
TrustFLEX Step by Step Guide

Azure IoT with Custom PKI

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1 Introduction

This document gives a detailed walk through of the custom public key infrastructure use case implementation. If familiar with Jupyter Notebook, can skip this section and move to Section 2.

1.1 Getting started with Jupyter Notebook Tutorials

Jupyter Notebook is open source web application which allows you to create documents that contain code that you can execute in place as well as narrative text. It provides GUI elements, ability to execute code in place, ability to add images and gives it the look and feel that normal code files lack.

Jupyter notebooks are mainly used to explain/evaluate code in an interactive way.

1.1.1 Starting Jupyter Notebook

Jupyter notebook can be launched from the Anaconda Navigator main window.



1.2 Jupyter Notebook Basics

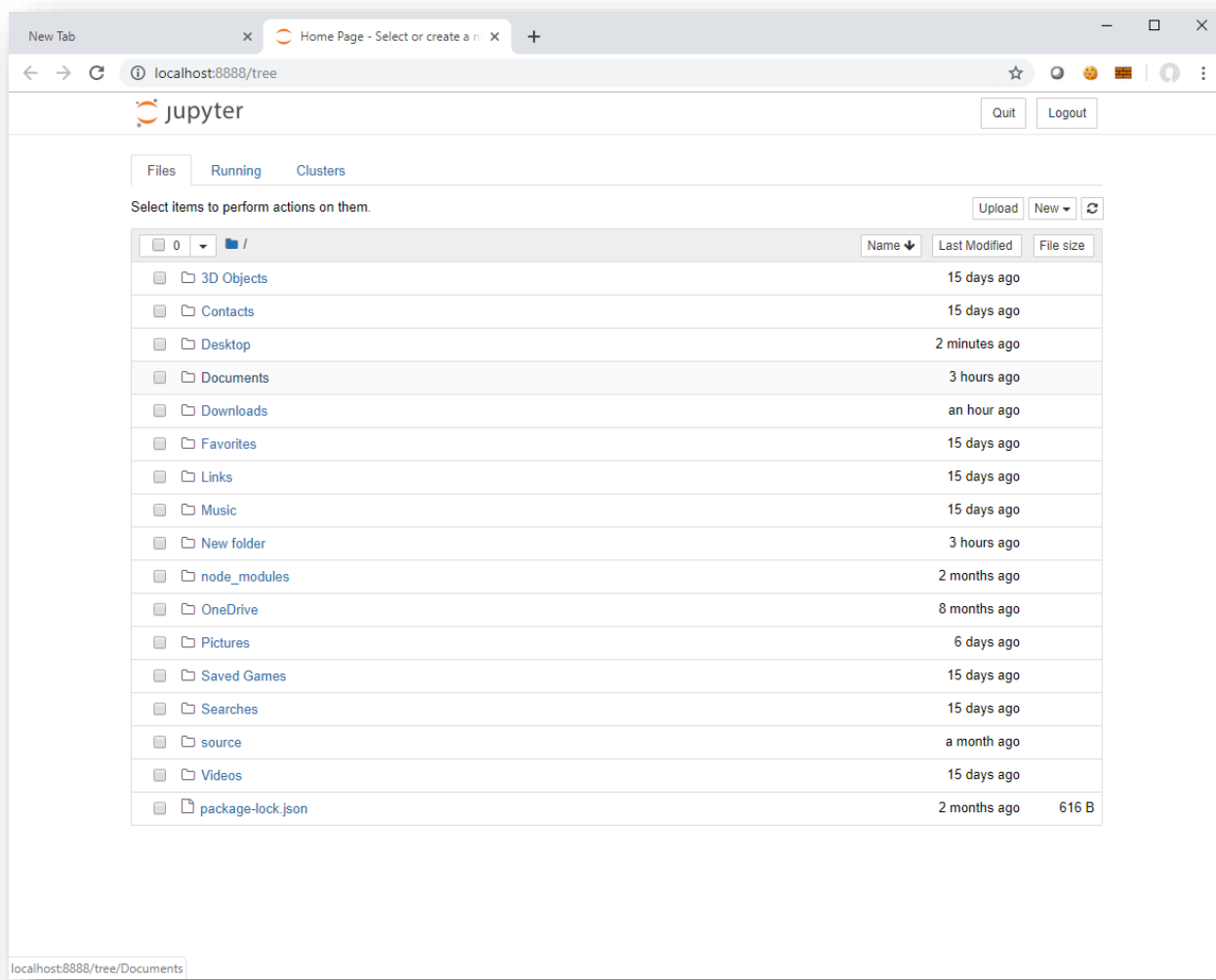
It is recommended to become familiar with Jupyter basic concepts with the online documentation, <https://jupyter-notebook.readthedocs.io/en/stable/examples/Notebook/Notebook%20Basics.html>

Some of the content is duplicated here for convenience. The online documentation should always be used as a reference.

1.2.1 The Notebook dashboard

When you first start the notebook server, your browser will open Notebook dashboard. The dashboard serves as a home page for the notebook. Its main purpose is to display the notebooks and files in the current directory.

For example, here is a screenshot of the Jupyter dashboard. The top of the notebook list displays clickable breadcrumbs of the current directory. By clicking on these breadcrumbs or sub-directories in the notebook list, you can navigate your file system.



1.3 Introduction to Jupyter Notebook GUI.

Jupyter Notebooks contain cells where you can either write code or markdown text. Notebooks contain multiple cells, some set as code and others markdown. Code cells contain code that can be executed live, and markdown contains text and images that explains the code.

Below image shows some options in a typical Jupyter Notebook. Individual cells can be executed by pressing on the RUN button as shown in the below image.

All cells in the Notebook can be executed in order by **Kernel->Restart & Run All**.



To run all cells in sequence.



2 Jupyter Notebook Tutorials

The TrustPlatform Design Suite comes with a number of Notebook Tutorials to easily prototype popular use cases for TrustFLEX and Trust&Go devices. Here is the list of Jupyter Notebook Tutorials.

Jupyter Notebook Tutorials	Relative Path	Applicable Devices
Manifest Generation	TrustnGO\00_resource_generation\TNGTLS_manifest_file_generation.ipynb	TrustnGO
Resource Generation	TrustFLEX\00_resource_generation\TFLXTLS_resource_generator.ipynb	TrustFLEX
Accessory Authentication	TrustFLEX\01_accessory_authentication\notebook\TFLXTLS_accessory_authentication.ipynb	TrustFLEX
Firmware Validation	TrustFLEX\02_firmware_validation\notebook\TFLXTLS_firmware_validation.ipynb	TrustFLEX
GCP Connect	TrustFLEX\03_gcp_connect\notebook\TFLXTLS_GCP_connect.ipynb	TrustFLEX
IP Protection	TrustFLEX\04_ip_protection\notebook\TFLXTLS_IP_protection.ipynb	TrustFLEX
Secure Public Key Rotation	TrustFLEX\05_public_key_rotation\notebook\TFLXTLS_public_key_rotation.ipynb	TrustFLEX
AWS Custom PKI	TrustFLEX\06_custom_pki_aws\notebook\TFLXTLS_aws_connect.ipynb	TrustFLEX
Azure Connect	TrustFLEX\07_custom_pki_azure\notebook\TFLXTLS_azure_connect.ipynb	TrustFLEX

3 Resource Generation Notebook

TFLXTLS device is one of the three devices available in the Trust Platform USB Dongle Board.

