NUC505 ICP Programming Tool User Guide

Application Note for 32-bit NuMicro® Family

Document Information

Abstract	This document introduces how to use the ICP programming tool to access SPI Flash/MTP memory during development or mass production phase.
Apply to	NuMicro® NUC505 Series

For additional information or questions, please contact: Nuvoton Technology Corporation.

www.nuvoton.com

1 Table of Contents

1 Overview

"ICP" is the acronym of In-Circuit Programming, which makes it possible that the user can update the specified MCU's memory under the software control without removing the mounted MCU chip from target PCB. For the NUC505 series, the programmable memory includes SPI Flash and MTP memory. The Nuvoton ICP Programming Tool supports "online" and "offline" programming mode.

The NUC505 provides a mechanism to protect firmware code in internal / external SPI Flash. It uses the information in MTP (Multiple-Time Programmable) memory to encrypt / decrypt code (or data) in SPI Flash and only allows authorized code to run on NUC505 to avoid pirate. The document describe how to use ICP tool to program code, program MTP to enable the protect mechanism (cipher function), and get the encrypted file for mass production.

1.1 Features

- In-Circuit programming target chip
- Online/offline programming mode
  - Online programming mode: The target device must be connected to PC and ICP Programming Tool.
  - Offline programming mode: After saving the file data into Nu-Link dongle, user can program the target devices with this dongle alone (instead of using PC and ICP Programming Tool).
- Backup SPI Flash data of target chip (if the target chip is not Flash protected)
- Backup offline Flash data of Nu-Link dongle (if offline data has been unprotected)
- Write software serials number (SN) to target chip
- Limit the maximum programming count
- Data encryption for online/offline programming
- Batch mode for online/offline programming

2 Protect Mechanism

2.1 Protection for Memory Outside Chip (PMOC)

Because code and data are stored in SPI Flash, anyone can get data from SPI Flash through SPI interface easily. The NUC505 provides a mechanism to protect the firmware code in internal / external SPI Flash. It uses the information in MTP to encrypt code (or data) when writing data to SPI Flash and decrypt code (or data) in SPI Flash. Others can't get correct data from SPI Flash without correct MTP key.

When MTP is programmed, Code Validation is active automatically. The code on Flash (or the file wants to write to SPI Flash) must pass the Code Validation flow.

The NUC505 will search the offset address 0~16KB of SPI Flash (or the file wants to write to SPI Flash) to check if there is a correct Signature at the offset address (compare with the data in NUC505 MTP, see Figure 2-1). If there is no Signature, boot or programming operation fails.

The protect mechanism is called Protection for Memory Outside Chip.

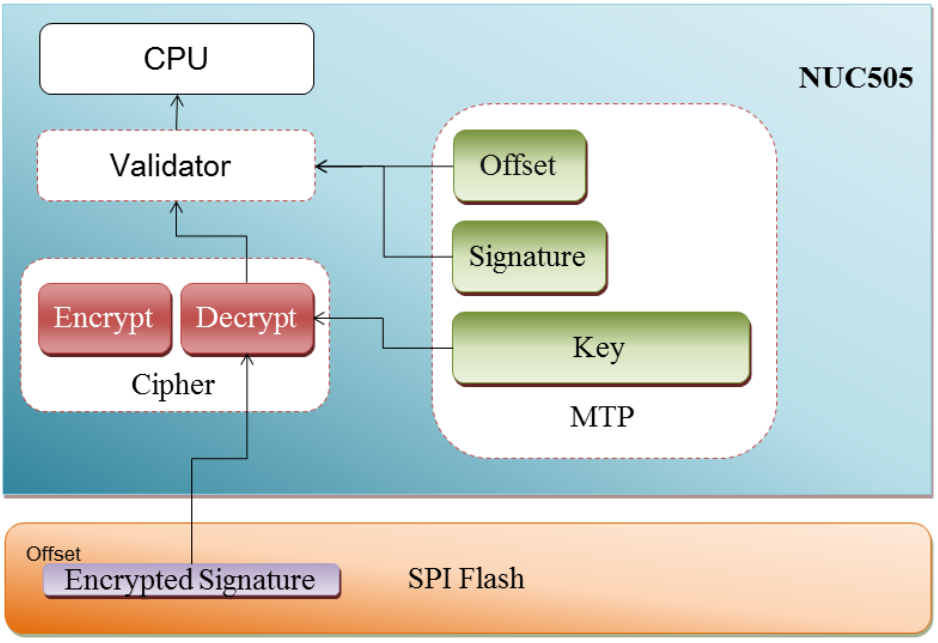

Figure 2-1 Code Validation Flow

2.2 Cipher function

The NUC505 provides Cipher function to encrypt data when writing data SPI Flash and decrypt data on SPI Flash when CPU executes code on SPI Flash or reads data from SPI Flash.

Figure 2-2 shows the path that NUC505 writes or reads data to/from SPI Flash. CPU can access SPI Flash without Cipher function, but the data is encrypted and useless without decrypted by correct Cipher Key. With Cipher function, CPU cannot execute / access correct code and data in SPI Flash if there is no correct Cipher Key.

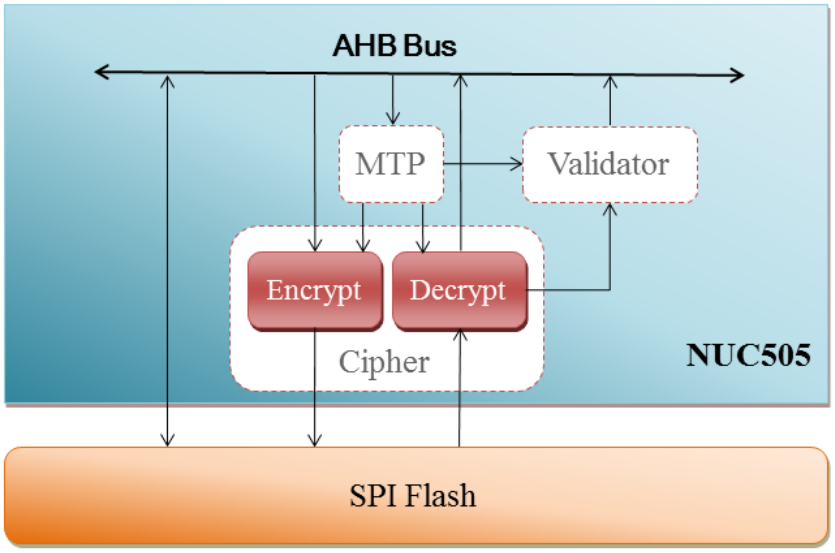

Figure 2-2 SPI Flash Data Access Path under PMOC

The following describes the difference between Plaintext (original data) and Ciphertext (the result of encryption performed on plaintext using a Cipher function). Take USBD_HID_MOUSE sample code for example.

File Data - Source data:

The file content is selected in the “Load file” section. Figure 2-3 shows source data.

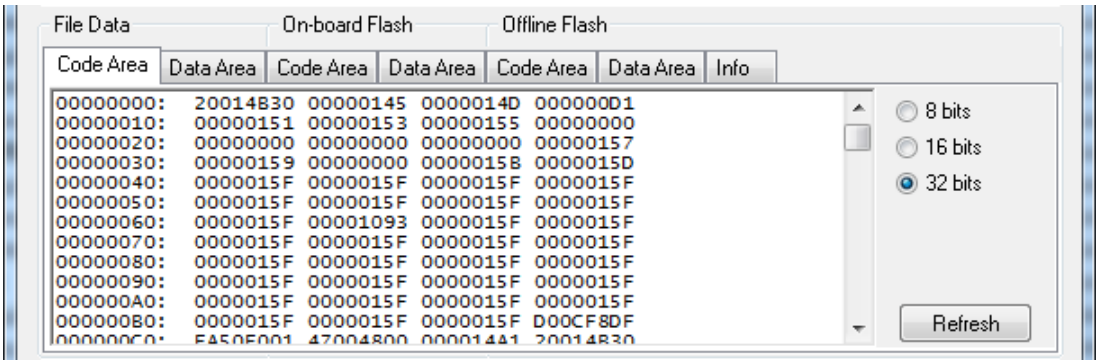

Figure 2-3 File Data Display Field

On-board Flash - Plaintext:

The data programmed on built-in Flash of the target chip is the same as the source data when MTP had never been programmed.

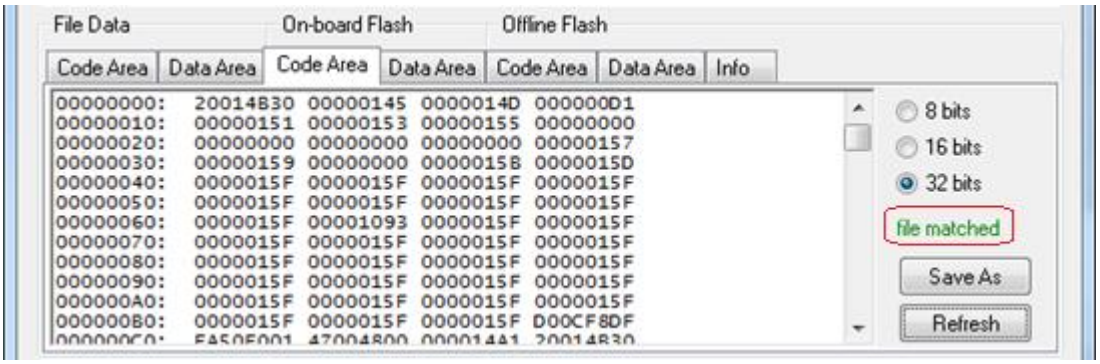

Figure 2-4 On-board Flash Data Display Field and Comparison Result

On-board Flash - Ciphertext:

When MTP had been programmed, the data programmed on built-in Flash of the target chip - Ciphertext would be different from the source data. CPU cannot access correct code and data in SPI Flash if there is no correct Cipher Key.

