Renesas RA Family

Implementing Production Programming Tools for RA Cortex-M85 with Device Lifecycle Management

Introduction

Renesas RA Family MCUs implement boot mode, which provides access to built-in firmware that allows the system configuration to be interrogated and updated. Boot mode is entered when the MCU is reset with the MD pin on the device pulled low. When the MCU is in boot mode, user code in flash/MRAM will not be active. An MCU in boot mode enumerates as a COM port when accessed through either a serial port or a USB virtual COM port. Tools running on an external system, such as a Windows PC, can then communicate with the MCU over this interface.

During software development or small prototype production runs, standard Renesas tools, such as the Renesas Flash Programmer (RFP), may be used with boot mode. In such cases, the system developer may not need to be aware of the full details of boot mode and how it works.

However, for companies who provide production programming tools—or users who plan to create their own tools for production purposes—such tools may well be required to communicate with boot mode, particularly for the RA8 MCU Family devices based on Cortex-M85 and Cortex-M22 that implement Device Lifecycle Management (DLM) capabilities.

The full specification of the boot mode interface for these RA Family MCUs is detailed in Renesas Boot Firmware application note, e.g. R01AN7140 (RA8M1), R01AN7290 (RA8D1) which is available for download from the Renesas website. This application note expands on the boot mode interface specification to provide more practical examples of how to interface with boot mode, from both the hardware and software perspectives. Demonstration code, written in Python, is provided to illustrate how boot mode access can be accomplished.

Note: We do not guarantee any operations not described in this document.

Supported MCU Groups

At the time of the release, the supported MCU groups are:

- RA8M1 Group
- RA8D1 Group
- RA8T1 Group
- RA8E1 Group
- RA8E2 Group
- RA8P1 Group

Required Resources

Development tools and software

- Python v3.12 or later (https://www.python.org/downloads/)
- pySerial v3.5 (https://pyserial.readthedocs.io/en/latest/pyserial.html#installation)
- PyCryptodome (Installation — PyCryptodome 3.4.6 documentation)
- Renesas Flash Programmer v3.19.00 or later (https://www.renesas.com/rfp)

Hardware

- EK-RA8M1, Evaluation Kit for RA8M1 MCU Group (http://www.renesas.com/ra/ek-ra8m1)
- EK-RA8P1, Evaluation Kit for RA8P1 MCU Group (http://www.renesas.com/ra/ek-ra8p1)
  - For demonstration purposes, this application note makes use of the RA8M1/P1 MCU and the EK-RA8M1/P1 evaluation board. However, the available functionality will be the same on the other supported MCU groups except when specifically noted.
- Workstation running Windows® 10
  - Demonstration code should also work on other platforms that support Python and pySerial, but this has not been tested.
- One USB device cable (type-A male to micro-B/type-C male) or
- One USB to TTL Serial 3.3-V UART Converter with four pieces of male to female jumper wire.

Prerequisites and Intended Audience

The intended audience is engineers creating production programming tools to use with Renesas RA Family MCUs. Before using this application note and associated demonstration code, users should acquire the following documentation for reference:

- Application note "Renesas Boot Firmware for (the MCU that is under consideration) Group". E.g. Renesas Boot Firmware for RA8M1 MCU Group (R01AN7140).
- The MCU User's Manual: Hardware (for the MCU that is under consideration).
- Application note "Device Lifecycle Management for RA8 MCUs" (R01AN0785).

These documents are available on the Renesas website and are referenced in this application project.

Contents

1. Production Programming Concepts

This section introduces some of the concepts behind the operations required to perform production programming of RA8 MCU Family devices based on Cortex-M85 and that implement Device Lifecycle Management (DLM) capabilities.

1.1 Background

With many Arm Cortex-M based MCUs from a variety of silicon manufacturers, it is often possible for most production programming operations—in particular programming of an application image into flash memory—to be carried out over a Serial Wire Debug (SWD) connection to the target MCU, as SWD is also used for debugging purposes during the software development process.

The RA8 MCU Family devices based on Cortex-M85 with DLM capabilities, it extends this flexibility even further. In addition to SWD, you can enter boot mode and carry out production programming and device configuration operation via SCI/UART or USB. This application note will show how to invoke and communicate with boot mode over both SCI/UART and USB.

Boot mode is entered when the MCU is reset with the MD pin on the device pulled low. In boot mode, rather than any user code in flash being executed, a terminal-like interface is made available through either a serial port (often referred to in Renesas documentation as SCI/UART) or a USB virtual COM port. Tools running on an external system, such as a Windows PC, can then communicate with the MCU over this interface.

Boot mode is also available on other RA Family MCUs based on Cortex-M23, Cortex-M4 and Cortex-M33 CPUs, as well as on Cortex-M85 based MCUs that do not implement DLM capabilities. However, on such MCUs, the functionality provided by boot mode is somewhat different and production programming can generally be carried out over SWD without requiring any access to boot mode (although programming can also be done through boot mode).