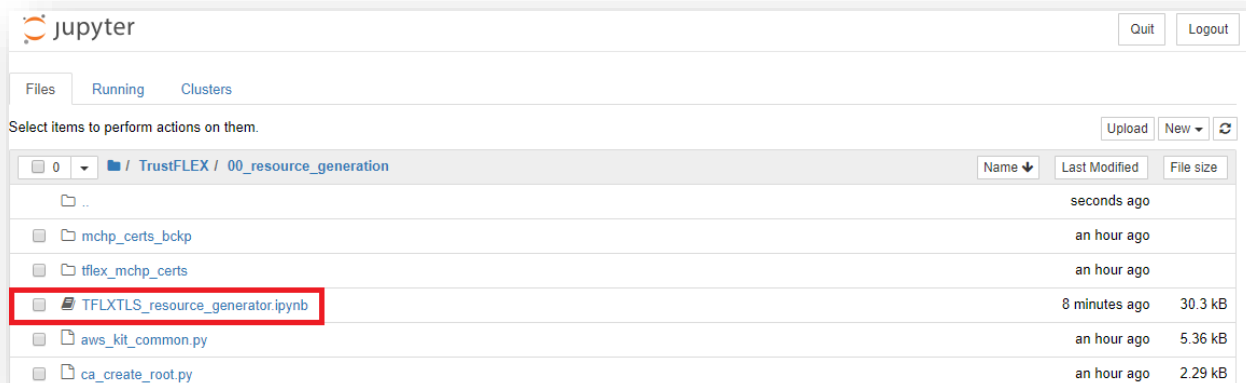
TrustFLEX devices come pre-programmed with certificates in slots 10, 11 and 12, also slots 0-4 have pre-generated private keys, other than the mentioned slots all the other slots have no meaningful data in them.

The Resource Generator Notebook will create development keys and certificates for all slots that can be further customized. Keys and Certificate chains are stored in the PC filesystem. These keys should never be used for production purposes as their generation is not handled in a secure environment. These development keys will be later used by the other notebooks to implement the various pre-defined use cases.

By default, Jupyter starts in Users directory (\$HOME for MacOS or Linux systems). For the remainder of this document, it will be assumed that the trust_platform folder is contained in Users directory. If this is not the case, please move trust_platform folder to your Users directory

Within the Jupyter Dashboard, navigate

trust_platform\DesignTools\TrustFLEX\00_resource_generation folder to open **TFLXTLS_resource_generator.ipynb** notebook

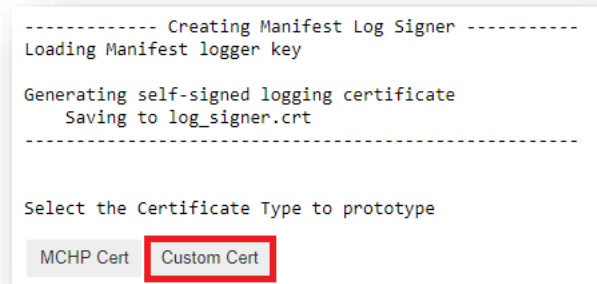


Run all cells of the Crypto Resource Generator Notebook: Kernel->Restart & Run All

Note: Before executing the cells on Crypto Trust Platform, its required to have factory default program running on SAMD21 of Trust Platform. Refer to [4.3 CryptoAuth TrustPlatform Factory reset](#) section for reloading default program.



It will execute and prompt you to choose between MCHP certificate and a custom certificate chain, press "Custom Cert" option for this use case.



Now it prompts you to enter the organization name, enter the name that will be used as an Organization Name in the certificate template. The name length is limited to 24 characters.

The Notebook will generate several keys and certificates. Make sure you have an error free output before continuing to the next steps of the training.

The output log should resemble this:

Loading root CA key

Generating self-signed root CA certificate
Saving to root-ca.crt

Loading signer CA key

Generating signer CA CSR
Saving to signer-ca.csr

Loading signer CA CSR
Loading from signer-ca.csr

Loading root CA key
Loading from root-ca.key

Loading root CA certificate
Loading from root-ca.crt

Generating signer CA certificate from CSR
Saving to signer-ca.crt

Signer Certificate written successfully to device
Device Certificate written successfully to device
Thing ID c21a93e8d413135f21f452b620a4c83bdf25b589

Generating signer certificate definition header file - cust_def_1_signer.h
Generating device certificate definition header file - cust_def_2_device.h
Generating signer certificate definition source file - cust_def_1_signer.c
Generating device certificate definition source file - cust_def_2_device.c

Custom certificate generation and provisioning - SUCCESS

Root Certificate:
Loading from root-ca.crt
Crypto Authentication Root CA 000
-----BEGIN CERTIFICATE-----
MIIBzzCCAXSgAwIBAgIQQMs/k4fC+GzN1M6BcRRO2DAKBggqhkJOPQQDAjBPMSEw
HwYDVQQKDBhOaWNvbGFzIE9yZyBOYW1lICAgICAgICAgKjAoBgNVBAMMIUNyeXB0
byBBdXR0ZW50aWNhdGlvbiBSb290IENBIDAwMDAeFw0xOTA5MDQyMzU2MTRaFw00
NDA4MjgyMzU2MTRaME8xITAfBgNVBAoMGE5pY29sYXMgT3JnIE5hbWUgICAgICAg
IDEqMCgGA1UEAwwhQ3J5cHRvIEF1dGhlnbnRyY2F0aW9uIFJvb3QgQ0EgMDAwMFkw
EwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEIqwwOu9E0hvjvMFontRrZtzTWWxmVwV7
8M07s/VjM/rwu/I486yjOI1vq9k00JkBALrbt0wd5GkZM53nEgfJjKMyMDAwHQYD
VR0OBBYEFFsENZIG+D4+r93QBNORixk/r7OoMA8GA1UdEwEB/wQFMAMBAf8wCgYI
KoZIzj0EAwIDSQAwwRgIhAMyFkf/jAiA5jDncnH7VI9Em5IHsvUgtKB24OhqxjTi
AiEAIJ0EnZukMELq4xsjG7+v6xxlswV2p8fOj6N2ZcyPbU0=
-----END CERTIFICATE-----

Validate Root Certificate:
OK

TFLXTLS Signer Certificate:

Loading from signer-ca.crt

Crypto Authentication Signer FFFF

-----BEGIN CERTIFICATE-----

```
MIICAJCCAaigAwIBAgIQV2Ww7Rjyk6b9YwLY0gGENDAKBggqhkJOPQQDAjBPMSEw
HwYDVQQKDBhOaWNvbGFzIE9yZyBOYW1lICAgICAgICAgICAgICAgICAgICAgICAg
byBBdXR0ZW50aWNhdGlviBSb290IENBIDAwMDAeFw0xOTA5MDQyMzAwMDBaFw0y
OTA5MDQyMzAwMDBaME8xITAFBgNVBAoMGE5pY29sYXMgT3JnIE5hbWUgICAgICAg
IDEqMCgGA1UEAwwhQ3J5cHRvIEF1dGhlnRnRyY2F0aW9uIFNpZ25lciBGRkZGMFkw
EwYHkoZiZj0CAQYIKoZiZj0DAQcDQgAE/P6/EAYOcTP1vokpVfiaDMRsA7oT4G2e
MIK9CdY7UWpdKMKVawmPUN9/VGtxsqTCx56eWy1axyyochG8wHn1N6NmMGQwDgYD
VR0PAQH/BAQDAgGGMBIGA1UdEwEB/wQIMAYBAf8CAQAwHQYDVROBBYEFMSkbTjX
FC6EP2hKktjVw6wNRUswMB8GA1UdIwQYMBaAFFsENZIG+D4+r93QBNORixk/r7Oo
MAoGCCqGSM49BAMCA0gAMEUCIDAFcGgep1/zM4EqMuoSVY6yZLUK+nyIzpFuLZLd
Ft4IAiEAquDmkmfbh55ReRRfBMkSqc4XaOhe+IVmBUkewZbWLjs=
```

-----END CERTIFICATE-----

Validate TFLXTLS Signer Certificate:

OK

TFLXTLS Device Certificate:

Loading from device_cert.crt

01230F56F23B90ED01 ATECC

-----BEGIN CERTIFICATE-----

```
MIIB8jCCAzmGawIBAgIQVwWq4kNX7BMjyrX9u7BITzAKBggqhkJOPQQDAjBPMSEw
HwYDVQQKDBhOaWNvbGFzIE9yZyBOYW1lICAgICAgICAgICAgICAgICAgICAgICAg
byBBdXR0ZW50aWNhdGlviBTaWduZXIgaRkZGRjAeFw0xOTA5MDQyMzAwMDBaFw0y
OTA5MDQyMzAwMDBaMEYxITAFBgNVBAoMGE5pY29sYXMgT3JnIE5hbWUgICAgICAg
IDEmMB8GA1UEAwwhYm90aW9uZm9udmFkEwYHkoZiZj0CAQYIKoZiZj0DAQcDQgAE
MU8lzxexIXkDvc2ZDlC73zYifdsIU9KJBfkcmCV4741o
h5RkF4B+5JFt0reMN8xOoO+RtS9/9MqvWYV6vSZru6NgMF4wDAYDVROTAQH/BAIw
ADAQBgNVHQ8BAf8EBAMCAYYwHQYDVROBBYEFMIak+jUEXNfIfRStiCkyDvfJbWJ
MB8GA1UdIwQYMBaAFFMSkbTjXFC6EP2hKktjVw6wNRUswMAoGCCqGSM49BAMCA0cA
MEQCIAQ9tMIwvgFvK8XHXPhmEO0nFY3A69A8X36FXPEUTBPqAiBZcSgnfxUtvVxg
2TguAwM+ZFHQjpZvEvOfiZ7mmgZtEA==
```

-----END CERTIFICATE-----

Validate Device Certificate:

OK

reading slot 0 public key

reading slot 1 public key

reading slot 2 public key

reading slot 3 public key

reading slot 4 public key

Generated the manifest file 01230f56f23b90ed01.manifest

Certificate related steps completed successfully

At the end of the execution, a Custom PKI chain will be generated on your PC and TrustFLEX device specific slots (10 through 12) will be overwritten with the custom certificates.

The Notebook has also generated a manifest file to be uploaded into the public cloud of your choice (Google GCP, AWS IoT and Microsoft Azure).

4 Use Case Prototyping

This hands-on lab is intended to demonstrate the usage of TrustFLEX to secure an Azure IoT connection based on a custom PKI.

The Azure IoT device reference implementation is provided as an MPLAB X project and the generation of a custom PKI is achieved through the execution of Jupyter Notebook Tutorials.

Here are the steps that will be required to complete this Tutorial:

- Configure Azure CLI
- Register Custom PKI signer
- Build the Azure IoT device source code and flash it to the USB Dongle Board

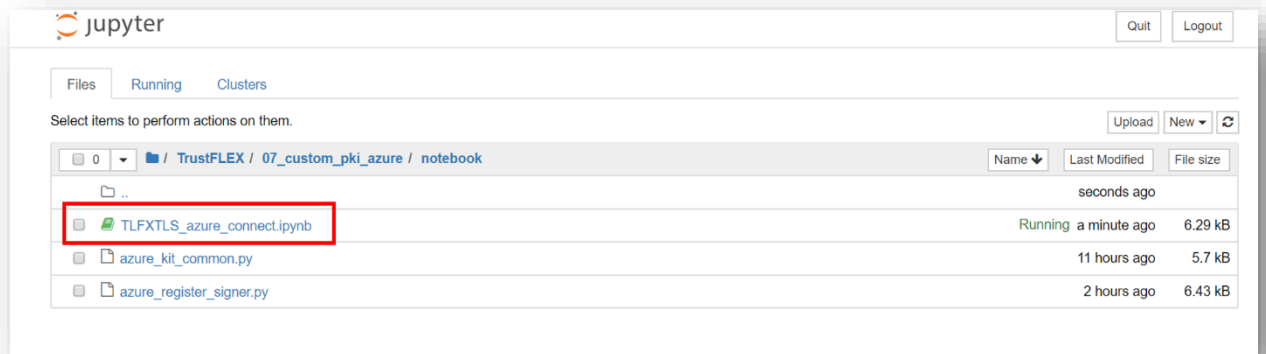
Note: It is required to have an Azure IoT test account setup. Instruction to setup the account quickly is provided in

docs\TrustFLEX_guide_Azure_demo_account_setup.pdf. Once the account is setup, IoT hub HostName should be updated in **docs\Azure_iot_hub_details.csv**