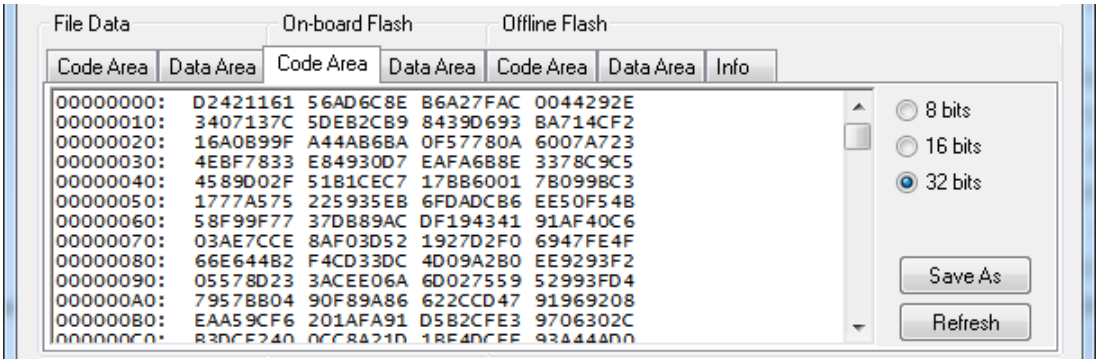

Figure 2-5 On-board Flash Data Display Field

2.3 Enable Cipher

The length of NUC505 Cipher Key is 64-bit and stored in MTP memory. MTP cannot be read back and modified. If the Cipher key exists (writes Key to MTP), The NUC505 Cipher is active and all data through Cipher will be encrypted / decrypted during run-time operations.

3 Preparing for ICP Programming Tool

3.1 System Requirements

The hardware and software requirements for installing the ICP Programming Tool are as follows:

- PC/AT compatible machine with Pentium or higher CPU
- XVGA(1024*768) color monitor
- At least 512M RAM for best performance
- At least 20M free disk space
- Windows 2000/XP/Vista/7/8

3.2 Hardware Installation

Steps of Hardware Installation:

1) Plug a USB cable into the USB port for Nu-Link of Tinny board.
2) Configure NUC505 to ICP mode (Set SW1 – S3 to 0).

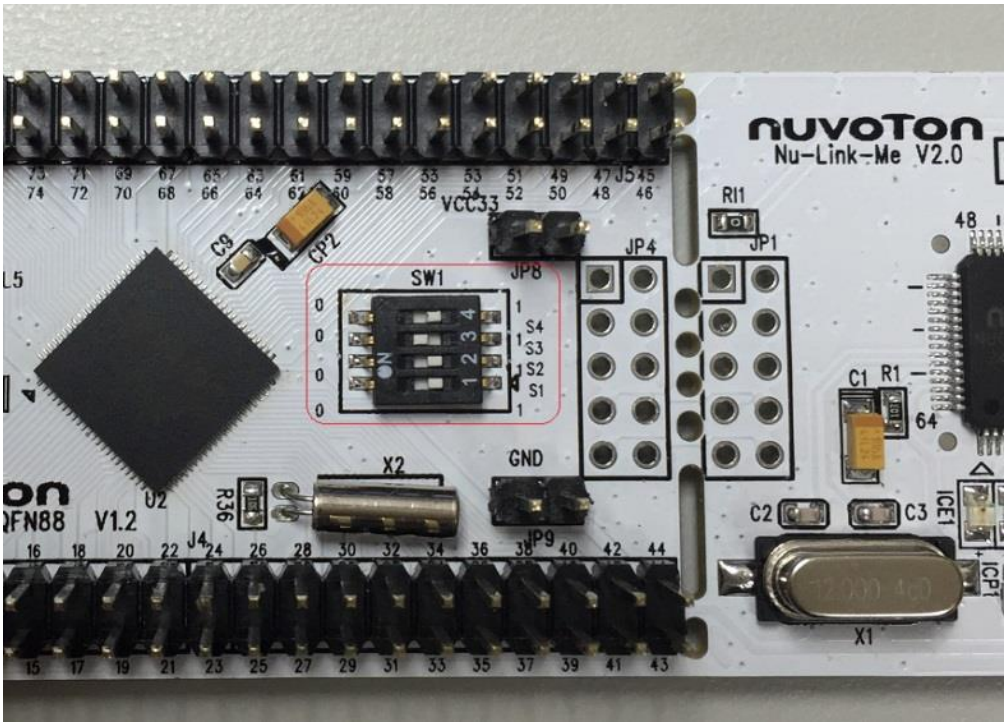

Figure 3-1 NUC505 Mode Switch

3) Connect the ICP Programming Tool board with the ICE interface of Tinny board.

3.3 Software Installation

Please run the installer package to install the software. The NUC505 is supported after Version 1.27. After installing the software, you can find the “Nuvoton Tools” on the “Start Menu” and the shortcut of ICP Programming Tool.

3.4 ICP Interface

Figure 3-2 shows the selection form at startup of the ICP Programming Tool.

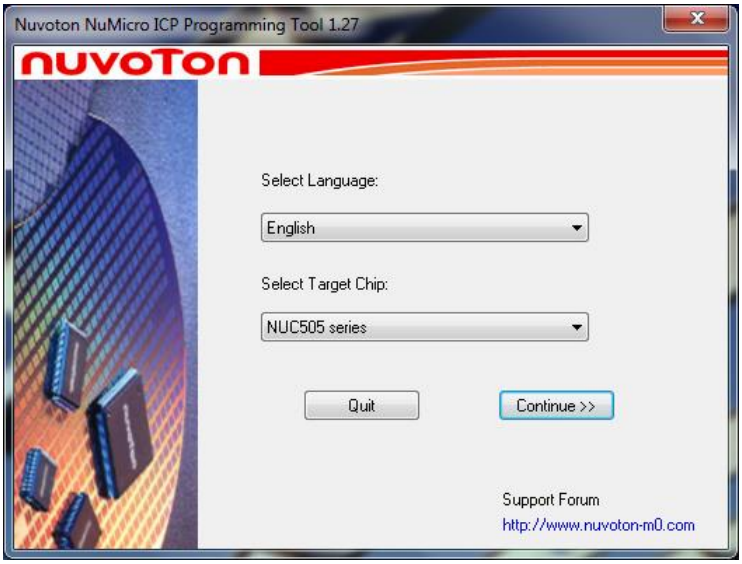

Figure 3-2 Chip Series and Language Selection

4 Starting to Use ICP Programming Tool

This chapter introduces the general operations in ICP Programming Tool. Please refer to Figure 4-1 for information on each section in the ICP Programming Tool Interface.

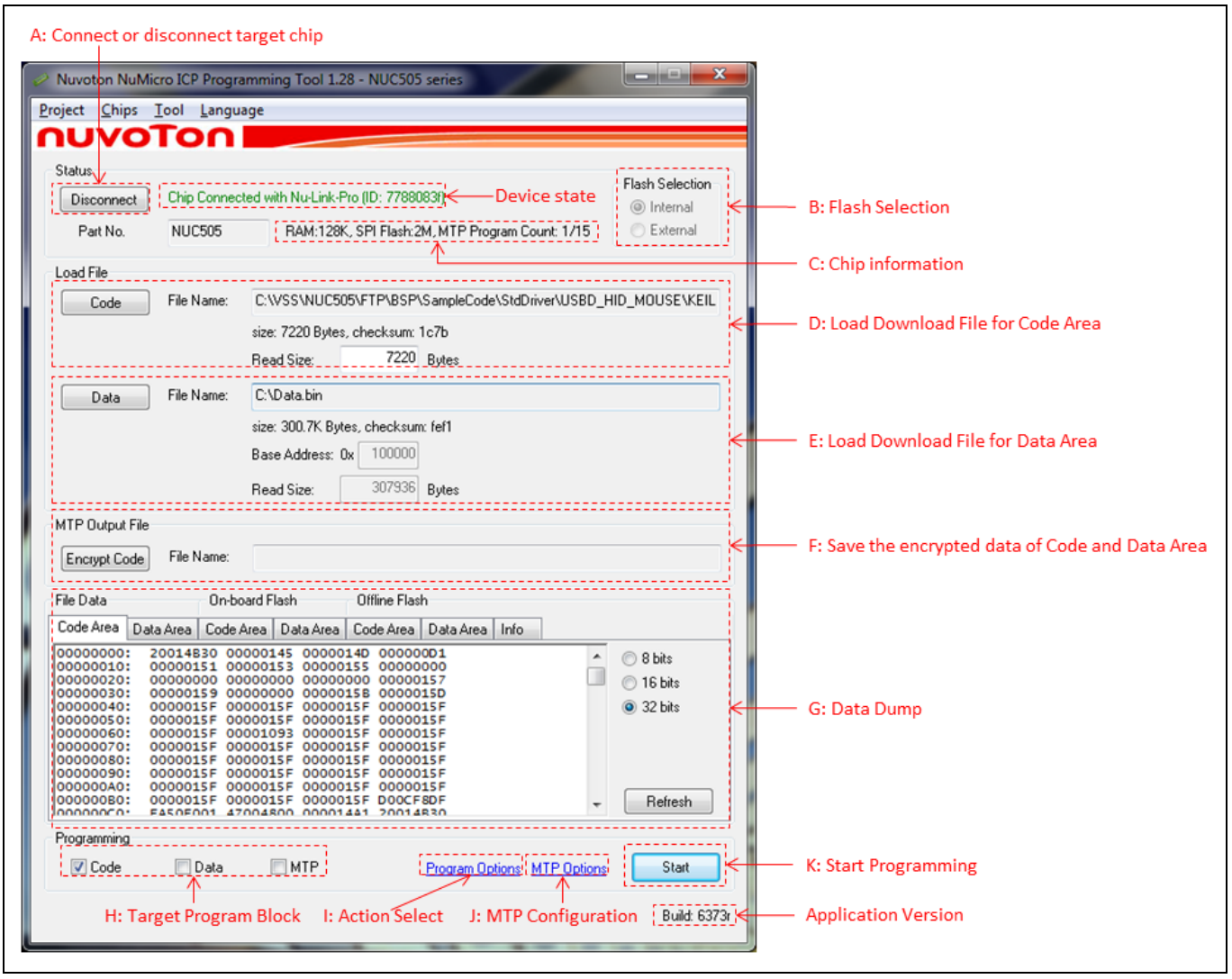

Figure 4-1 ICP Programming Tool User Interface for NUC505

4.1 Connect Status & Chip Information

Before connected

The ICP Programming Tool will try to connect the target chip once the user clicks the "**Connect**" button.

