
ARC labs handbook

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OVERVIEW

This is a handbook for ARC labs which is a part of ARC university courses. It's written to help students who attend the ARC university courses and anyone who is interested in DesignWare® ARC® processors to get started in DesignWare® ARC® processors processor development. It describes all the basic elements of ARC labs and how to finish the labs with step by step approach.

This book can be used as a Lab teaching material for ARC university courses at undergraduate or graduate level with majors in Computer Science, Computer Engineering, Electrical Engineering; or for professional engineers.

This handbook includes 12 labs currently (more labs will be added in the future), which can be classified into 3 levels:

- Level1: ARC basic

The labs in this level cover the basic topics about DesignWare® ARC® processors, e.g., the installation of tools, hello world, interrupts, timers and so on.

- Level2: ARC advance

The labs in this level cover the advanced topics about DesignWare® ARC® processors, e.g., RTOS, customized linkage, ARC DSP and so on.

- Level3: ARC exploration

The labs in this level will cover some complex applications, e.g., IoT application, embedded machine learning and so on.

Most of labs are based on the embARC Open Software Platform (OSP) is an open software platform to facilitate the development of embedded systems based on DesignWare® ARC® processors.

It is designed to provide a unified platform for DesignWare® ARC® processors users by defining consistent and simple software interfaces to the processor and peripherals, together with ports of several well known FOSS embedded software stacks to DesignWare® ARC® processors.

For more details about embARC OSP, please refer its [online docs](#)

1.1 Supported Hardware Platform

The following hardware platforms are supported in this handbook:

- [ARC EM Starter Kit](#)
- [ARC IoT Development Kit](#)

You can go to the specific link to get the board's data sheet and user manual

1.2 Reference

Here is reference for this hand book.

Item	Name
1	ARC EM Databook
2	MetaWare docs
3	ARC EM Starter Kit User Guide
4	ARC GNU docs

GETTING STARTED

Use this guide to get started with your ARC labs development.

2.1 Software Requirement

- **ARC Development Tools** Choose **MetaWare Toolkit** and/or **ARC GNU Toolchain** from the following list according to your requirement.
 - MetaWare Toolkit
 - * **Premium MetaWare Development Toolkit (2017.09)** The DesignWare ARC MetaWare Development Toolkit builds upon a 25-year legacy of industry-leading compiler and debugger products. It is a complete solution that contains all the components needed to support the development, debugging and tuning of embedded applications for the DesignWare ARC processors.
 - * **DesignWare ARC MetaWare Toolkit Lite (2017.09)** A demonstration/evaluation version of the MetaWare Development Toolkit is available for free from the Synopsys website. MetaWare Lite is a functioning demonstration of the MetaWare Development Toolkit, but has a number of restrictions, including a code-size limit of 32 Kilobytes and no runtime library sources. It is available for Microsoft Windows only.
 - ARC GNU Toolchain
 - * **Open Source ARC GNU IDE (2017.09)** The ARC GNU Toolchain offers all of the benefits of open source tools, including complete source code and a large install base. The ARC GNU IDE Installer consists of Eclipse IDE with **ARC GNU plugin for Eclipse**, **ARC GNU prebuilt toolchain** and **OpenOCD for ARC**
- **Digilent Adept Software** for Digilent JTAG-USB cable driver. All the supported boards are equipped with on board USB-JTAG debugger, so just one USB cable is required, no need for external debugger.
- **Tera Term** or **PuTTY** for serial terminal connection, 115200 baud, 8 bits data, 1 stop bit and no parity (115200-8-N-1) by default.

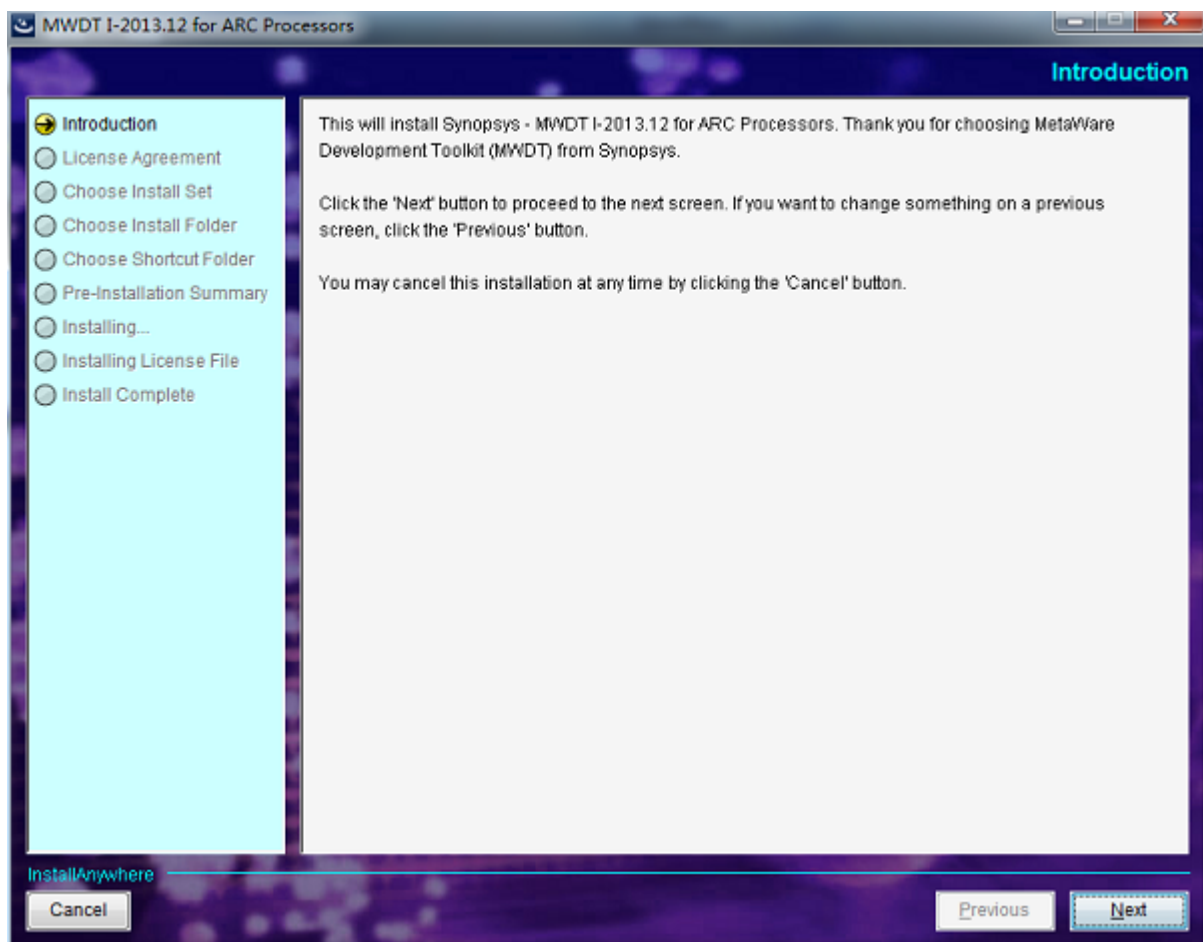
Note: If using embARC with GNU toolchain on Windows, install **Zadig** to replace FTDI driver with WinUSB driver. See **How to Use OpenOCD on Windows** for more information.