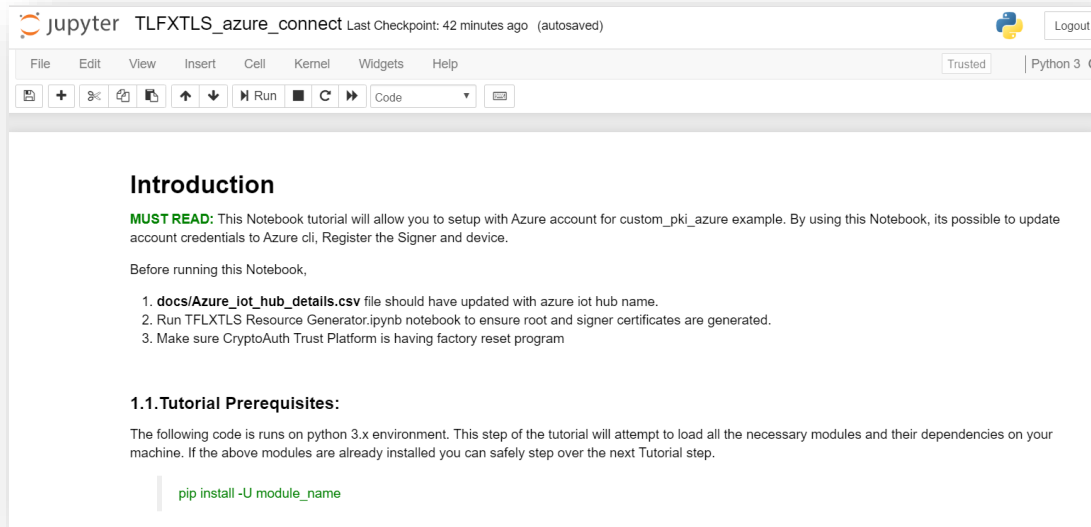
4.1 Running Custom PKI example on Jupyter Notebook

By running this following step, we can configure the Azure command line with Azure credentials, register the signer certificate to Azure IoT.

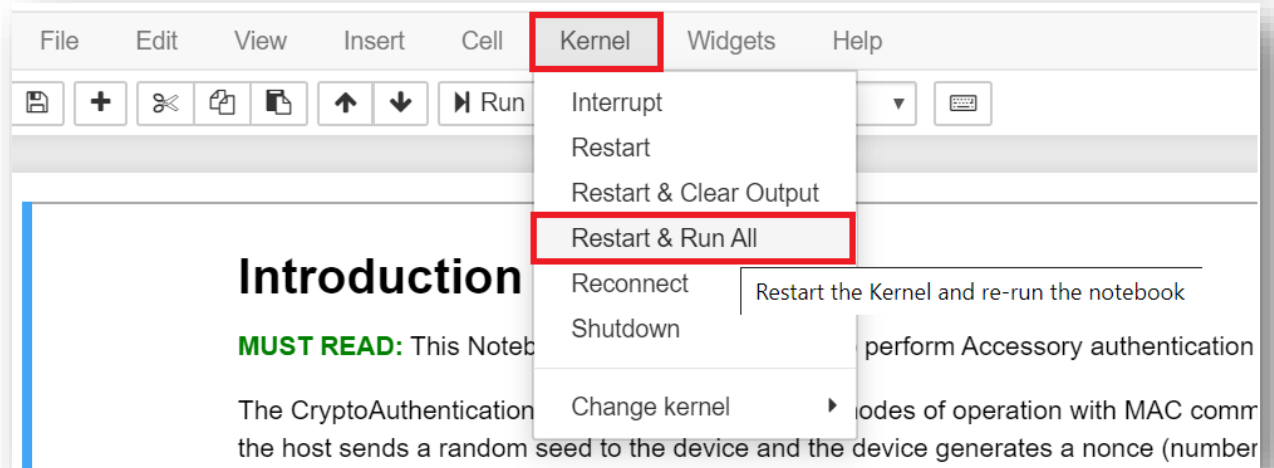
1. From the Jupyter Home page, navigate to **TrustFLEX\07_custom_pki_azure\notebook\TLFXTLS_azure_connect.ipynb** notebook file and open it.



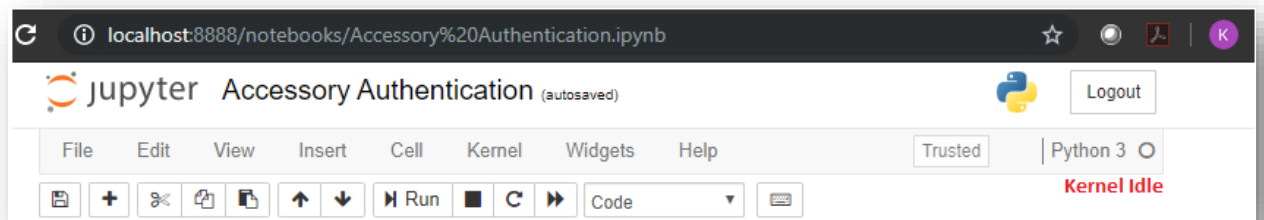
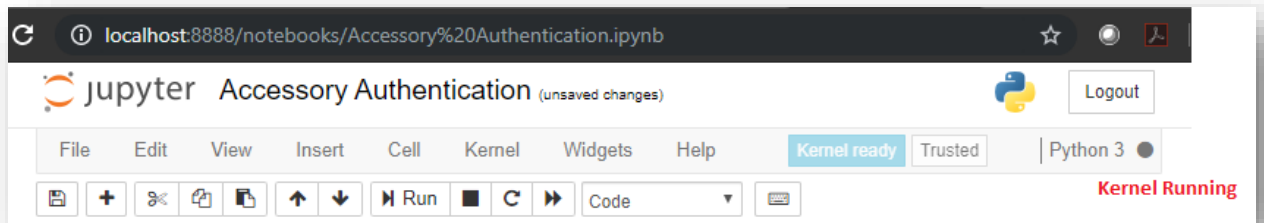
Opening the Jupyter notebook example should load the following on the browser.



2. Run All Cells by using Kernel -> Restart & Run All



It may take a while to complete, wait for the kernel to complete all processing i.e. from Kernel Running to Kernel Idle state (Check circle above **RED** text)

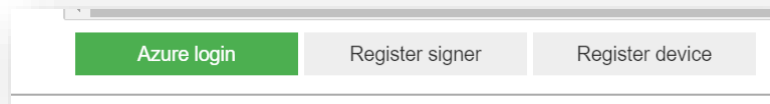


3. Navigate through different cells output for the description of the step and result from the execution.

4. There are 3 major steps:

Configure Azure command line interface:

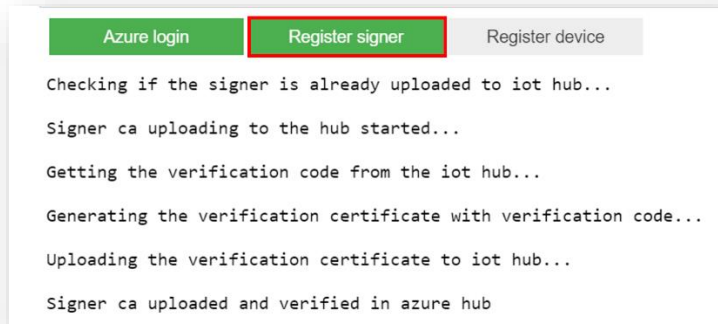
Before we can interact with Azure, we need to configure the tools with the appropriate Azure credentials. These credentials are composed of the **azure account login**. Clicking the button will open azure login portal in new tab in browser. Enter the credentials of your account.