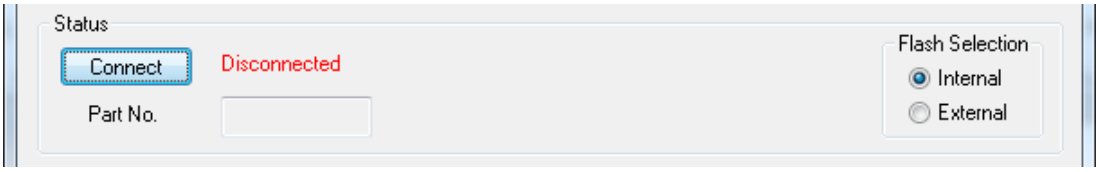

Figure 4-2 Connect Status - Disconnected

After the USB dongle is connected successfully

The ICP Programming Tool shows "ICE Connected".

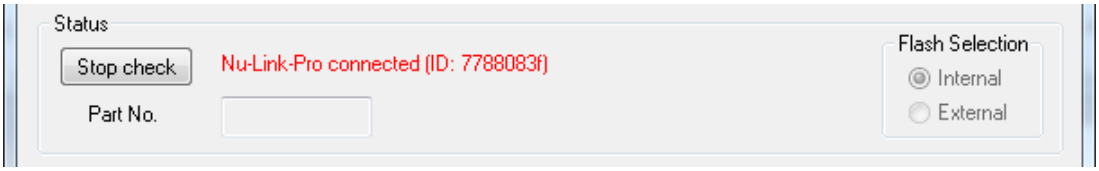

Figure 4-3 Connect Status - Nu-Link-Pro Connected

After the target chip is connected successfully

The ICP Programming Tool would read chip information (including Part No., RAM size, SPI Flash size and MTP status) and show the information on section C in Figure 4-1.

Figure 4-4 Chip Information

If MTP had been programmed, the ICP Programming Tool would show the MTP programming times and the code written into SPI Flash would be encrypted. The Cipher function can be disabled in Program Options.

Figure 4-5 Chip Information - MTP Burned

If MTP is locked, MTP status shows “MTP: Locked” in red. MTP can be programmed 15 times, but MTP cannot be programmed after MTP locked.

Figure 4-6 Chip Information - MTP Locked

The “MTP” option is also disabled in the **programming** section.

Figure 4-7 MTP Option Disabled when MTP Locked

4.2 File Information

Load File:

Select a file for programming. Then the file size and checksum information will be displayed. Before starting to program a target board, user can select blocks for programming – Code / Data. The supported file format includes **bin** or **Intel hex** (Intel 8, 16, 32).

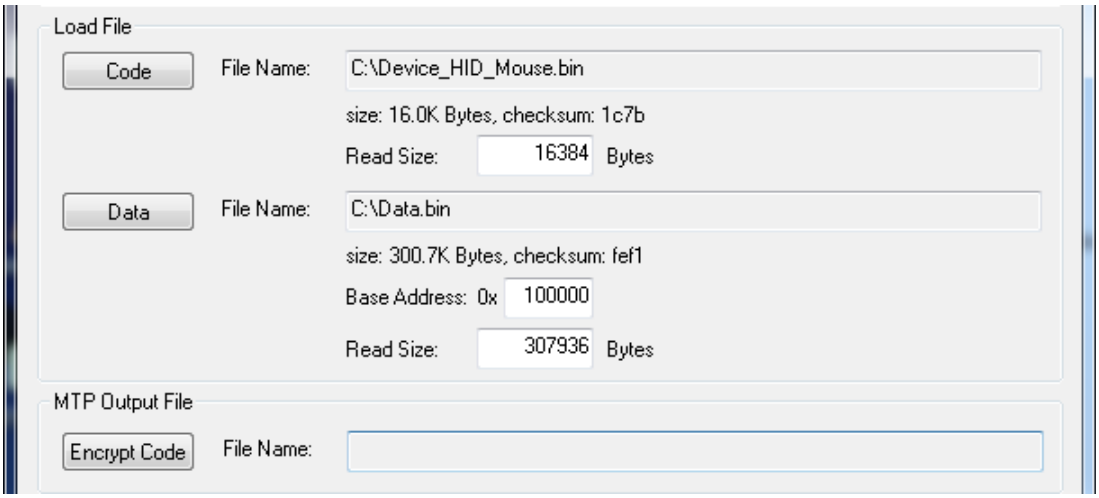

Figure 4-8 Load File Setting

Base Address & Read Size:

The field is for Data Dump function and is only enabled when Target Block “Data” is selected in the **programming** section. Due to reading all contents of SPI Flash is time-consuming, partial-read from the assigned base address (Code Area is fixed at 0x0) and read size are provided (referring to D and E in Figure 4-1). The “Base Address” and “Read Size” show different input format respectively.

MTP Output File:

If MTP had been programmed or MTP selected for this program, user could assign the file path (referring to F in Figure 4-1). When the programming process is complete, the ICP tool would merge the encrypted data of Code Area and Data Area into a binary file and save it to the assigned path.

4.3 Data Dump

Once refresh, the data information section will show three parts of Flash data information respectively, including “File Data”, “On-board Flash”, and “Offline Flash”. Take USBD_HID_MOUSE sample code for example.

File Data:

The file content is selected in the “Load file” section.

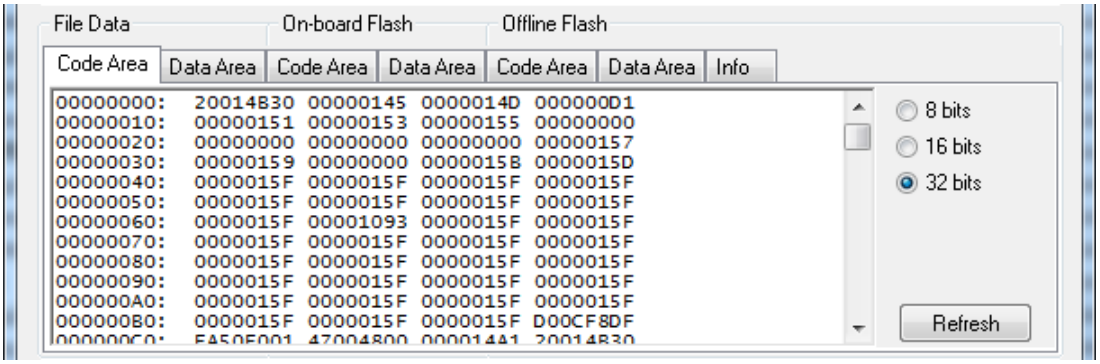

Figure 4-9 File Data Display Field

On-board Flash:

The data programmed on built-in Flash of the target chip. If MTP had never been programmed, the ICP Tool shows the comparison result.

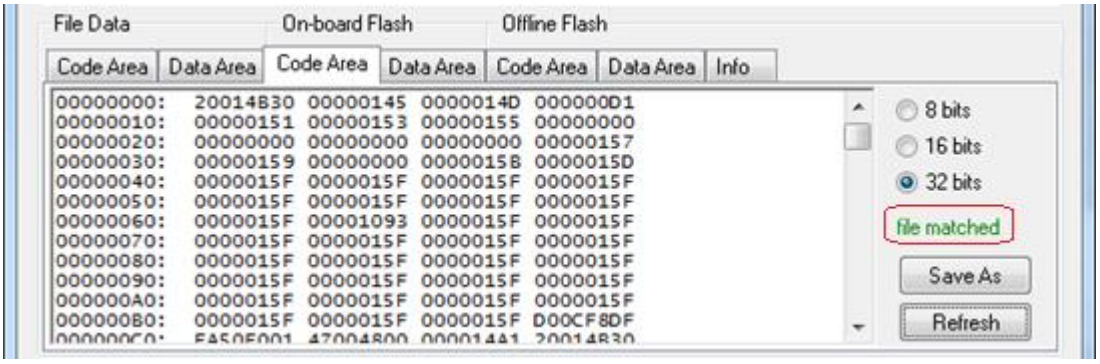

Figure 4-10 On-board Flash Data Display Field and Comparison Result

If MTP had been programmed, the ICP Tool did not show the comparison result (only get the encrypted data).

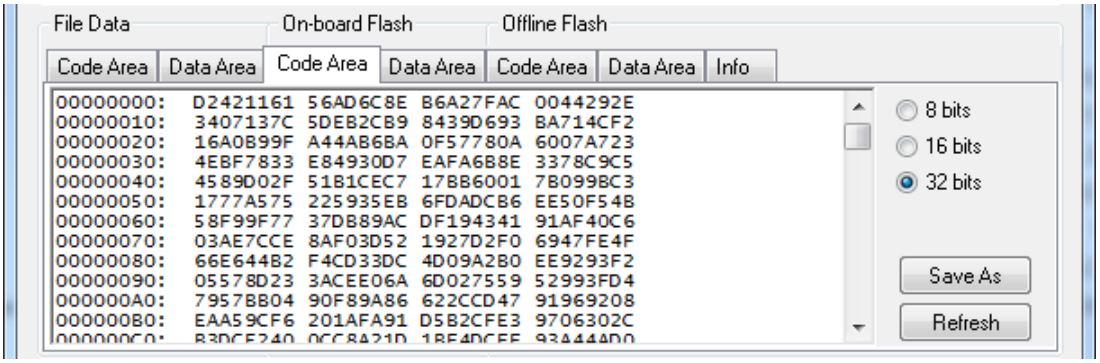

Figure 4-11 On-board Flash Data Display Field

4.4 Programming Options

There are three Programming options available for selection: Code, Data, and MTP.

Code:

If MTP had been programmed, the Code area must be programmed (target block “Code” must be selected) for PMOC validation. Otherwise, user would get the warning message “Code Area must be programmed!”.

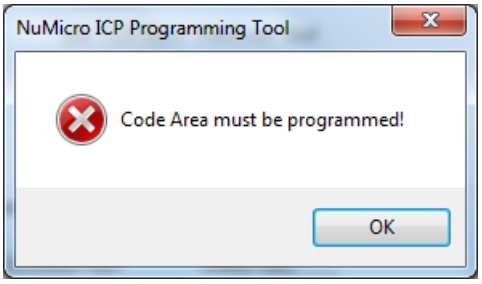

Figure 4-12 Warning Message - “Code Area must be programmed!”