2.2 Install Software Tools

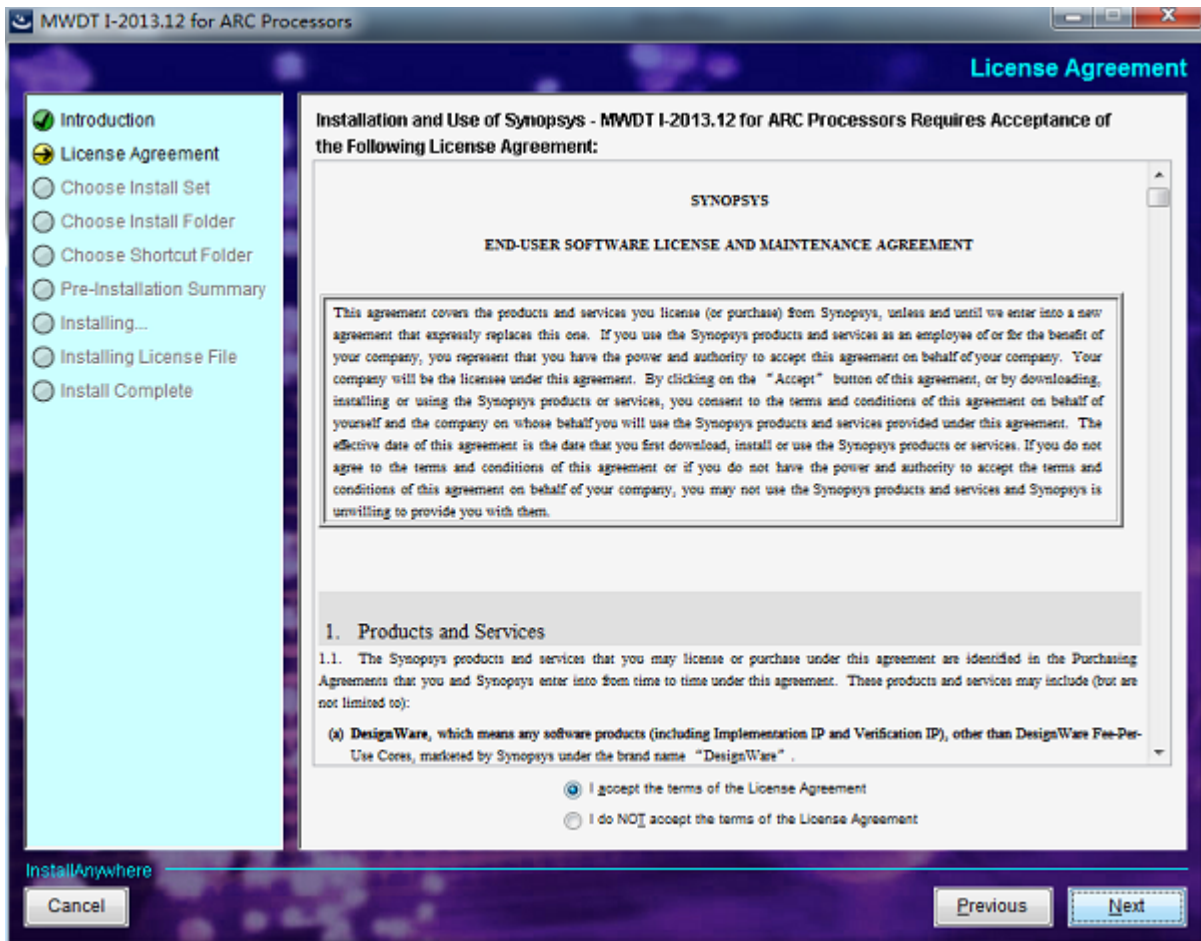
2.2.1 Install Metaware Toolkit

Here we will start install MetaWare Development Toolkit (2017.09).

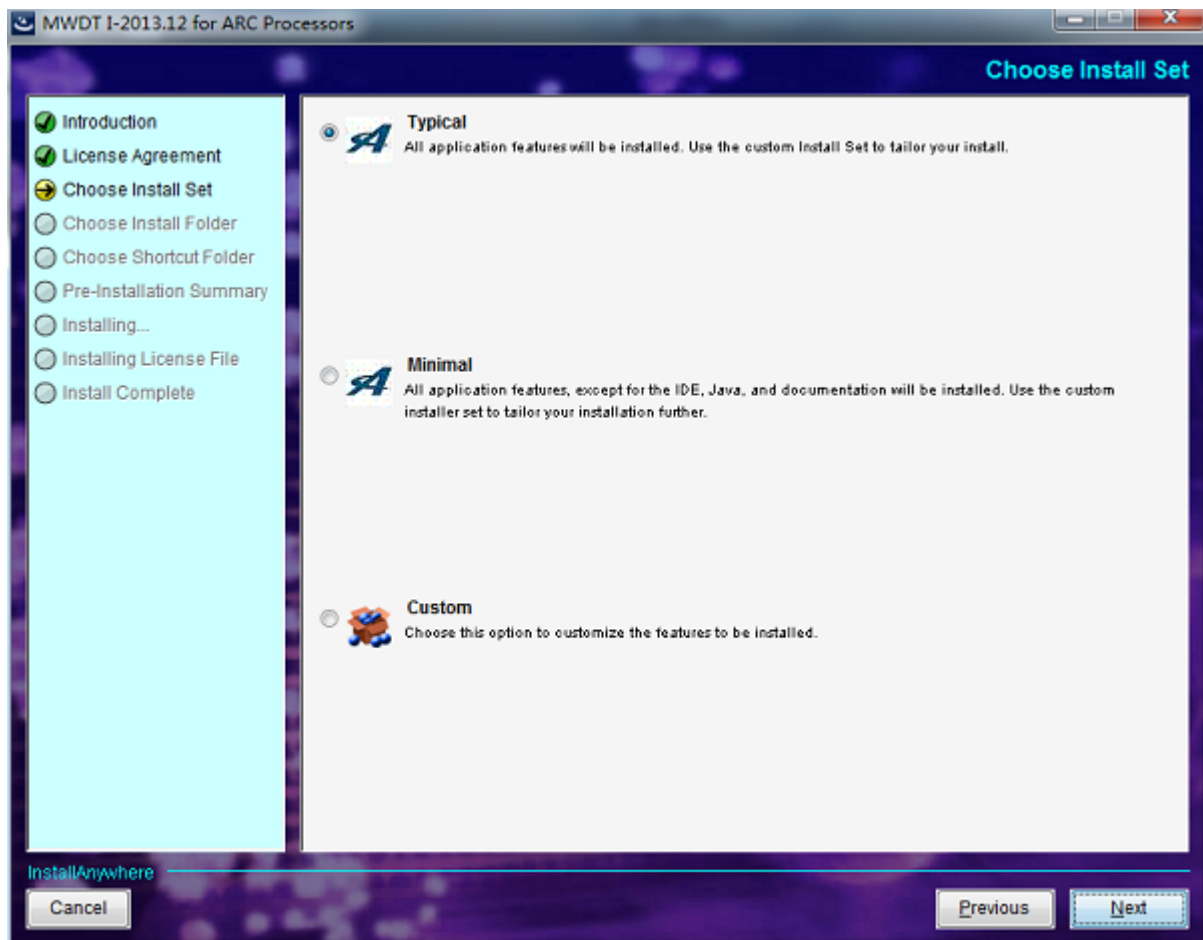
1. Double click the **mw_dekit_arc_i_2017_09_win_install.exe**, it will show