Register Signer Module:

Code block of this step generates "**Register signer**" button. Clicking the button, it registers the custom PKI signer module to the Azure account. To establish a secure communication with Azure IoT, we need to register the Custom PKI signer certificate to Azure IoT

Upon successful execution, the log should look like this.



Once this step is completed, signer module is successfully registered to Azure IoT.

Register Device:

Code block of this step generates "**Register Device**" button. Clicking the button Registers the device to the azure iot hub and output log should be as below.

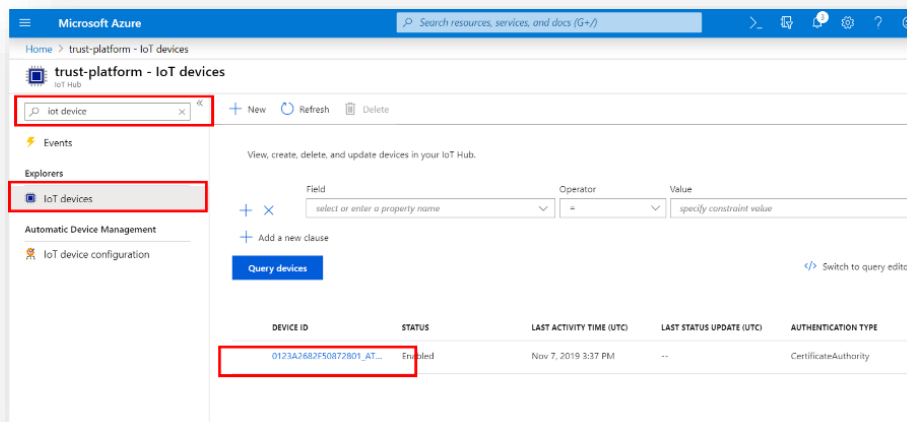


NOTE: Make sure that you executed C project successfully before executing the next step .To execute C project, refer "[Running Azure IoT example on Embedded platform](#)" section.

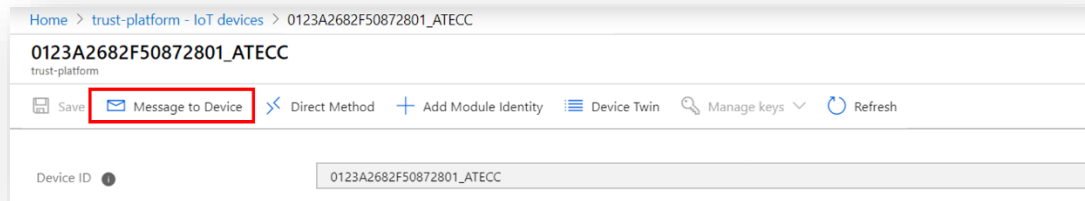
Control Trust Platform Azure Cloud

In this section we are going to control the status led on the Trust platform device from the Azure cloud.

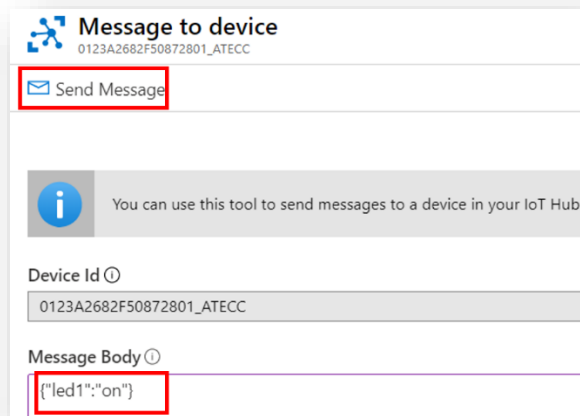
1. In the <https://portal.azure.com/> select your IoT hub created, search for iot device and select **IoT devices** from Explorers.
2. From the Device ID select the device id that want to be controlled. The Device ID Should be same as the highlighted one previous step **Register Device**



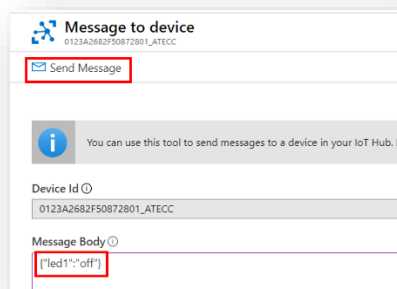
3. In the Device ID window, select the Message to Device



4. Now to Turn the led on the Trust platform board. Paste the message `{"led1":"on"}` to the message body and click Send Message.



5. Now to Turn the led on the Trust platform board. Paste the message `{"led1":"off"}` to the message body and click Send Message



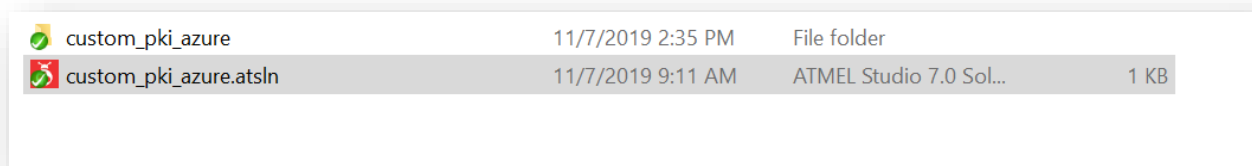
4.2 Running Custom PKI example on Embedded platform

Once the resources are generated both Atmel Studio and MPLAB projects provided can be used to run the use case on CryptoAuth Trust Platform.

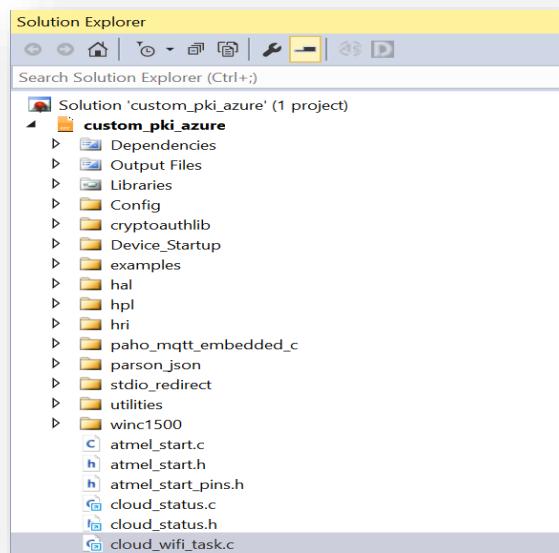
This project can configure the Wi-Fi credentials, establish a TLS connection, subscribe to MQTT. It is required to use the Azure IoT Jupyter notebook to register the signer module.