If MTP had been programmed, the code (plaintext) must meet PMOC mechanism (MTP signature and offset rule, please refer to section 2.1). Otherwise, the code could not be written into SPI Flash successfully.

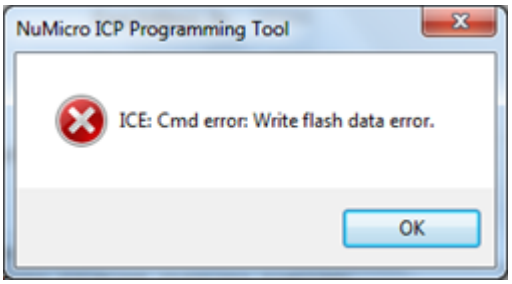

Figure 4-13 Warning Message - “Write flash data error"

Data:

It’s optional. The Base address can be assigned after Data Block is selected.

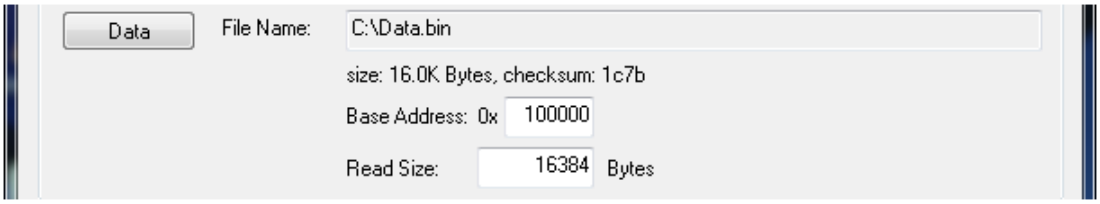

Figure 4-14 Data Area Base Address Setting

MTP:

If MTP is locked, the “MTP” option is also disabled.

Figure 4-15 MTP option Disabled when MTP Locked

4.5 Program Options

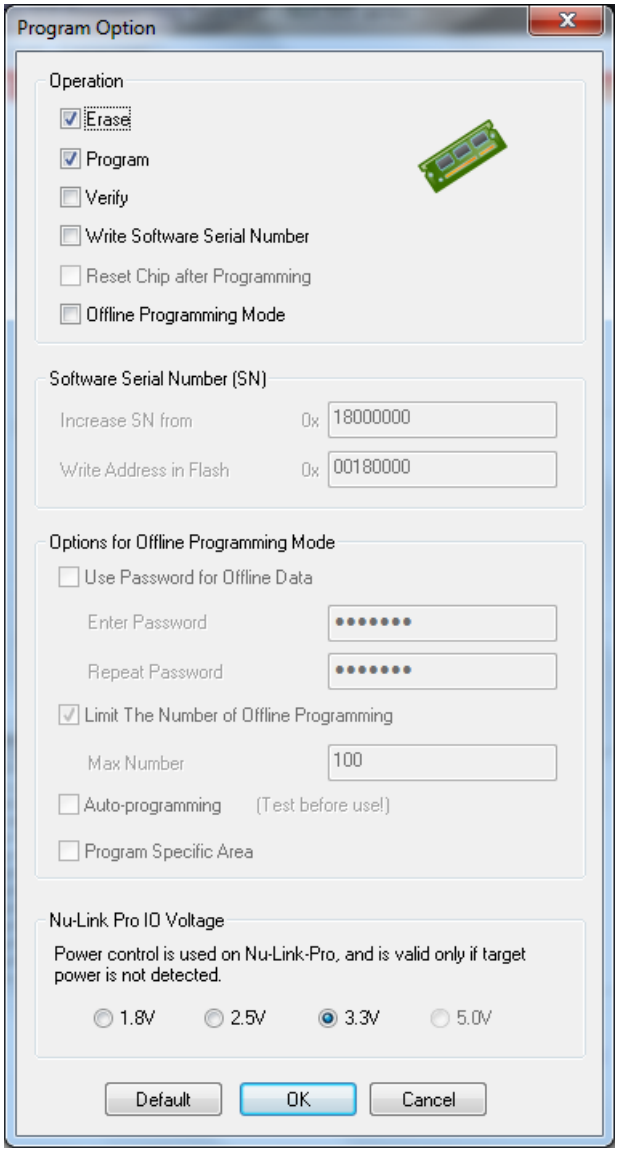

Figure 4-16 Program Option Window

1. The operation options includes erase, program, verify, and offline programming mode settings.
2. User can enable “Write Software Serials Number”, and assign “SN start value” and “target Flash address where SN saved”.
3. User can specify the password for offline programming mode and the limitation of maximum programming count for security issue.
4. If MTP had been programmed, an additional option “Disable Cipher” would be shown on the “Program Option”.

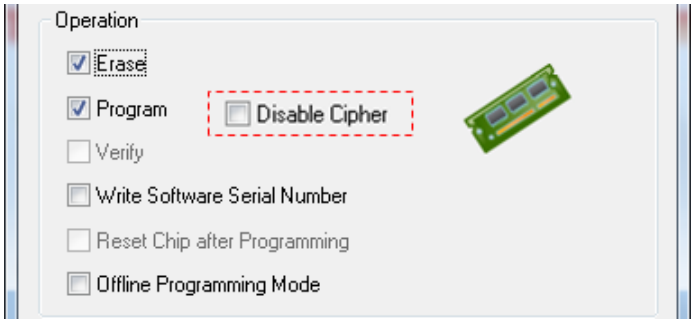

Figure 4-17 Disable Cipher

If you want to write the encrypted code (Ciphertext, such as the file created by “MTP Output File”), the “Disable Cipher” option must be selected (The validation function for Writing Flash will be disabled). Then any code can be written into SPI Flash. Therefore, the encrypted code must be valid, otherwise the code cannot boot successfully.

4.6 MTP Options

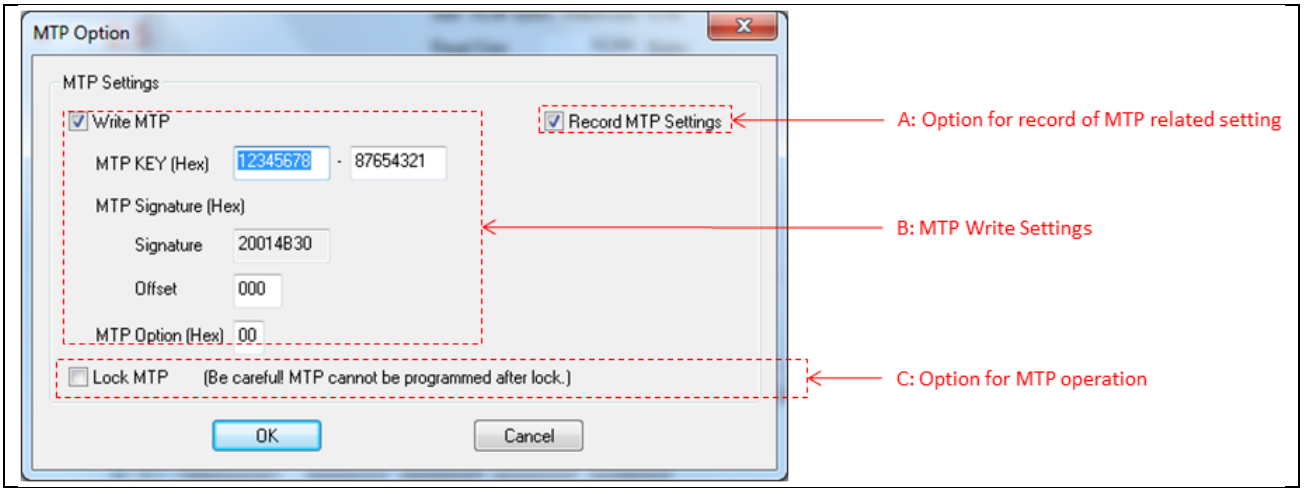

Figure 4-18 MTP Setting Window

On the MTP Option form, user can select the desired operation and fill in MTP keys and signature. The options and fields are described below:

1. **Write MTP:** Write 64-bit key, 32-bit Signature, 12-bit Offset, and 1-byte option with hex-code input format. If the file for Code Area is loaded, the Tool will search the corresponding 32-bit value and fill in the “Signature” automatically according to the address of “Offset”.
2. **Lock MTP:** Lock MTP. MTP cannot be programmed after lock.

3. **Record MTP Settings:** If this option is checked, the MTP settings including MTP Key and Signature on MTP Option Dialog will be recorded after clicking “OK”. When the ICP Tool is reopened, the previous MTP settings will be restored.

5 Programming User Guide

Before MTP is programmed, user can read / write the SPI Flash like general SPI Flash (Cipher function is disabled). But after MTP is programmed, Cipher function is active automatically and the behavior of SPI Flash access is different from general SPI Flash (see Section 2.2).The descriptions are divided into two parts: Cipher Function Disabled and Cipher Function Enabled.

5.1 Cipher Function Disabled

The section describes the flow to write/read SPI Flash when Cipher function is disabled. The behavior is the same as general SPI Flash.

5.1.1 Program Code to SPI Flash without Cipher

Steps of Programming Code to SPI Flash:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

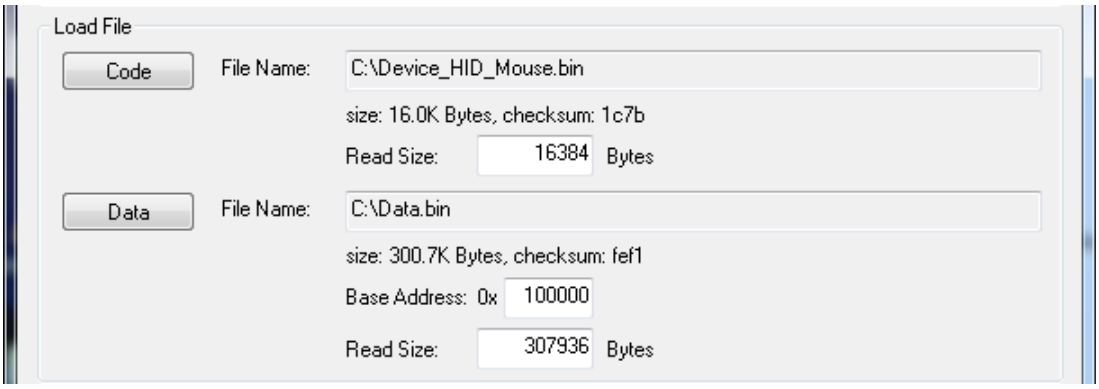

Figure 5-1 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

Figure 5-2 "Programming" Setting - Data

2) Select the operations you want to include in the procedure through "Program Options" in the **Programming** section – Erase, Program, or Verify.