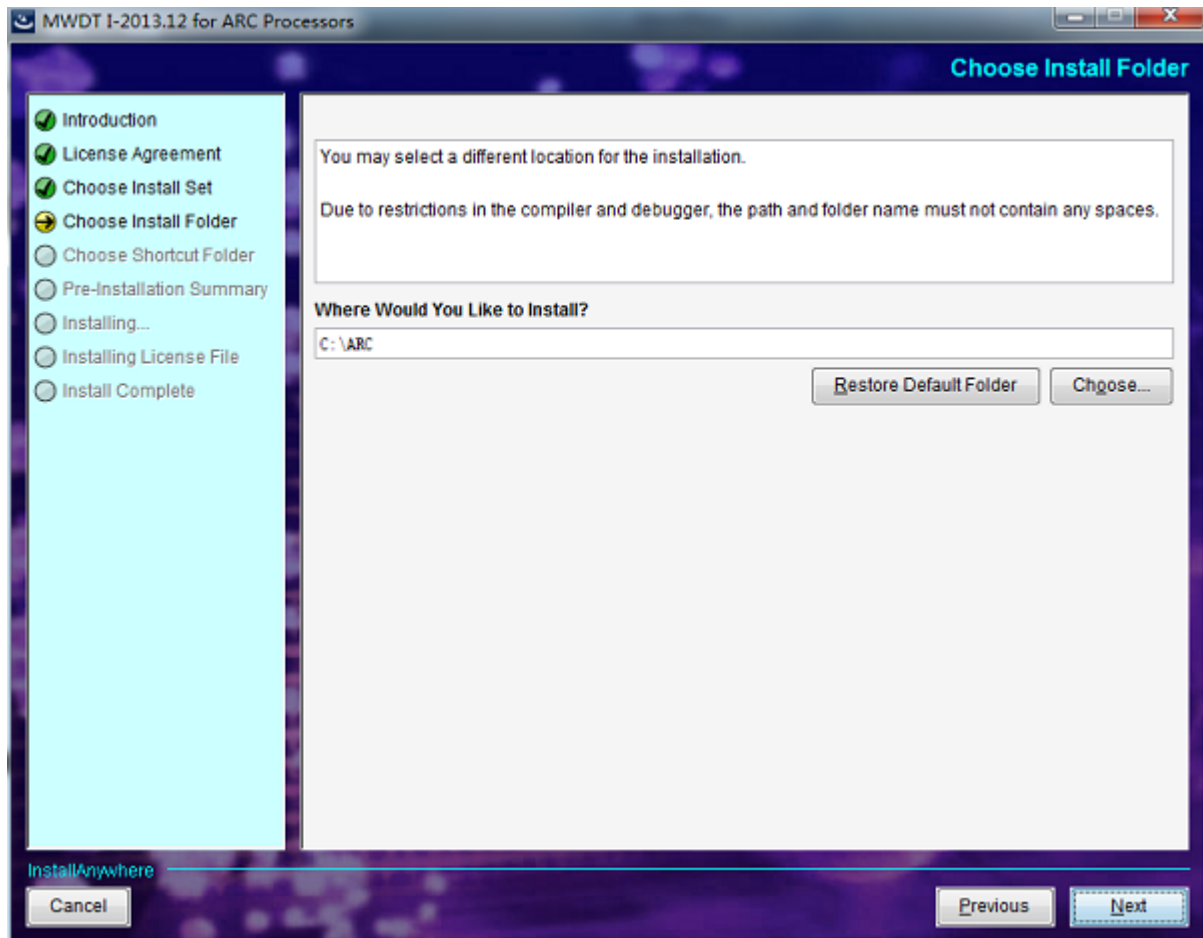
2. Click next, choose I accept, continue to click next



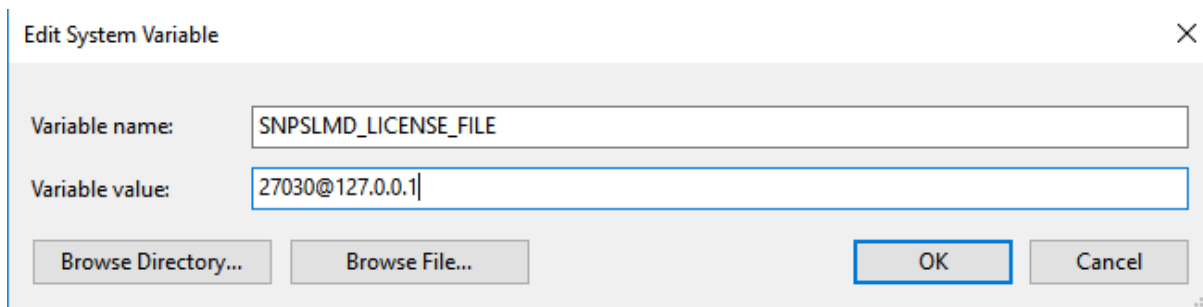
3. Choose Typical installation, then click next



4. Set the install path (please use English letters only and no space), then click next until the installation is finished



5. Set the license file (SNPSLMD_LICENSE_FILE) for MetaWare Development Toolkit. It can be a real file containing license, also can be a license server
 - For Windows, go to Computer->property->Advanced->Environment Variables->System Variables->New to Set



- For Linux, please add SNPSLMD_LICENSE_FILE into your system variables

6. Test the MetaWare Development Toolkit and its license

Open cmd.exe in Windows and find the queens.c in the installation folder of MetaWare Development Toolkit, e.g., **C:\ARCMetaWare\arc\demos\queens.c**. Type the following commands in cmd

```
# On Windows
cd C:\ARC\MetaWare\arc\demos
mcc queens.c
```

If you get the following message and no error, it means MetaWare Development Toolkit is successfully installed and license is ok.

```
MetaWare C Compiler N-2017.09 (build 005)      Serial 1-799999.
(c) Copyright 1987-2017, Synopsys, Inc.
MetaWare ARC Assembler N-2017.09 (build 005)
(c) Copyright 1996-2017, Synopsys, Inc.
MetaWare Linker (ELF/ARCompact) N-2017.09 (build 005)
(c) Copyright 1995-2017, Synopsys, Inc.
```

2.2.2 Install ARC GNU Toolchain

2.2.3 Install embARC OSP

2.2.4 Install USB-JTAG Drivers

2.3 Final Check

Check the following items and set development environment.

- Make sure the paths of the above required tools for the MetaWare toolkit and ARC GNU toolchain are added to the system variable **PATH** in your environment variables.
- We recommend users to install ARC GNU IDE to default location. Otherwise you need to make additional changes as below.
 - If running and debugging embARC applications using **arc-elf32-gdb** and **OpenOCD for ARC**, make sure 1) the path of **OpenOCD** is added to the **PATH** in your environment variables, and 2) modify **OPENOCD_SCRIPT_ROOT** variable in `<embARC>/options/toolchain/toolchain_gnu.mk` according to your **OpenOCD** root path.
 - If running GNU program with using the GNU toolchain on Linux, modify the **OpenOCD** configuration file as Linux format with LF line terminators. **dos2unix** can be used to convert it.

Note: Check the version of your toolchain. The embARC software build system is purely makefile-based. make/gmake is provided in the MetaWare toolkit (gmake) and ARC GNU toolchain (make)

3.1 Overview

3.2 Labs

3.2.1 Level 1 Labs

How to use ARC IDE

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How to use embARC OSP

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ARC features: timer and auxiliary registers

Purpose

- To learn the timer resource of ARC EM processor

- To learn how to use the auxiliary registers to control the timer
- Read the count value of the timer, and implement a time clock by the timer

Equipment

PC, IoTDK, embARC OSP, example \Lab\timer in embARC OSP

Content

Read the auxiliary registers of ARC EM to get the version and other setting information of the timer resource. As all the EM processors have **Timer0**, we use the **Timer0** in this lab, and write the auxiliary registers to initialize, start and stop the timer. By reading the count value of the timer, we can calculate the execution time of a code block with the count value and the clock frequency.