4.2.1 Atmel Studio:

1. Open **custom_pki_azure.atsln** project by navigating
TrustFLEX\07_custom_pki_azure\c\studio\custom_pki_azure.atsln



2. In the project navigate to **custom_pki_azure -> cloud_wifi_task.c** file



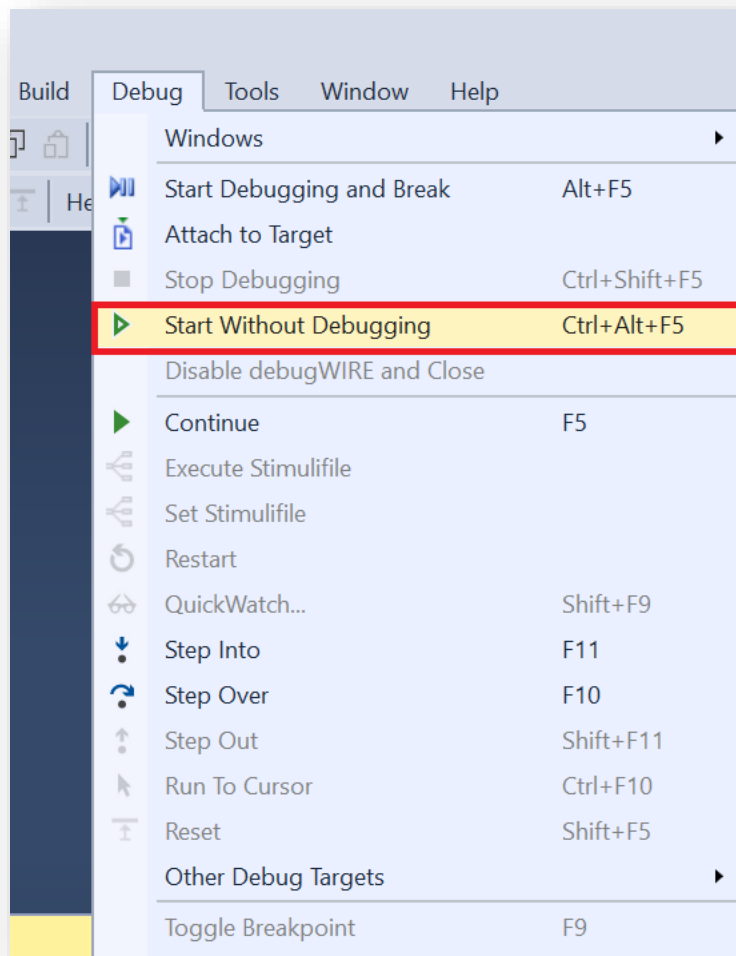
update the following constants before building the project:

- MAIN_WLAN_SSID
- MAIN_WLAN_PSK
- CLOUD_ENDPOINT

The Highlighted area in CLOUD_ENDPOINT string should have the Azure IOT Hub Name. The IoT Hub name can be got from the azure portal or from the docs/Azure_iot_hub_details.csv file.

```
#define CLOUD_ENDPOINT "xxxxxxxxxxxx.azure-devices.net"
```

3. Program the CryptoAuth Trust Platform by navigating to **Debug -> Start Without Debugging**



This step may take some time, wait for Atmel Studio to compile and program the device.

Once the programming is done, reset the hardware (press the reset button) and view the Console messages by using applications like 'Tera Term'. Open the application with the COM related to CryptoAuth Trust Platform with 115200-8-N-1 settings.

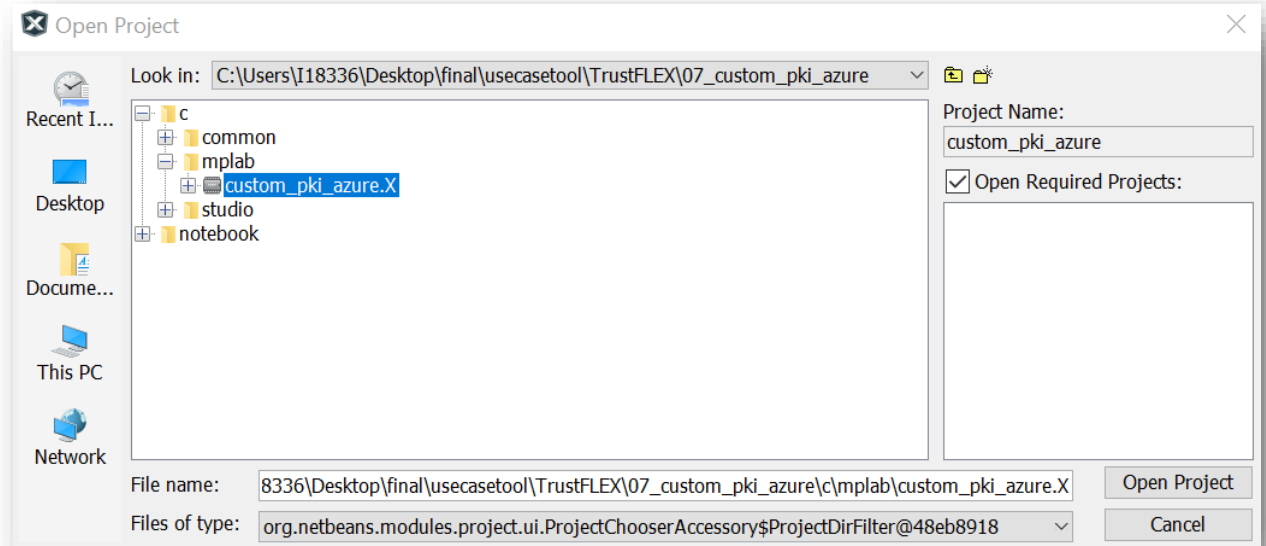
```
Attempting to connect to Azure IoT ...
  SSID:      karthi
  Password: karthikeyan
WINC1500 WIFI: Connected to the WIFI access point.
WINC1500 WIFI: Device IP Address: 192.168.119.192
WINC1500 WIFI: DNS lookup:
  Host:      trust-platform.azure-devices.net
  IP Address: 40.83.177.42
<APP><INFO>Socket 0 session ID = 1
SUCCESS: Azure Demo: Connected to Azure IoT.

SUCCESS: Subscribed to the MQTT update topic subscription:
SUCCESS: devices/0123A2682F50872801_ATECC/messages/devicebound/#

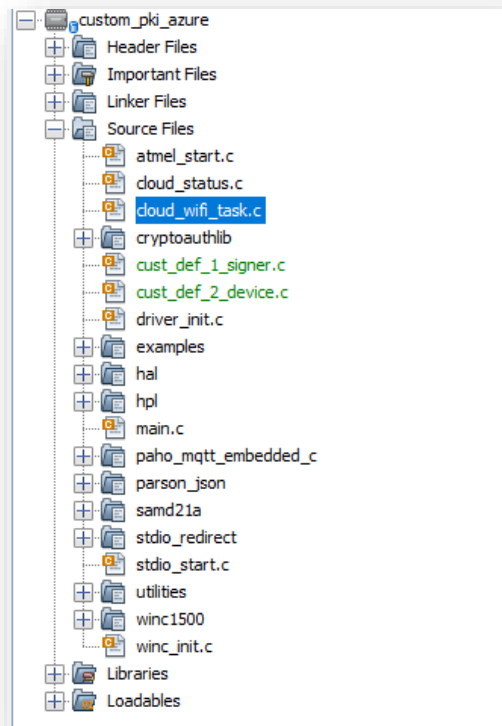
Publishing MQTT Shadow Update Message:
00000000 7B 22 6C 65 64 31 22 3A 22 6F 66 66 22 7D      {"led1":"off"}
```