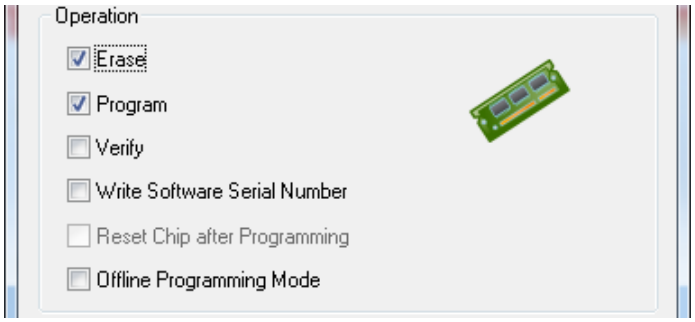

Figure 5-3 Program Option - Operation

3) Click the “**Start**” button to program SPI Flash.

Figure 5-4 "Start" Button

5.1.2 Read Code/Data from SPI Flash without Cipher

Steps of Reading Code/Data from SPI Flash:

1) Please set the “Read Size” field for code and “Read Size” &“Base Address” for Data if needed (User needs to know the size of code area to load the data size).

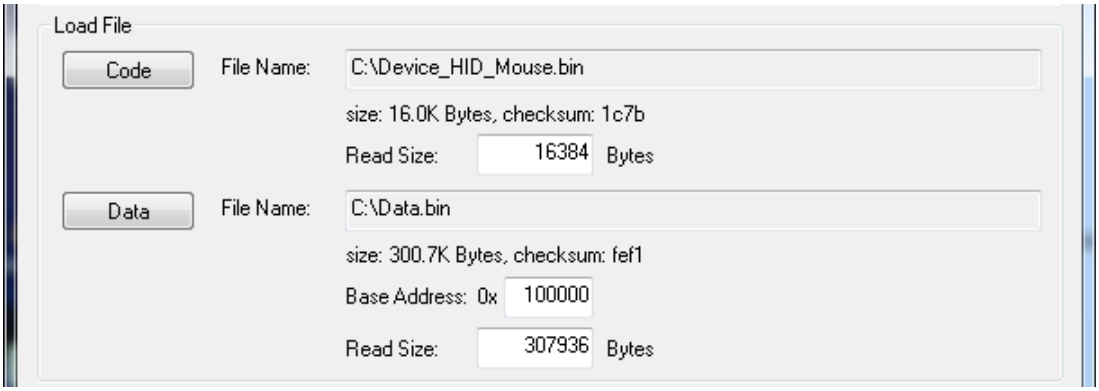

Figure 5-5 Load File Setting

The field is for Data Dump function and is only enabled when Target Block “Data” is selected in the **Programming** section

Figure 5-6 "Programming" Setting - Data

2) Please click the “**Refresh**” button for “On-board Flash” to see dump data in “Code Area” window or “Data Area” window (it shows the comparison result); click “Save as” for “On-board Flash” to save data to file.

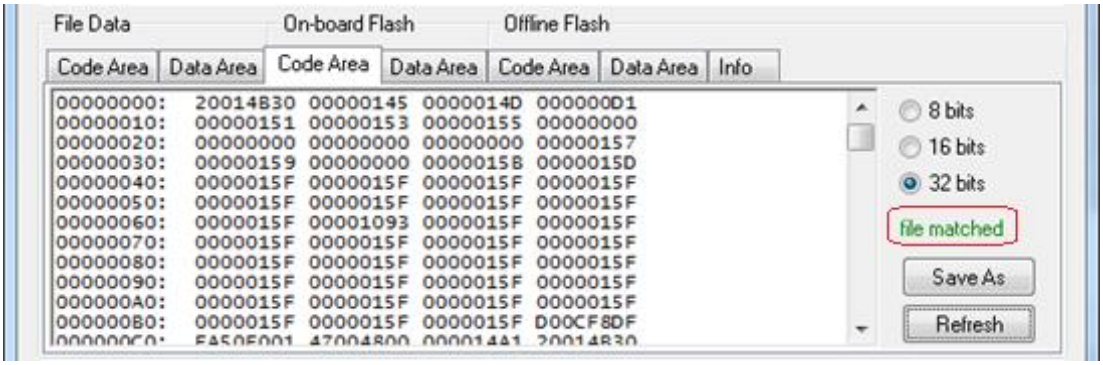

Figure 5-7 On-board Flash Data Display Field and Comparison Result

5.2 Cipher Function Enabled

This section describes the flow to write/read SPI Flash with Cipher function and program MTP. The NUC505 Cipher function will be enabled after MTP is programmed. Therefore, MTP should be programmed or will be programmed later to enable Cipher function.

User can check the following table to find out what file / information he should have and the subsection he should focus on

Section	File Format	Program MTP?	Read back?	Comment
5.2.1	Plaintext	Yes	Yes	Use updated MTP info to encrypt.
5.2.2	Plaintext	Yes	No	Use updated MTP info to encrypt
5.2.3	Plaintext	No	Yes	Use current MTP info to encrypt
5.2.4	Plaintext	No	No	Use current MTP info to encrypt
5.2.5	N/A	Yes	No	Only update MTP
5.2.6	N/A	No	Yes	Only Read back data
5.2.7	Ciphertext	Yes	No	Disable Cipher
5.2.8	Ciphertext	No	No	Disable Cipher

Table 5-1

5.2.1 Program MTP and Plaintext Code with Cipher, and Get Encrypted File

Steps of Program MTP and Plaintext Code with Cipher, and Get Encrypted File:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

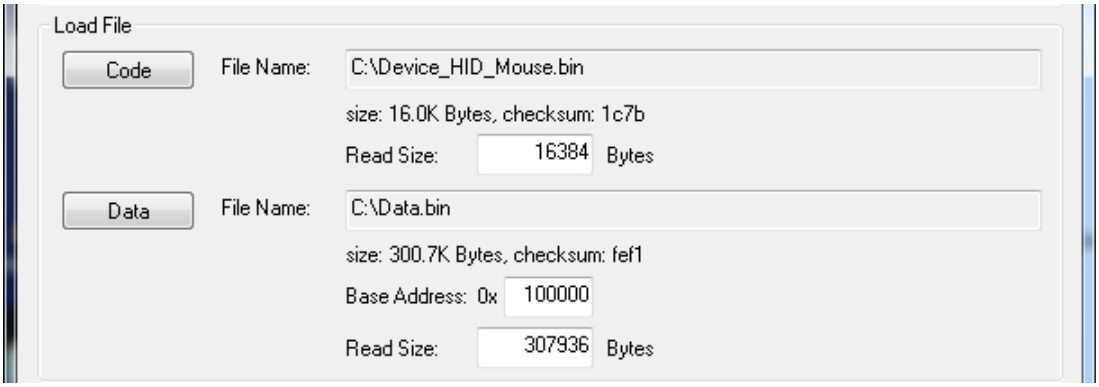

Figure 5-8 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

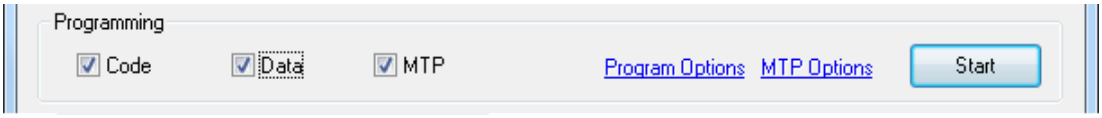

Figure 5-9 "Programming" Setting - Data

2) Set MTP information through the "MTP Option" in the **Programming** section

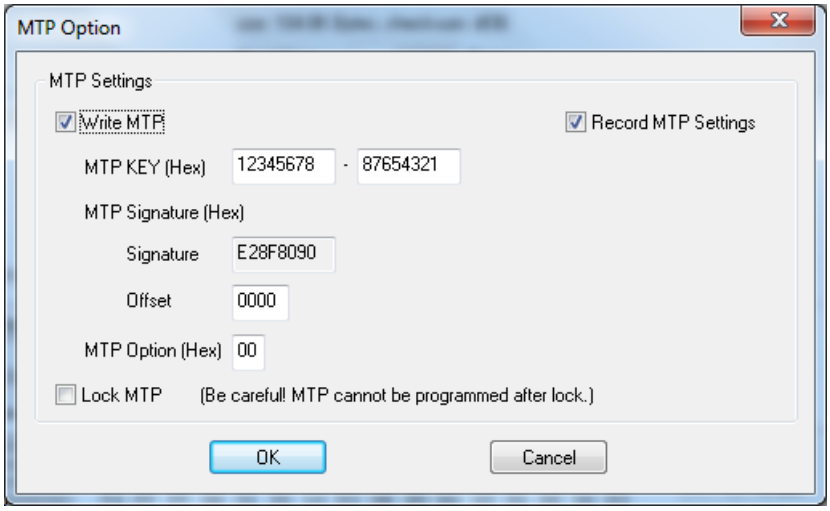

Figure 5-10 MTP Setting Window

- User can select "Write MTP" or "Lock MTP" only.

- Please make sure that code can run before selecting the **Lock MTP** option.
- "Signature" is filled automatically according to whether the "Offset" when "Code" in **Load File** section is set. Please make sure that the "Signature" is correct if you fill it by yourself.
- Cipher is disabled and Code Validation is also disabled (you can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.
- "MTP" checkbox in the **Programming** section must be selected.

Figure 5-11 "Programming" Setting - MTP

3) Select the operations you want to include in the procedure through "Program Options" in the **Programming** section – Erase, Program, or Verify.