Principles

Introduction of timer and auxiliary registers

The timers in ARC EM processor

- Two 32-bits programmable timers **Timer0** and **Timer1**
- One 64-bits **RTC**(Real-Time Counter)

All the times are configurable, for example, there are four EM processor cores in **ARC EMSK1.1**, the configuration information are as follow.

Timer	EM4	EM4_16CR	EM4	EM4_16CR
HAS_TIMER0	1	1	1	1
HAS_TIMER1	1	0	1	0
RTC_OPTION	0	0	0	0

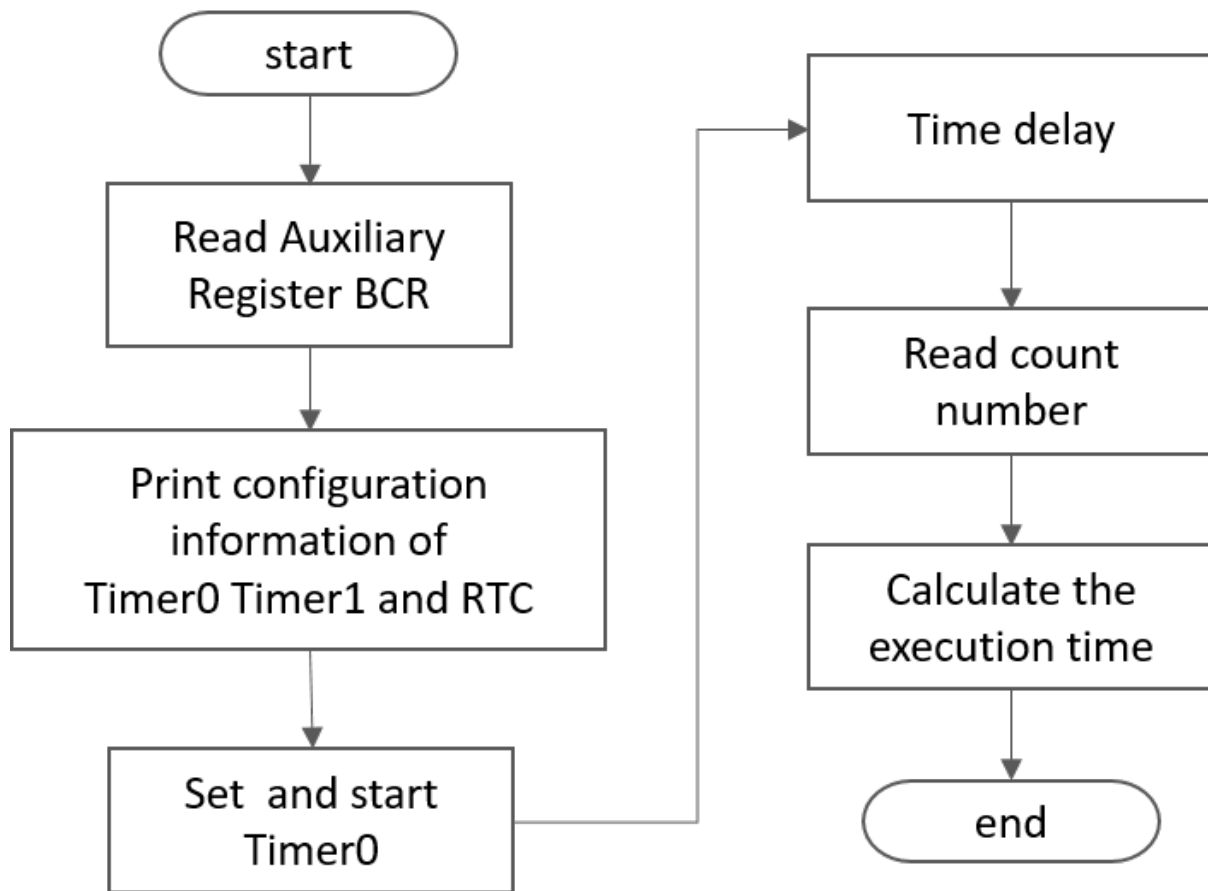
The auxiliary register Timer BCR stored the timer resource information of an EM processor core, the register address of **TIMER_BUILD** is *0x75*.

TIMER_BUILD

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESERVED								P1			P0			RESERVED				RTC	T1	T0	VERSION										

As we know the timer resources the EM processor configured, we can get the timer's configuration information and control the timers by writing and reading the auxiliary register of that timer. For example, there are the related auxiliary registers of the **Timer0**.

Auxiliary Register	Name	Permission	Description
0x21	COUNT0	RW	Processor timer 0 count value
0x22	CONTROL0	RW	Processor timer 0 control value
0x23	LIMIT0	RW	Processor timer 0 limit value

Program flow chart**Steps****Makefile configuration**

There are two ways to do the configuration.

First, configured by compile command, for example:

```
make BOARD=iotdk BD_VER=10 CUR_CORE=arcem9d -j4 TOOLCHAIN=gnu run
```

Second, configured by modifying the makefile. At here, the compile command will be very simple, for example:

```
make -j4 run
```

Open the folder *embarc_osp\example\Lab\timer*, and open the *makefile*, here is the default configuration.

```
# Application name
APPL ?= lab_3_Timer_Interrupts

##
# Current Board And Core
##
BOARD ?= iotdk
BD_VER ?= 10
CUR_CORE ?= arcem9d
```

(continues on next page)

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```
##
# Set toolchain
##
TOOLCHAIN ?= gnu

#
# root dir of embARC
#
EMBARC_ROOT = ../../..

MID_SEL = common

# application source dirs
APPL_CSRC_DIR = .
APPL_ASMSRC_DIR = .

# application include dirs
APPL_INC_DIR = .
```

- Reconfigure **BOARD** and **CUR_CORE**, in this lab, we use the launch board *iotdk*

```
##
# Current Board And Core
##
BOARD ?= iotdk
BD_VER ?= 10
CUR_CORE ?= arcem9d
```

- Reconfigure **TOOLCHAIN**, select the toolchain *gnu* or *metaware* you used

```
##
# Set toolchain
##
TOOLCHAIN ?= gnu
```

- Reconfigure **EMBARC_ROOT**, make sure the relative path between *embARC* *OSP* root folder and the *timer* folder is correct.

```
#
# root dir of embARC
#
EMBARC_ROOT = ../../..
```

Main code

Read auxiliary register **BCR_BUILD**

We can use the function `_arc_aux_read` to read the auxiliary register for the timer resource information.

Read auxiliary register **TIMER_BUILD**. In the register **TIMER_BUILD** The lower 8 bits indicate the core version information, the bit 9 indicate the **Timer0**, the bit 10 indicate the **Timer1**, the bit 11 indicate the **RTC**. Here is the code:

```
uint32_t bcr = _arc_aux_read(AUX_BCR_TIMERS);
int timer0_flag=(bcr >> 8) & 1;
int timer1_flag=(bcr >> 9) & 1;
int RTC_flag=(bcr >> 10) & 1;
```

Read timer related auxiliary registers, for example, the **Timer0**. Here is the code:


```
EMBARC_PRINTF("Does this timer0 exist?  YES\r\n");
/*Read auxiliary register configuration information*/
EMBARC_PRINTF("timer0's operating mode:0x%08x\r\n",_arc_aux_read(AUX_TIMER0_CTRL));
EMBARC_PRINTF("timer0's limit value :0x%08x\r\n",_arc_aux_read(AUX_TIMER0_LIMIT));
EMBARC_PRINTF("timer0's current cnt_number:0x%08x\r\n",_arc_aux_read(AUX_TIMER0_
↪CNT));
```

Stop-Set-Start the Timer0

We can use the function `_arc_aux_write` to write the auxiliary register.

To control the **Timer0** with the related auxiliary registers.

- **COUNT0**: write this register to set the initial value of the **Timer0**. It will increase from the set value at anytime you write this register.
- **CONTROL0**: write this register to update the control modes of the **Timer0**.
- **LIMIT0**: write this register to set the limit value of the **Timer0**, the limit value is the value after which an interrupt or a reset must be generated.

In this lab, we should stop timer before setting and starting it, the function `timer_stop` is already encapsulated in embARC OSP, you can use this function or directly write the register. And then set the timer work mode, enable interrupt or not and set the limit value. At last start the timer. Here is the code:

```
/* Stop it first since it might be enabled before */
_arc_aux_write(AUX_TIMER0_CTRL, 0);
_arc_aux_write(AUX_TIMER0_LIMIT,0);
_arc_aux_write(AUX_TIMER0_CNT, 0);
/* This is a example about timer0's timer function. */
uint32_t mode = TIMER_CTRL_NH; /*Timing without triggering interruption.*/
uint32_t val = MAX_COUNT;
_arc_aux_write(AUX_TIMER0_CNT, 0);
_arc_aux_write(AUX_TIMER0_LIMIT,val);
/* start the specific timer */
_arc_aux_write(AUX_TIMER0_CTRL,mode);
```

When the timer is running, we can read the count value of the timer, and calculate the execution time of a code block. Here is the code:

```
uint32_t start_cnt=_arc_aux_read(AUX_TIMER0_CNT);
/**
 * code block
 */
uint32_t end_cnt=_arc_aux_read(AUX_TIMER0_CNT);
uint32_t time=(end_cnt-start_cnt)/(BOARD_CPU_CLOCK/1000);
```

Compile and debug

- Compile and download

Open cmd under the folder *example\Lab\timer*, input the compile command as follow:

```
make -j4 run
```

Note: If your toolchain is metaware, you should use `gmake`. If you don't use core configuration specified in makefile, you need to pass all the make options to trigger make command

- Output

| _ \ _____ - - - - - | | _) - -
 | (_) / _ \ \ / \ / / _ \ ' _ / _ \ / _ \ | _ \ | | |
 | _ / (_) \ v v / _ / | | _ / (| | | _) | | _ |
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 | _ /

 _ - - - - | | _ / \ | _ \ / _ |
 / _ \ ' _ \ _ \ | ' _ \ / _ \ | | _) | |
 | _ / | | | | | _) / _ \ | _ < | | _
 \ _ | | | | | _ . _ / \ _ \ | \ _ \ _ |

```
embARC Build Time: Aug 22 2018, 15:32:54
Compiler Version: Metaware, 4.2.1 Compatible Clang 4.0.1 (branches/release_40)
Does this timer0 exist? YES
timer0's operating mode:0x00000003
timer0's limit value :0x00023280
timer0's current cnt_number:0x0000c236

Does this timer1 exist? YES
timer1's operating mode:0x00000000
timer1's limit value :0x00000000
timer1's current cnt_number:0x00000000

Does this RTC_timer exist? NO

The start_cnt number is:2
/***** TEST MODE START *****/

This is TEST CODE.

This is TEST CODE.

This is TEST CODE.

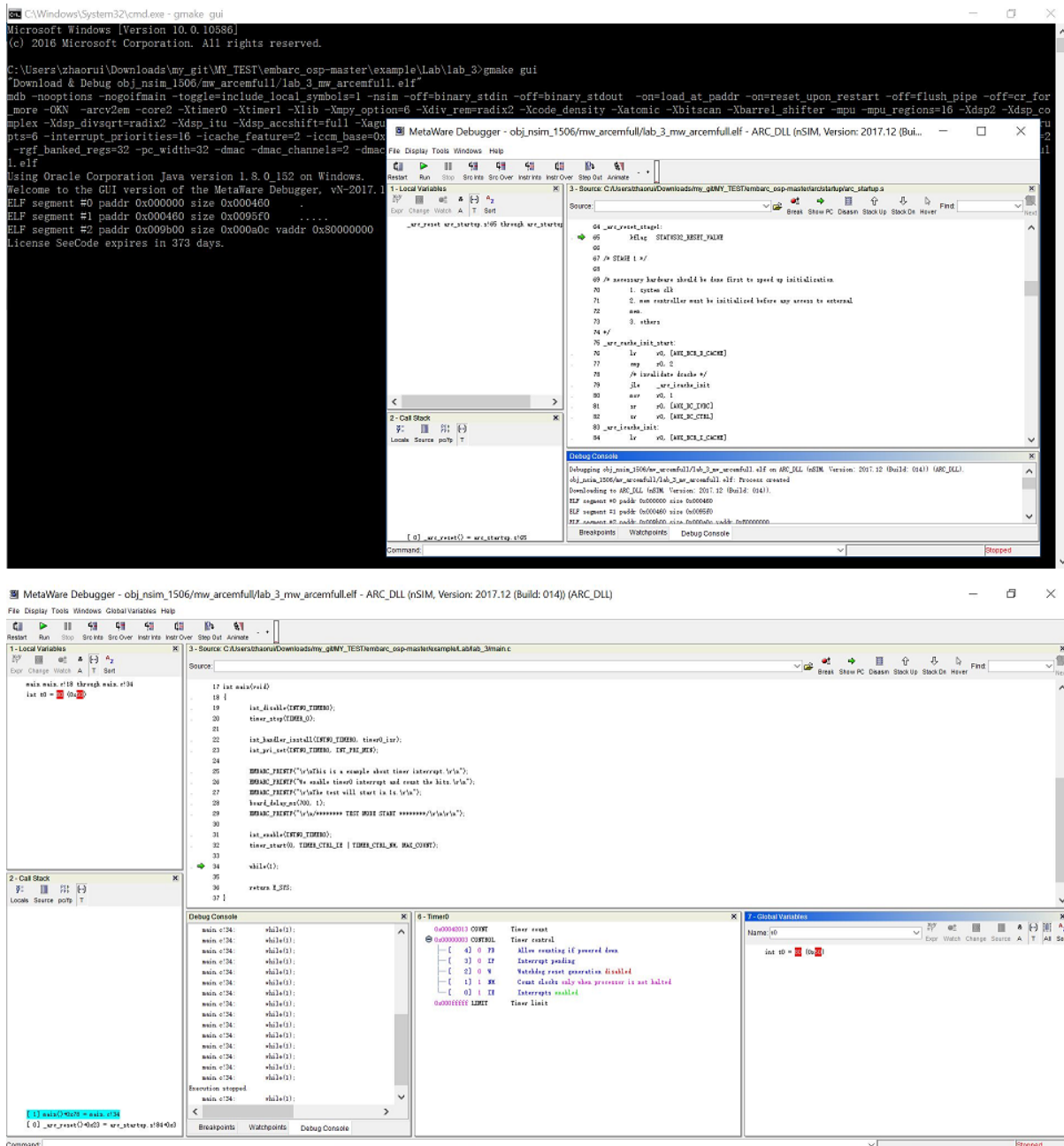
/***** TEST MODE END *****/
The end_cnt number is:16785931
The board cpu clock is:144000000

Total time of TEST CODE BLOCK operation:116
```

- Debug

Open cmd under the folder *example\Lab\timer*, input the command as follow:

```
make gui
```



The debug view will pop up automatically, we can watch the variables and registers.

Exercises

In the debug view, observe and understand the contents of the interrupt vector table.

Note: Click the Memory button in the debug view Debugger drop-down menu to see the contents of the memory in real time.

ARC features: interrupts

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A simple bootloader

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3.2.2 Level 2 Labs

A WiFi temperature monitor

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3.2. Labs

Steps

- Learn how to use the AWS IoT Cloud
- Learn how to use the EMSK Board peripheral modules and onboard resources

Equipment

Required Hardware

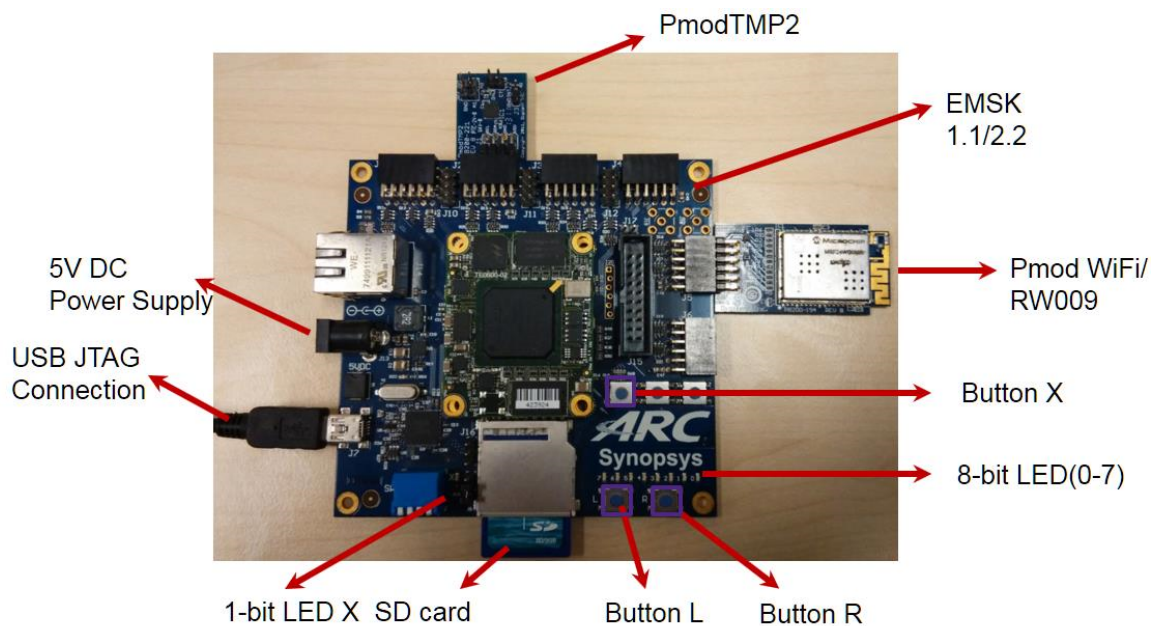
- [DesignWare ARC EM Starter Kit(EMSK)]
- [Digilent PMOD WiFi(MRF24WG0MA)]
- [Digilent PMOD TMP2]
- SD Card
- WiFi Hotspot(SSID:**embARC**, Password:**qazwsxedc**, WPA/WPA2 encrypted)

Required Software

- Metaware or ARC GNU Toolset
- Serial port terminal, such as putty, tera-term or minicom

Hardware Connection(EMSK Board)

- Connect PMOD WiFi to J5, connect PMOD TMP2 to J2.

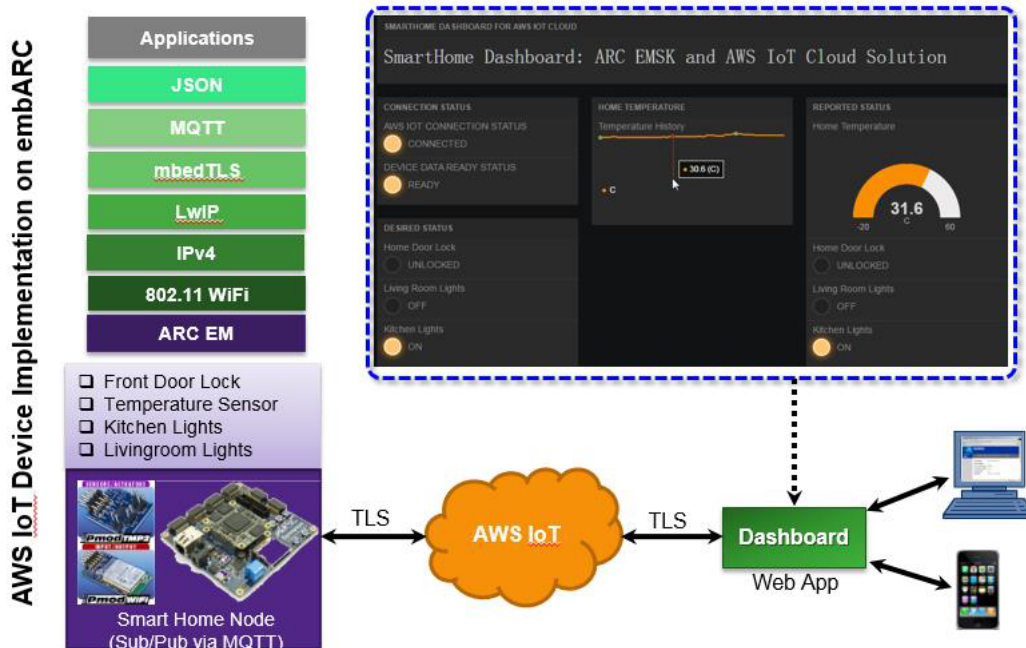


- Required hardware: EMSK 1.1/2.2, PmodTMP2, PmodWiFi, SDCard
- USB UART can be connected to PC for interoperation using NT-Shell.
 - Configure your hardware with proper core configuration.
 - The hardware resources are allocated as following table.

Hardware Resources	Represent
BUTTON R	Livingroom Lights Control
LED 0-1	Livingroom Lights Status(On or Off)
BUTTON L	Kitchen Lights Control
LED 2-3	Kitchen Lights Status(On or Off)
BUTTON X	Front Door Lock Control
LED 4-5	Front Door Lock Status(On or Off)
LED 7	WiFi connection status(On for connected, Off for not)
LED X	Node working status(toggling in 2s period if working well)
PMOD TMP2	Temperature Sensor
PMOD WiFi	Provide WiFi Connection

Content

This article provides instructions on how to establish connection between the EMSK and Amazon Web Services Internet of Things (AWS IoT) cloud in a simulated smart home application. AWS IoT is a managed cloud platform that lets connected devices securely interact with cloud applications and other devices. It supports Message Queue Telemetry Transport (MQTT) and provides authentication and end-to-end encryption.



This application is designed to show how to connect only 1 EMSK and AWS IoT Cloud using embARC. The connection between EMSK and AWS IoT Cloud is secured by TLS.

Principles

This application demonstrates the smart home solution based on EMSK by establishing the connection between EMSK Board and AWS IoT Cloud. The AWS IoT Device C SDK for the embedded platform has been optimized and transplanted for embARC.

In the application, the EMSK Board peripheral modules and onboard resources are used to simulate the objects which is controlled and monitored in smart home, the AWS IoT Cloud is used as the Cloud host and control platform which communicate with the EMSK Board through the MQTT protocol, and a special HTML5 Web APP is designed, which provide a dash board to monitor and control smart home nodes.

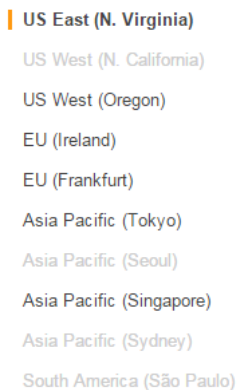
Steps

Creating and setting smart home node

1. Create an AWS account in [\[here\]](#). Amazon offers various account levels, including a free tier for AWS IoT.
2. Log into AWS console and choose AWS IoT.

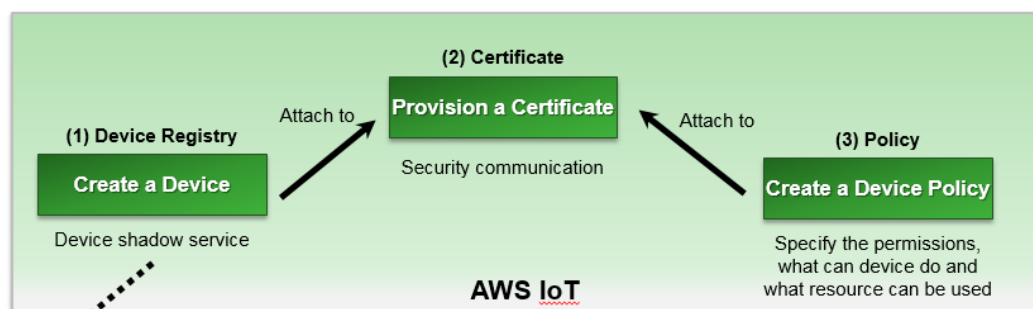


3. Choose an appropriate IoT server in the top right corner of the AWS IoT console page.



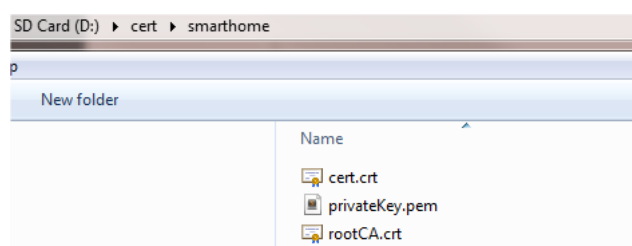
4. Create your smart home node in the thing registry and generate X.509 certificate for the node. Create an AWS IoT policy. Then attach your smart home node and policy to the X.509 certificate.

Note: for more details [\[Using a Smart Home Iot Application with EMSK\]](#)

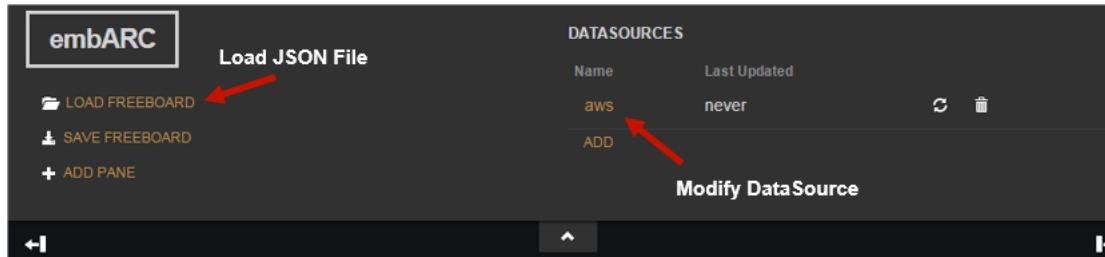


Topics

5. Download the root CA certificate from [\[here\]](#). Rename it rootCA.crt. Copy the certificate files cert.crt, privateKey.pem and rootCA.crt to folder `cert\smarthome`. Insert the SD card to your PC, and copy the certificate folder cert to the SD Card root.

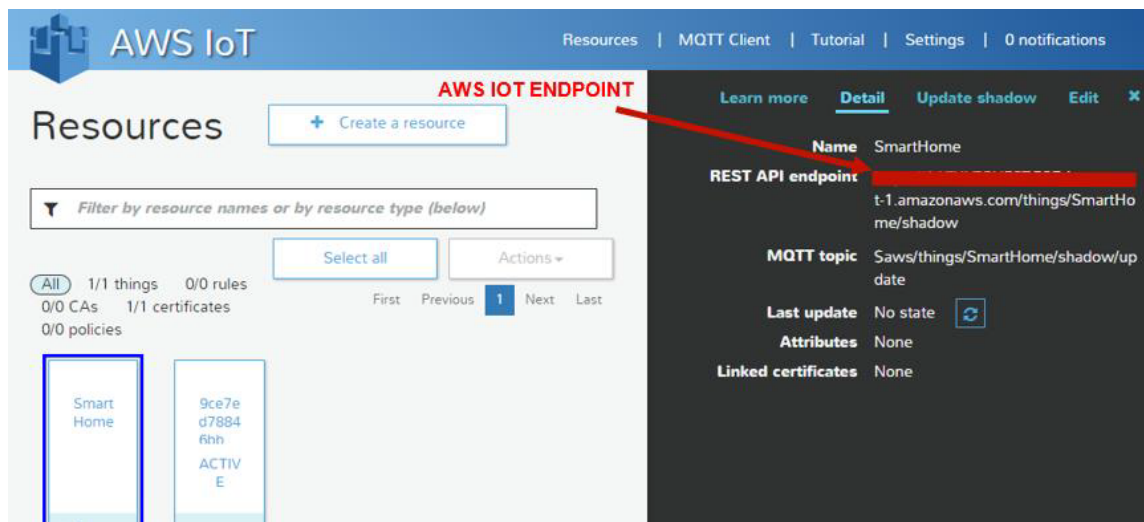


6. Open the [Web App] in a web browser and load the configuration file dashboard-smarthomesinglething.json obtained from *embARC\example\freertos\iot\aws\smarthome_demo*. The dashboard can be loaded automatically

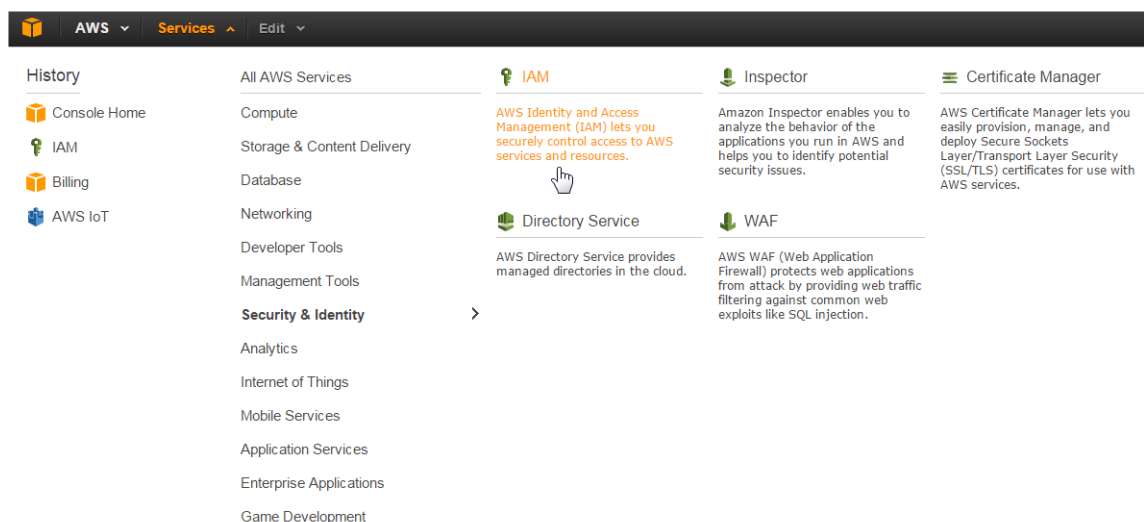


7. Click “ADD” to go to DATASOURCE page and fill up the forms.
- TYPE: Choose AWS IoT.
 - NAME: Name is aws.

- AWS IOT ENDPOINT: Go to AWS IoT console and click your smart home node “SmartHome”. Copy the content XXXXXXXXXXXXXXXX.iot.us-east-1.amazonaws.com in REST API endpoint to AWS IOT ENDPOINT.



- d) **REGION:** Copy the AWS region of your smart home node in REST API endpoint to **REGION**. For example, <https://XXXXXXXXXXXXXXXXX.iot.us-east-1.amazonaws.com/things/SmartHome/shadow>. **REGION** is us-east-1.
- e) **CLIENT ID:** Leave it blank as default.
- f) **ACCESS KEY** and **SECRET KEY:** Go to AWS Services page and click “IAM”.

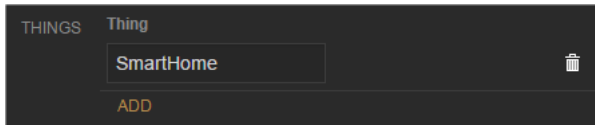


Go to User page and click “Create New Users”. Enter User Names “AWSIoTUser”. Then download user security credentials, Access Key ID and Secret Access Key. Copy Access Key ID to **ACCESS KEY** and Secret Access Key to **SECRET KEY**.



Go to User page and click “AWSIoTUser”. Click “Attach Policy” to attach “AWSIoTDataAccess” to “AWSIoTUser”.

- g) THINGS: AWS IoT thing name “SmartHome”.



- h) Click “Save” to finish the setting.

Building and running AWS IoT smart home example

1. The AWS IoT thing SDK for C has been ported to embARC. Check the above steps in order for your IoT application to work smoothly. Go to `embARC\example\freertos\aws\smarthome_demo`. Modify `aws_iot_config.h` to match your AWS IoT configuration. The macro `AWS_IOT_MQTT_HOST` can be copied from the REST API endpoint in AWS IoT console. For example, <https://XXXXXXXXXXXXX.iot.us-east-1.amazonaws.com/things/SmartHome/shadow>. `AWS_IOT_MQTT_HOST` should be `XXXXXXXXXXXXX.iot.us-east-1.amazonaws.com`.