4.2.2 MPLAB:

1. Open **custom_pki_azure.X** project by navigating to MPLAB -> File -> Open Project -> **TrustFLEX\07_custom_pki_azure\c\mplab\custom_pki_azure.X**



2. Open **cloud_wifi_task.c** file by navigating to **custom_pki_azure** -> **Source Files** -> **cloud_wifi_task.c**



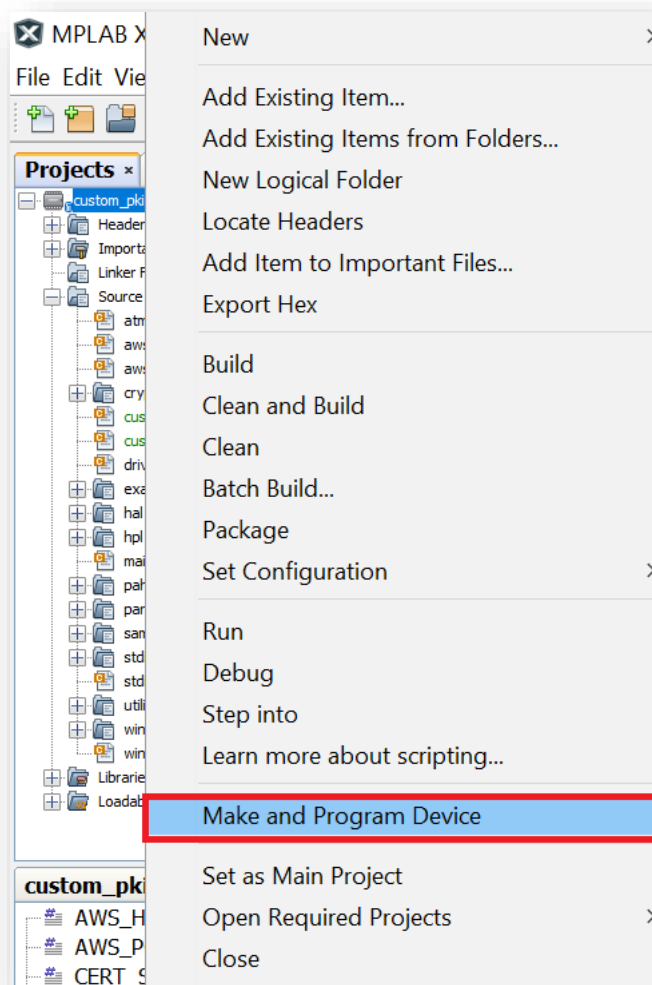
update the following constants before building the project:

- MAIN_WLAN_SSID
- MAIN_WLAN_PSK
- CLOUD_ENDPOINT

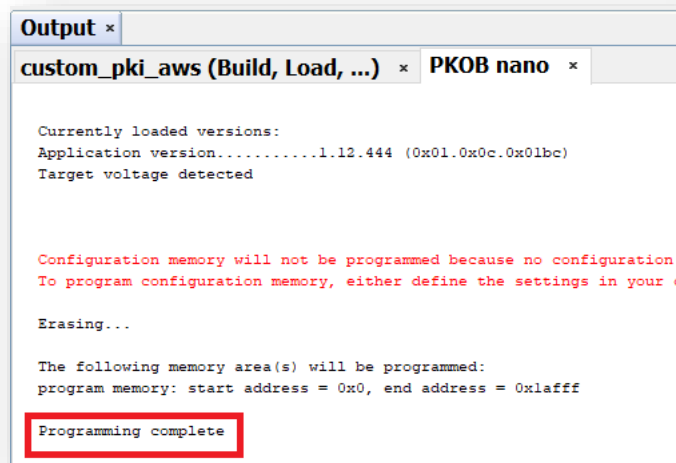
The Highlighted area in CLOUD_ENDPOINT string should have the Azure IOT Hub Name

```
#define CLOUD_ENDPOINT "trust-platform.azure-devices.net"
```

3. Program the CryptoAuth Trust platform by navigating to **custom_pki_azure -> Make and Program Device**



This step may take some time, wait for MPLAB to program the device. Once it is done programming you will see "**Programming complete**" message in Output Window.



```
Output x
custom_pki_aws (Build, Load, ...) x PKOB nano x

Currently loaded versions:
Application version.....1.12.444 (0x01.0x0c.0x01bc)
Target voltage detected

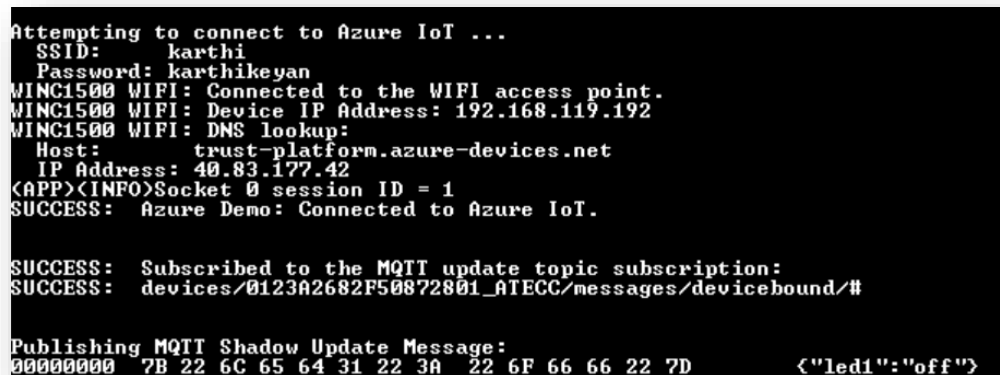
Configuration memory will not be programmed because no configuration b
To program configuration memory, either define the settings in your co

Erasing...

The following memory area(s) will be programmed:
program memory: start address = 0x0, end address = 0x1afff

Programming complete
```