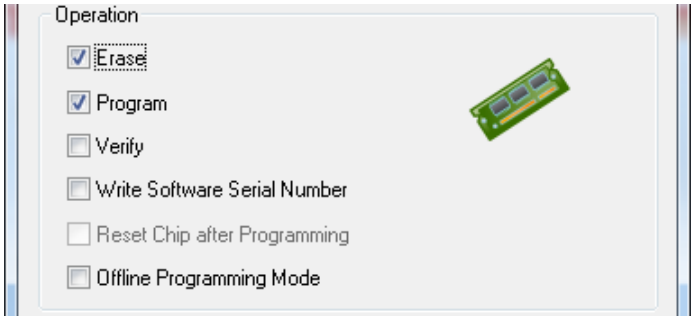

Figure 5-12 Program Option - Operation

4) Click the "**MTP Output File**" button to set the encrypted file name and path.

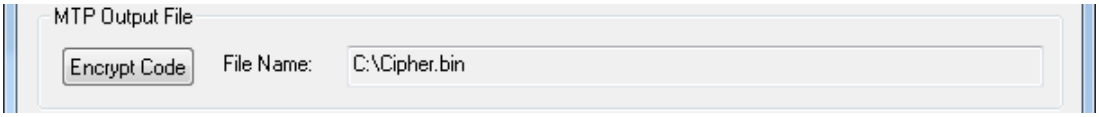

Figure 5-13 Encrypted File Output Setting

5) Click the "**Start**" button to program SPI Flash with Cipher, program MTP, and get the encrypted file.

Figure 5-14 "Start" Button

5.2.2 Program Plaintext Code with Cipher and MTP

Steps of Program Plaintext Code with Cipher and MTP:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

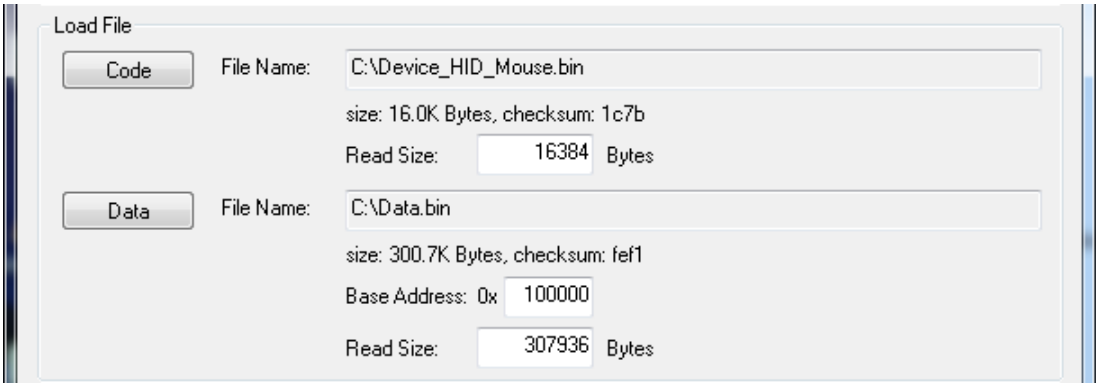

Figure 5-15 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

Figure 5-16 "Programming" Setting - Data

2) Set MTP information through the "MTP Option" in the **Programming** section

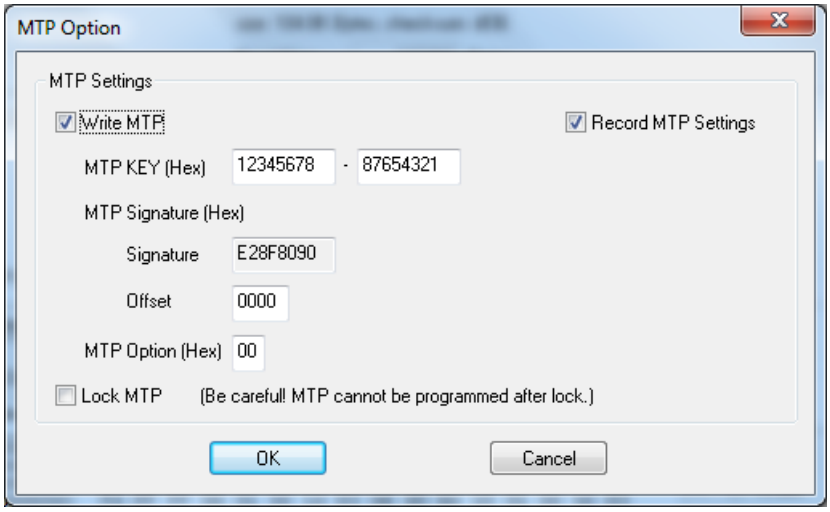

Figure 5-17 MTP Setting Window

- User can select “Write MTP” or “Lock MTP” only.
- Please make sure that code can run before selecting the **Lock MTP** option.
- “Signature” is filled automatically according to whether the “Offset” when “Code” in **Load File** section is set. Please make sure that the “Signature” is correct if you fill it by yourself.
- Cipher is disabled and Code Validation is also disabled (you can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.
- “MTP” checkbox in the **Programming** section must be selected.

Figure 5-18 "Programming" Setting - MTP

3) Select the operations you want to include in the procedure through “Program Options” in the **Programming** section – Erase, Program, or Verify.

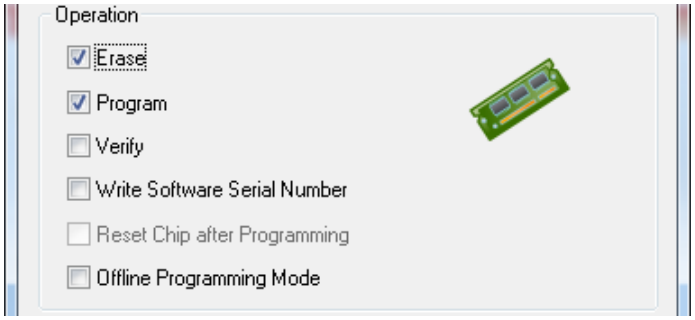

Figure 5-19 Program Option - Operation

4) Click the “**Start**” button to program SPI Flash with Cipher and MTP.

Figure 5-20 "Start" Button

5.2.3 Program Plaintext Code with Cipher and Get Encrypted File

Steps of Program Plaintext Code with Cipher and Get Encrypted File:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

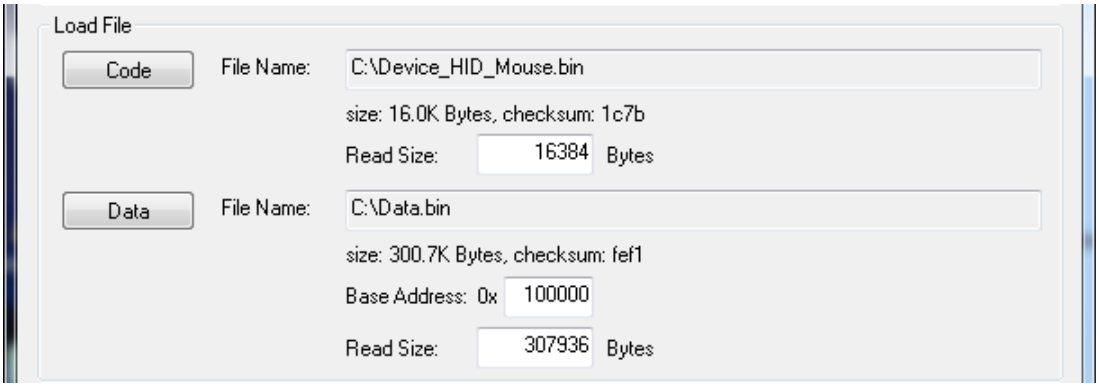

Figure 5-21 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

Figure 5-22 "Programming" Setting - Data

MTP certainly is programmed. After MTP is programmed, PMOC protection is also active. User must pass the PMOC validation (The code (plaintext) must meet the MTP signature and offset rule). Otherwise, the code cannot be written into SPI Flash successfully. Please check if the source code is valid for PMOC.

2) Select the operations you want to include in the procedure through “Program Options” in the **Programming** section – Erase, Program, or Verify.

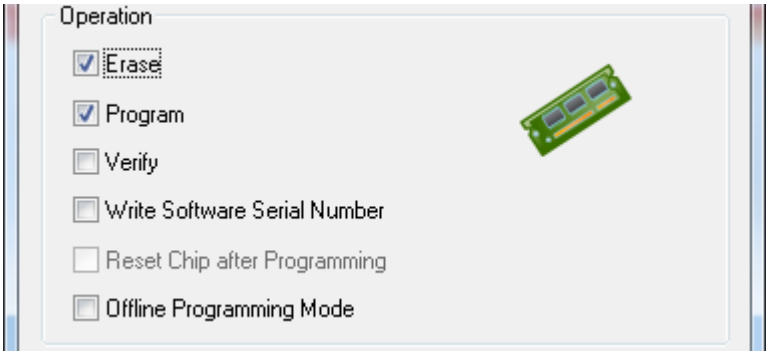

Figure 5-23 Program Option - Operation

3) Click the “**MTP Output File**” button to set the encrypted file name and path.

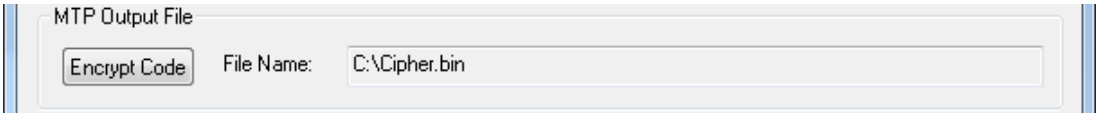

Figure 5-24 Encrypted File Output Setting

4) Click the “**Start**” button to program SPI Flash with Cipher and get the encrypted file.

