that Messages are Successfully Being Sent to AWS

When the device has been successfully programmed, the next step is to make sure that messages are being received in AWS:

- 1. Sign in to the AWS Management Console and select the IoT Core service.
- 2. Select **Test** in the menu on the left-hand side
- 3. In the Subscription topic field, enter buttonPresses.
- 4. Click the **Subscribe to topic** button.
- 5. Press the SW0 button on the board and observe that the button press is successfully registered in the cloud.

# 2.3 Step 3: Receiving MQTT Messages from the Cloud

Now that the project has been successfully modified to send messages to a custom topic, it is time to find a way to subscribe to this topic:

1. Change the definition of NUM\_TOPICS\_SUBSCRIBE in mqtt\_config.h (Header Files -> MCC Generated Files -> config) to allow up to two simultaneous MQTT topic subscriptions:

```
#defineNUM TOPICS SUBSCRIBE2
```

# Implementing the Example Application

2. Edit the subscribeToCloud function in application\_manager.c to include a subscription to the buttonPresses topic. The fully modified function is provided below. Either copy and replace the subscribeToCloud function in its entirety or add the last two lines of the code below in your MPLAB X project.

```
staticvoidsubscribeToCloud(void)
{
    sprintf(mqttSubscribeTopic, "$aws/things/%s/shadow/update/delta", cid);
    CLOUD_registerSubscription((uint8_t*)mqttSubscribeTopic, receivedFromCloud);
    sprintf(tutorialMqttSubscribeTopic, "buttonPresses");

CLOUD_registerSubscription((uint8_t*)tutorialMqttSubscribeTopic, receiveButtonPressFromCloud);
}
```

- The second parameter of the CLOUD\_registerSubscription function is a handler that dictates which
  function will be run when a message is received to the specified topic. The
  receiveButtonPressFromCloud function will therefore have to be implemented to handle any
  received messages.
- 3. Add the following function definition to application\_manager.c (somewhere above the subscribeToCloud function) to make the device's LEDs blink twice when a message is received:

```
staticvoidreceiveButtonPressFromCloud(uint8_t *topic, uint8_t *payload) {
    LED_test();
    LED_test();
}
```

4. Build the project and program the device in MPLAB X. If multiple AVR-IoT or PIC-IoT devices are available, try programming several of them using the same project.

Remember that all of the devices first will have to be provisioned for use with an AWS account. Note also that even though AVR-IoT and PIC-IoT devices can be connected to AWS simultaneously and communicate with each other over MQTT, the GitHub project used in this tutorial is only compatible with either AVR-IoT devices or PIC-IoT devices. To use devices from two different device families together, it is necessary to complete this tutorial individually for the AVR-IoT and PIC-IoT repositories on GitHub and program the devices with the compatible firmware.

The device(s) should now be configured correctly. If the SWO button is pressed on any of the configured IoT kits, the LEDs on all configured IoT kits should blink twice. If this is not the case, make sure that the tutorial has been followed correctly and that the devices are properly conditioned.

# 3. Resources

- PIC-IoT WA Development Board Product Page
- AVR-IoT WA Development Board Product Page
- Get Started with MPLAB® X IDE and Microchip Tools
- AWS IoT Developer Guide
- IoT Provisioning Tool
- GitHub repositories with the IoT Boards' pre-loaded firmware:
  - For the PIC-IoT Development Boards
  - For the AVR-IoT Development Boards

# 4. Revision History

Revision	Date	Description
A	08/2020	Initial document release

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ISBN: 978-1-5224-6655-0

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Detroit   Tel: 86-186-6233-1526   Tel: 886-2-2508-8600   Tel: 39-0331-742611   Novi, MI   China - Wuhan   Tel: 86-27-5980-5300   Tel: 66-2-694-1351   Italy - Padova   Houston, TX   China - Xian   Vietnam - Ho Chi Minh   Tel: 39-049-7625286   Tel: 86-29-8833-7252   Tel: 86-29-8833-7252   Tel: 86-29-8833-7252   Tel: 86-29-8833-7252   Tel: 84-28-5448-2100   Netherlands - Drunen   Tel: 31-416-690399   Fax: 31-416-690340   Tel: 31-773-8323   China - Zhuhai   Tel: 31-773-5453   Tel: 86-756-3210040   Tel: 86-756-3210040   Tel: 86-756-3210040   Tel: 951-273-7800   Tel: 631-435-6000   San Jose, CA   Tel: 408-735-9110   Tel: 408-735-9110   Tel: 408-335-9110   Tel: 408-345-900   Fax: 44-118-921-5800   Tel: 905-695-1980   Tel: 905-705-705-705-705	Tel: 972-818-7423	Tel: 86-755-8864-2200		Tel: 972-9-744-7705
Detroit	Fax: 972-818-2924	China - Suzhou	Taiwan - Taipei	Italy - Milan
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Houston, TX	Tel: 248-848-4000	Tel: 86-27-5980-5300	Tel: 66-2-694-1351	Italy - Padova
Indianapolis	Houston, TX	China - Xian	Vietnam - Ho Chi Minh	Tel: 39-049-7625286
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