Once the programming is done, reset the hardware (press the reset button) and view the Console messages by using applications like 'Tera Term'. Open the application with the COM related to CryptoAuth Trust Platform with 115200-8-N-1 settings.



```
Attempting to connect to Azure IoT ...
SSID: karthi
Password: karthikeyan
WINC1500 WIFI: Connected to the WIFI access point.
WINC1500 WIFI: Device IP Address: 192.168.119.192
WINC1500 WIFI: DNS lookup:
Host: trust-platform.azure-devices.net
IP Address: 40.83.177.42
<APP><INFO>Socket 0 session ID = 1
SUCCESS: Azure Demo: Connected to Azure IoT.

SUCCESS: Subscribed to the MQTT update topic subscription:
SUCCESS: devices/0123A2682F50872801_ATECC/messages/devicebound/#

Publishing MQTT Shadow Update Message:
00000000 7B 22 6C 65 64 31 22 3A 22 6F 66 66 22 7D <"led1":"off">
```

4.3 CryptoAuth Trust Platform Factory reset

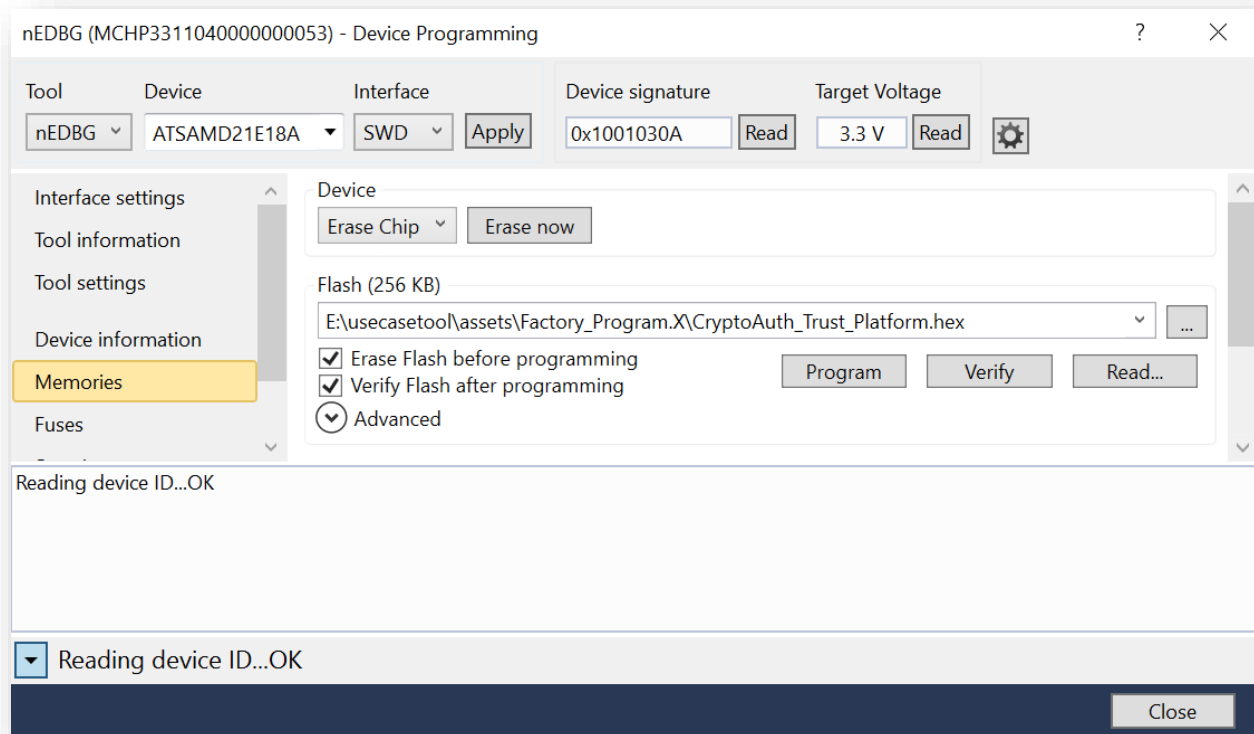
If any embedded project is loaded to CryptoAuth Trust Platform, the default program that enables interaction with CryptoAuth Trust Platform tools will be erased.

Before using the CryptoAuth Trust Platform with any other notebook or tools on PC, its required to reprogram the default firmware. Default hex file is available at

assets\Factory_Program.X\CryptoAuth_Trust_Platform.hex

To reprogram using Atmel Studio:

1. Navigate to AtmelStudio -> Tools -> Device Programming
2. Select Tool as nEDBG and Apply
3. Go to Memories and navigate to above path under Flash dropdown
4. Check both Erase Flash and Verify Flash
5. Click on Program



To reprogram using MPLAB:

1. Open **assets\Factory_Program.X** project in MPLAB IDE
2. Program the Crypto Trust platform by navigating to
CryptoAuth_Trust_Platform_Factory_Program -> Make and Program Device

Now, CryptoAuth Trust Platform contains factory application that enables interactions with Notebooks and/or PC tools.

5 FAQ

1. What are the reasons for “**AssertionError: Can't connect to the USB dongle**” error?

There are many possibilities like,

1. Crypto Trust Platform is having different application than factory reset firmware. Refer to “CryptoAuth TrustPlatform Factory reset” section any usecase TrustFLEX Guide for reloading it
2. Check the switch positions on Crypto Trust Platform and/or ATECC608A Trust board
 - a. Correct Trust device should be connected and only one device of that type is allowed on the I2C bus. Multiple devices with same address results in error
3. Check USB connections to Crypto Trust Platform

2. How to reload factory default application to Crypto Trust Platform?

Refer to “CryptoAuth TrustPlatform Factory reset” section any usecase TrustFLEX Guide for reloading it.

3. Why does my C projects generates No such file or directory with ../../../../TFLXTLS_resource_generation/?

C project generates this error when the resources are not generated prior to using embedded projects. Running the resource generation notebook ensures these files and secrets are generated.

4. Before running any use case notebook and/or C project, why is it mandate to execute resource generation?

When resource generation notebook is executed, it generates and programs the required resources like secrets, keys and certificates. These are only prototyping keys and cannot be used for production. These keys will be used part of Usecase notebooks and C projects

5. How to know the resources being used in a use case?

Refer to individual Usecase description html for details on transaction diagrams, resources being used and other details. The resources required for given use case is mentioned in INFER CRYPTOGRAPHIC ASSETS section.

6. When should I select Custom certificates while doing resource generation?

Custom certificates are required when user wants to have their own root, signer instead of MCHP provided. The difference would be organization name, common name and validity are configurable

It is also possible to view the Console messages by using applications like TeraTerm. Open the application with the COM related to Crypto Trust Platform with 115200-8-N-1 settings

7. Why Azure demo application is not getting connected to cloud?

There are many possibilities like,

- a. Signer registration is not done to the account
- b. Device ID registration is not done to the account
- c. WiFi credentials are not populated or in correct in C project

- d. Azure IOT Hub name is not populated or in-correct in C project

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