Figure 5-25 "Start" Button

5.2.4 Program Plaintext Code with Cipher

Steps of Program Plaintext Code with Cipher:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

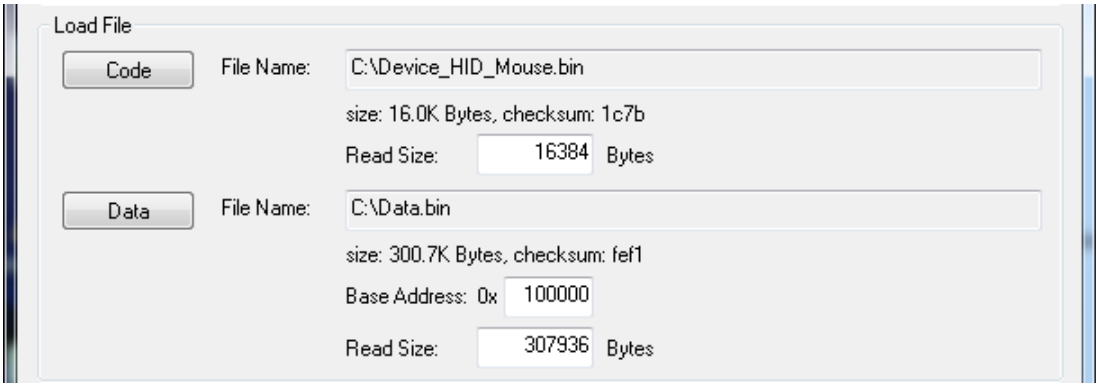

Figure 5-26 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

Figure 5-27 "Programming" Setting - Data

MTP certainly is programmed. After MTP is programmed, PMOC protection is also active. User must pass the PMOC validation (The code (plaintext) must meet the MTP signature and offset rule). Otherwise, the code cannot be written into SPI Flash successfully. Please check if the source code is valid for PMOC.

2) Select the operations you want to include in the procedure through "Program Options" in the **Programming** section – Erase, Program, or Verify.

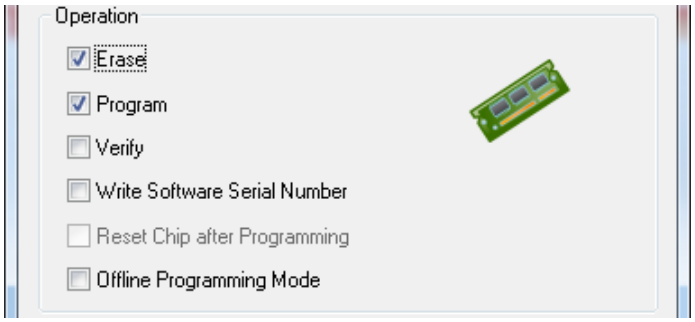

Figure 5-28 Program Option - Operation

3) Click the “**Start**” button to program SPI Flash with Cipher.

Figure 5-29 "Start" Button

5.2.5 Program MTP Only

Steps of Program MTP Only:

1) Set MTP information through the “MTP Option” in the **Programming** section

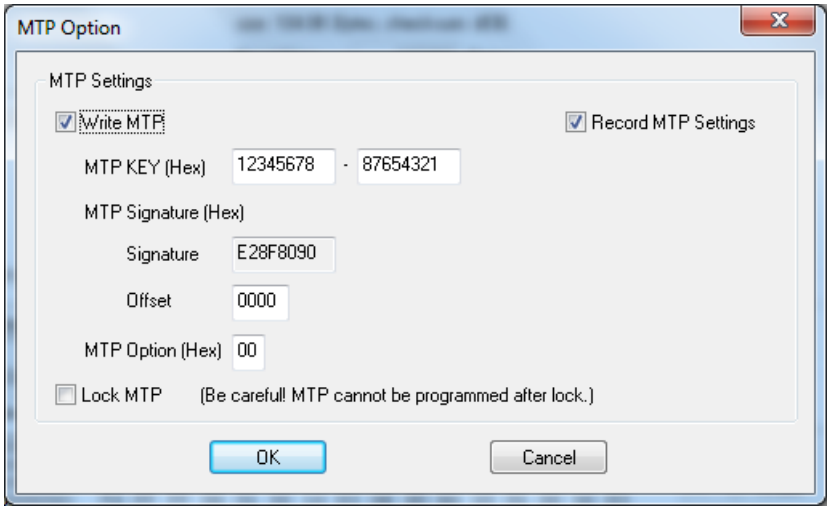

Figure 5-30 MTP Setting Window

- User can select “Write MTP” or “Lock MTP” only.
- Please make sure that code can run before selecting the **Lock MTP** option.
- “Signature” is filled automatically according to whether the “Offset” when “Code” in **Load File** section is set. Please make sure that the “Signature” is correct if you fill it by yourself.
- Cipher is disabled and Code Validation is also disabled (you can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.
- “MTP” checkbox in the **Programming** section must be selected.

Figure 5-31 "Programming" Setting - MTP

2) Select the operations you want to include in the procedure through “Program Options” in the **Programming** section – Erase, Program, or Verify.

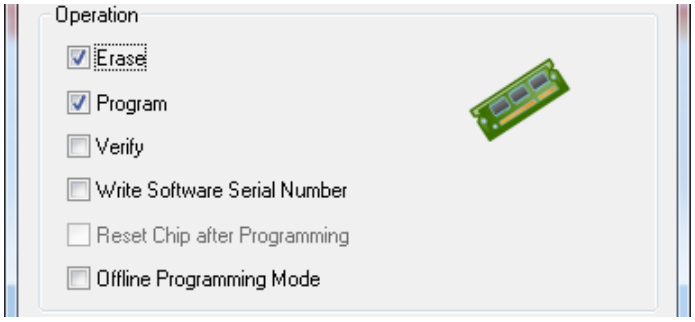

Figure 5-32 Program Option - Operation

3) Click the “**Start**” button to program MTP.

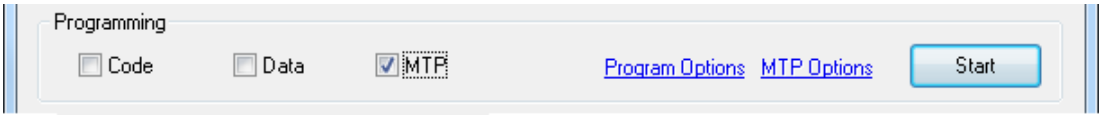

Figure 5-33 "Start" Button

5.2.6 Get Encrypted File

Steps of Get Encrypted File:

1) Please set the “Read Size” field for code and “Read Size” &“Base Address” for Data if needed (User needs to know the size of code area to load the data size).

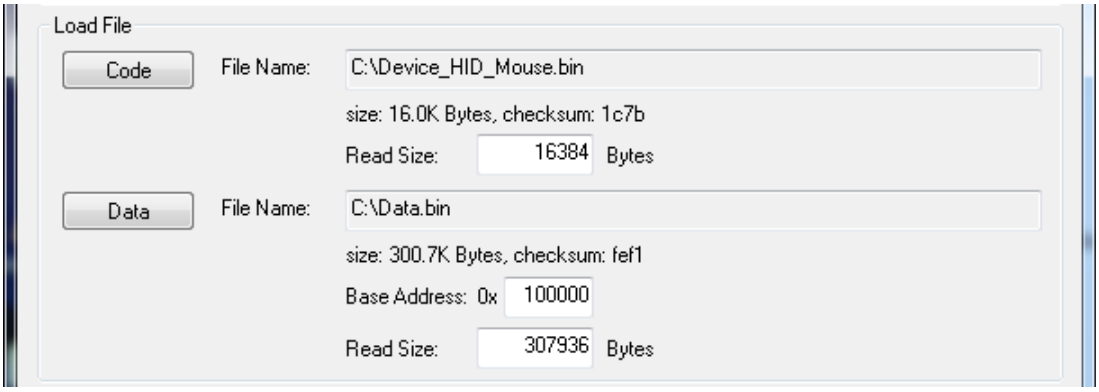

Figure 5-34 Load File Setting

The field is for Data Dump function and is only enabled when Target Block “Data” is selected in the **Programming** section

Figure 5-35 "Programming" Setting - Data

2) Please click the "**Refresh**" button for "On-board Flash" to see dump data in "Code Area" window or "Data Area" window (it shows the comparison result); click "Save as" for "On-board Flash" to save data to file.

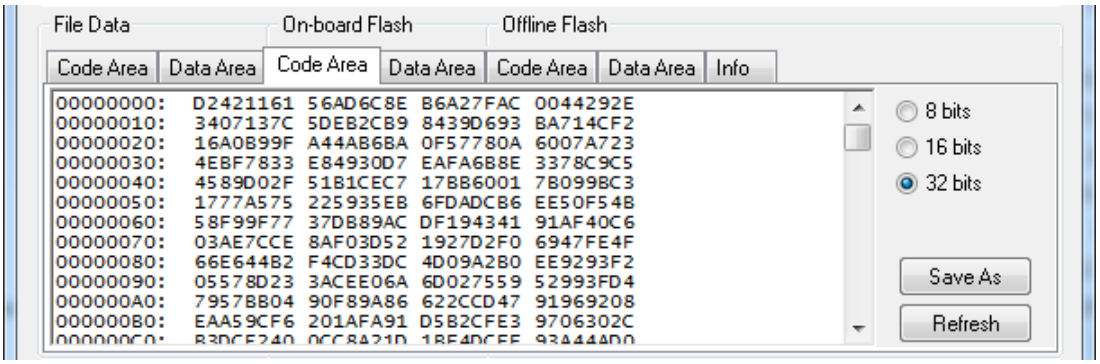

Figure 5-36 On-board Flash Data Display Field

5.2.7 Program Ciphertext Code without Cipher and MTP

Steps of Program Ciphertext Code with Cipher and MTP:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