```
// Get from console
// =====
#define AWS_IOT_MQTT_HOST      "XXXXXXXXXXXXX.iot.us-east-1.amazonaws.com" ///< Cus
#define AWS_IOT_MQTT_PORT      8883 ///< default port for MQTT/S
#define AWS_IOT_MQTT_CLIENT_ID "csdk-SH" ///< MQTT client ID should be unique for ev
#define AWS_IOT_MY_THING_NAME  "SmartHome" ///< Thing Name of the Shadow this device
#define AWS_IOT_ROOT_CA_FILENAME "rootCA.crt" ///< Root CA file name
#define AWS_IOT_CERTIFICATE_FILENAME "cert.crt" ///< device signed certificate file name
#define AWS_IOT_PRIVATE_KEY_FILENAME "privateKey.pem" ///< Device private key filename
// =====
```

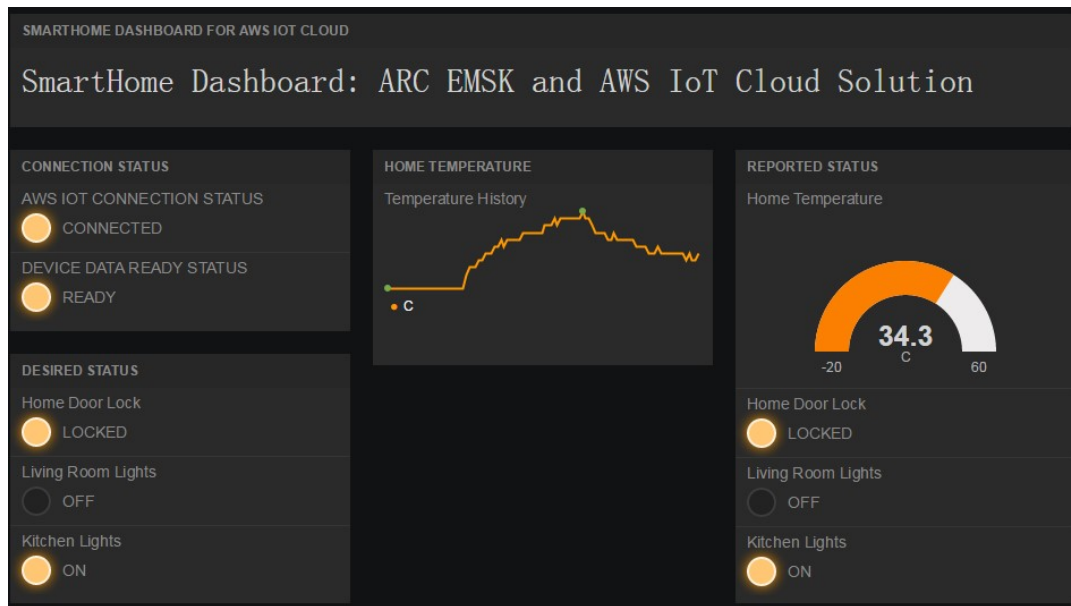
2. Use USB cable to connect the EMSK board. Set the baud rate of the terminal emulator to 115200.
3. Insert the SD Card into the EMSK board SD Card slot. Run the AWS IoT application using JTAG. Go to `embARC\example\freertos\aws\smarthome_demo` in command line, input the compile command as follow:

```
make TOOLCHAIN=gnu BD_VER=22 CUR_CORE=arcem7d run
```

4. FreeRTOS-based runtime environment can be loaded automatically. Wait for WiFi initialization and connection establishment(30 seconds or less) until the “WiFi connected” message is shown in the terminal emulator. “Network is ok” will be shown after the certificate files `cert.crt`, `privateKey.pem` and `rootCA.crt` are validated. The information in “reported”: {} is the state of the EMSK-based smart home node. “Updated Accepted !!” means the connection works between the smart home node and AWS IoT cloud.

```
Shadow Init
Shadow Connect
FrontDoor is open
Turn off KitchenLights
Turn off LivingRoomLights
Update Shadow: {"state":{"reported":{"temperature":29.600000,"doorLocked":false,
"KitchenLights":false,"LivingRoomLights":false}}, "clientToken":"csdk-SH-0"}
*****
Delta - FrontDoor state changed to 1
FrontDoor is locked
Delta - KitchenLights light state changed to 1
Turn on KitchenLights
Update Accepted !!
Update Shadow: {"state":{"reported":{"temperature":29.600000,"doorLocked":true,
"KitchenLights":true,"LivingRoomLights":false}}, "clientToken":"csdk-SH-1"}
*****
Update Accepted !!
Update Shadow: {"state":{"reported":{"temperature":29.600000,"doorLocked":true,
"KitchenLights":true,"LivingRoomLights":false}}, "clientToken":"csdk-SH-2"}
*****
```

4. Interact using EMSK and Dashboard. You can press the button L/R/X to see the led changes on board and also on dashboard web app. You can also click the lights of DESIRED STATUS pane on the dashboard app, and see the led changes on board and dashboard web app.



Exercises

This application is designed to show how to connect only 1 EMSK and AWS IoT Cloud using embARC. Try to do the Multi Node AWS IoT Smarthome Demo.

Note: Related demo codes you can find [\[here\]](#)

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