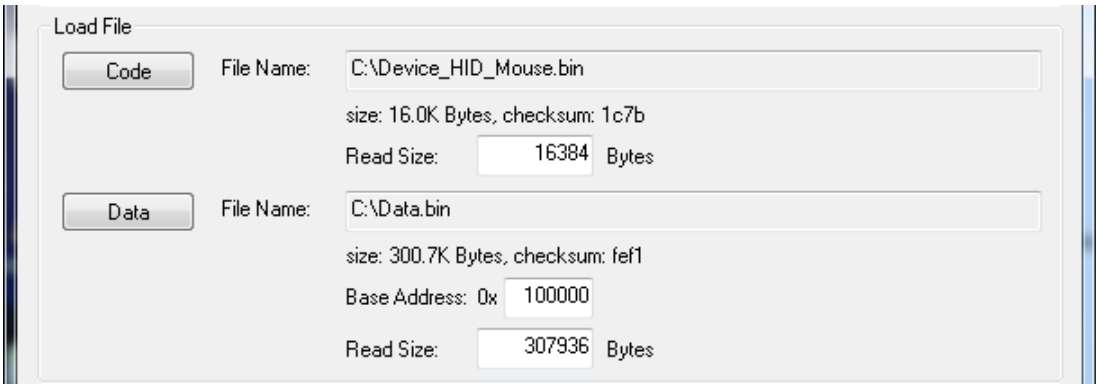

Figure 5-37 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

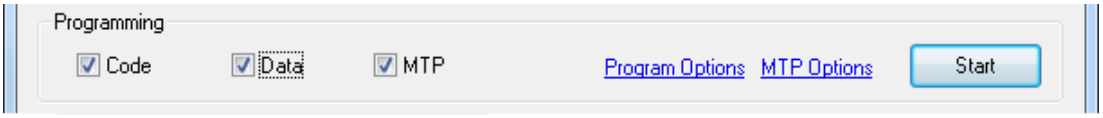

Figure 5-38 "Programming" Setting - Data

2) Set MTP information through the “MTP Option” in the **Programming** section

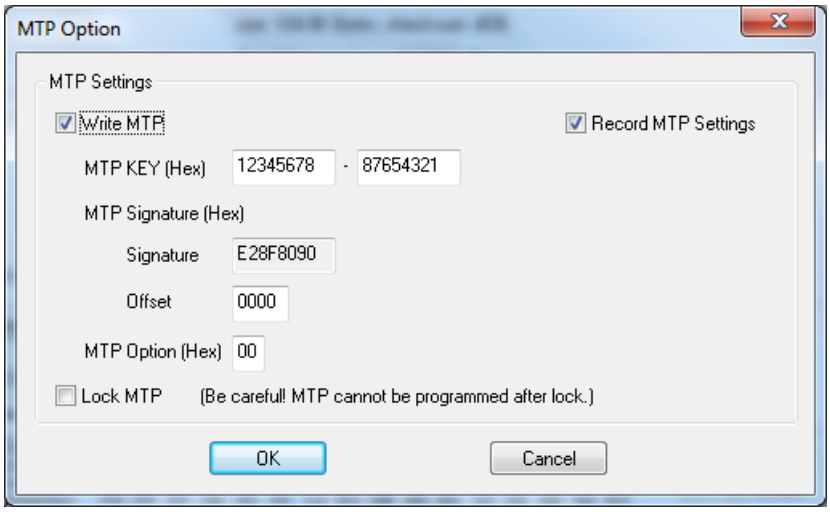

Figure 5-39 MTP Setting Window

- User can select “Write MTP” or “Lock MTP” only.
- Please make sure that code can run before selecting the **Lock MTP** option.
- “Signature” is filled automatically according to whether the “Offset” when “Code” in **Load File** section is set. Please make sure that the “Signature” is correct if you fill it by yourself.
- Cipher is disabled and Code Validation is also disabled (you can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.
- “MTP” checkbox in the **Programming** section must be selected.

Figure 5-40 "Programming" Setting - MTP

3) Select the operations you want to include in the procedure through “Program Options” in the **Programming** section – Erase, Program, or Verify.

The most important is to select the **Disable Cipher** option and make sure that the encrypted file is valid. If the file is invalid, the code cannot run (You can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.

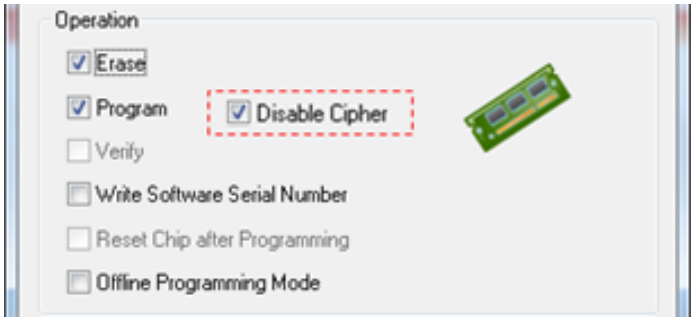

Figure 5-41 Program Option - Operation & Disable Cipher

4) Click the "**Start**" button to program SPI Flash with Cipher and MTP.

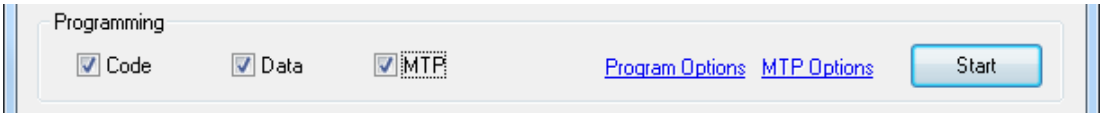

Figure 5-42 "Start" Button

5.2.8 Program Ciphertext without Cipher

Steps of Program Ciphertext Code without Cipher:

1) Please click the "**Code**" button to set a file for code and the "**Data**" button for data if needed.

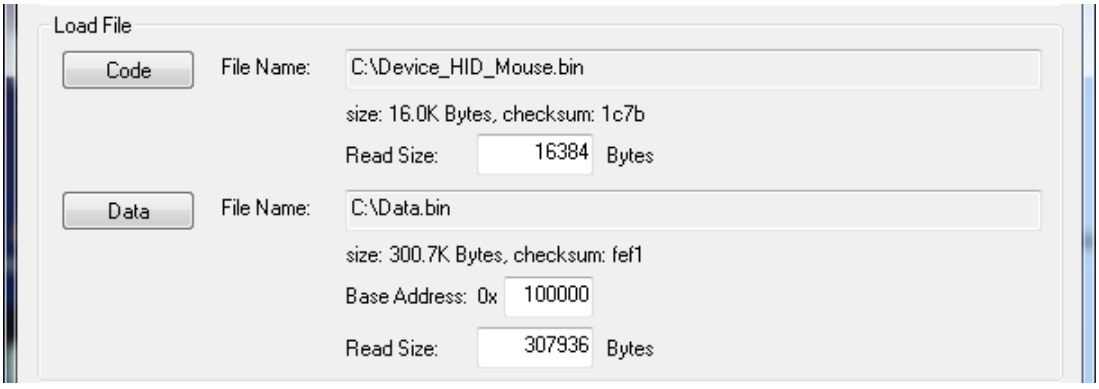

Figure 5-43 Load File Setting

The "**Data**" button is only enabled when the "**Data**" checkbox in the **Programming** section is selected.

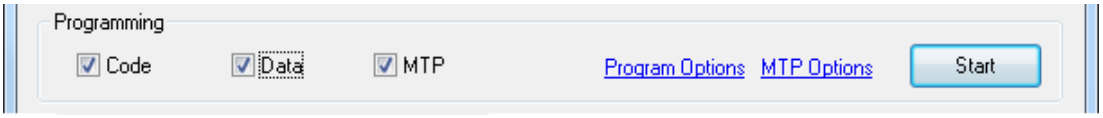

Figure 5-44 "Programming" Setting - Data

2) Select the operations you want to include in the procedure through “Program Options” in the **Programming** section – Erase, Program, or Verify.
The most important is to select the **Disable Cipher** option and make sure that the encrypted file is valid. If the file is invalid, the code cannot run (You can write any file into SPI Flash). Please make sure that the binary file is a valid encrypted file.

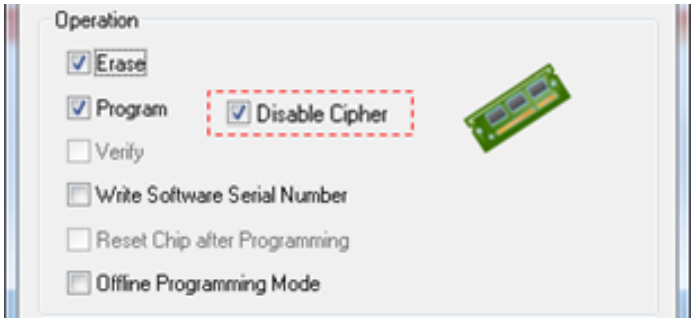

Figure 5-45 Program Option - Operation & Disable Cipher

3) Click the “**Start**” button to program SPI Flash

Figure 5-46 "Start" Button

6 Troubleshooting

6.1 Code Cannot Run

Code cannot run and there is no warning message when writing code into SPI Flash correctly (Read back data is the same as source binary file)

Possible Cause:

1) MTP had been programmed and the "**Disable Cipher**" option had been selected, the Cipher function would be disabled when programming SPI Flash.
   Solution: Please follow the step to check the situation

1) Please check if the "**Disable Cipher**" option is selected or not. If "**Disable Cipher**" option is selected, user must make sure that the file is the Ciphertext for the MTP information of the NUC505.

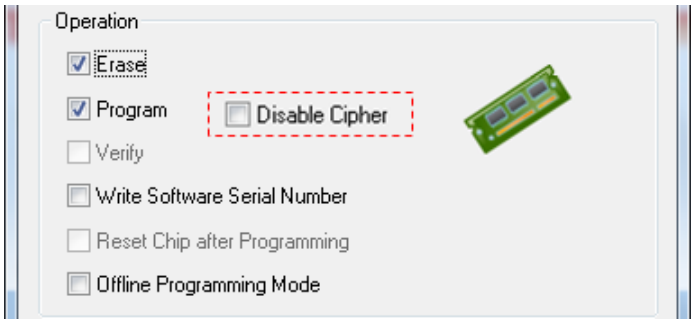

Figure 6-1 Program Option - Disable Cipher

6.2 Write SPI Flash Always Failed with Warning Message

The ICP Tool cannot write data into SPI Flash and ICP Programming Tool reports a “warning message” when writing Code Area.

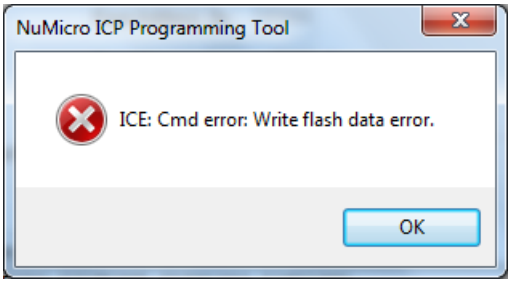

Figure 6-2 Warning Message - “Write flash data error"

Cause: MTP certainly is programmed. Because the Signature of the code is not the same as the Signature in NUC505 MTP to pass the PMOC validation, code can’t program to SPI Flash.

Solution:

Please check if the source code is valid for PMOC rule (see Section 2.1).

Revision History

Date	Revision	Description
2015.10.06	1.00	1. Initially issued.

Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, "Insecure Usage".

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