1.2 Typical Production Programming Flow

RA8 MCU Family devices based on Cortex-M85 with DLM capabilities are delivered from the factory in the Chip Manufacturing (CM) or Original Equipment Manufacturer (OEM) state. A typical production programming flow includes the following steps:

1. Establish the necessary hardware connections to enable the use of boot mode.
2. Reset the MCU into boot mode and establish communication from the host to the MCU over either SCI/UART or USB. Then, check the current DLM state.

   If the MCU is in the CM state, use the DLM state transition command to transition the DLM state from CM to OEM. This step is explained in more detail later in this document.
3. If the MCU is not in the CM or OEM state—for example, if this is an evaluation board that has already been used for other purposes—an "Initialize" command may be issued if the device is in the LCK_BOOT or RMA states. At the end of the "Initialize" command, the MCU is changed to the OEM state and Protection Level 2 (PL2) with the Code Flash, Data Flash (or MRAM on RA8P1) and Flash Option settings erased. This step is explained in more detail later in this document.
4. Reset to normal operation and program the MCU's flash memory over SWD.
   - This can also be done through boot mode but would generally be much slower.
   - This step is not demonstrated in this application note.
5. Reset MCU again into boot mode.
6. Set up the required "security related options" using boot mode operations. Details on how to perform these steps are explained in section 4. Items are demonstrated in the example code:

   a) Configure TrustZone partition boundaries.

   b) Inject DLM/AL Keys.

   c) Change to DLM/PL states.

1.3 Flash Programming

Generally, RA8 MCUs provide three types of flash memory, with slight differences in the way they are erased and programmed:

- Code Flash memory
- Data Flash memory
- Option Flash memory

With RA8P1, types of memory are:

- Code MRAM memory
- Extra MRAM memory

Although it is possible to program these flash memory areas through the boot mode interface, in many production programming tools it may be preferable to carry out such programming over an SWD connection.

Note: If programming flash through the boot mode interface, the DLM state of the MCU must first be changed from CM (factory default) to OEM.

For a particular MCU, details such as memory sizes and the mechanisms available to program each area are detailed in the Flash Memory chapter of the corresponding "User's Manual: Hardware".

Example flash source code in Keil MDK flash driver format is available in our Device Family Packs (DFP) on the Renesas RA Flexible Software Package (FSP) GitHub.

At the time of writing, the latest version is available as part of FSP 6.0.0 at:

- https://github.com/renesas/fsp/releases/download/v6.0.0/MDK_Device_Packs_v6.0.0.zip

Check the FSP GitHub for newer versions.

The Arm/Keil document for the code layout and functions of their flash driver format is available at:

- https://www.keil.com/pack/doc/CMSIS/Pack/html/algorithmFunc.html

Additional flash programming code is available for reference within the FSP drivers for each MCU group.

1.4 Device Lifecycle Management

Most RA8 family MCUs based on Arm Cortex-M85 CPUs adopt the concept of a device life cycle and maintain the life cycle state inside the device. The DLM state is used to restrict access to the MCU's internal resources through SWD/JTAG debugger and boot mode interfaces as the device lifecycle states progress. The DLM state is only configurable through boot mode over an SCI/UART, USB or SWD/JTAG connection. The set of boot mode commands that are possible are controlled by the current lifecycle state. Changing lifecycle state is also only possible using a boot mode command. Note that a production programming tool should always move a MCU into at least OEM (not leave it in the CM state).

Table 1 describes the DLM states that may be involved in the production programming stage.

Table 1. TrustZone-Enabled RA8 Family MCU Group Device Lifecycle States

Lifecycle	Definition	Protection Level	Boot mode access
CM	"Chip Manufacturing" (This state is not available on RA8P1)	PL2	Available. Cannot access code/data flash area.
OEM	"Original Equipment Manufacturer" The device is owned by the customer.	PL2 or PL1 or PL0	Available.
LCK_BOOT	"LoCKed BOOT interface" The debug interface and the serial programming interface and permanently disabled.	PL0	Not available.
RMA_REQ	"Return Material Authorization REQuest" Request for RMA. The customer must send the device to Renesas in this state.	PL0	Available. Cannot access code/data flash area.
RMA_ACK	"Return Material Authorization ACKnowledge" Failure analysis in Renesas.	PL2	Available. Cannot access code/data flash area.
RMA_RET	"Return Material Authorization ACKnowledge" The device is back to the customer. The device does not boot.	PL0	Not available.

The three Protection levels are:

- PL2: The debugger connection is allowed, with no restriction on access to memories and peripherals.
- PL1: The debugger connection is allowed, with access to only non-secure memory regions and peripherals.
- PL0: The debugger connection is not allowed.

Figure 1, Figure 2 and Figure 3 describe the possible transitions between DLM, PL and AL states. Production programming tools need to be able to inject the keys required to allow authenticated DLM state changes.

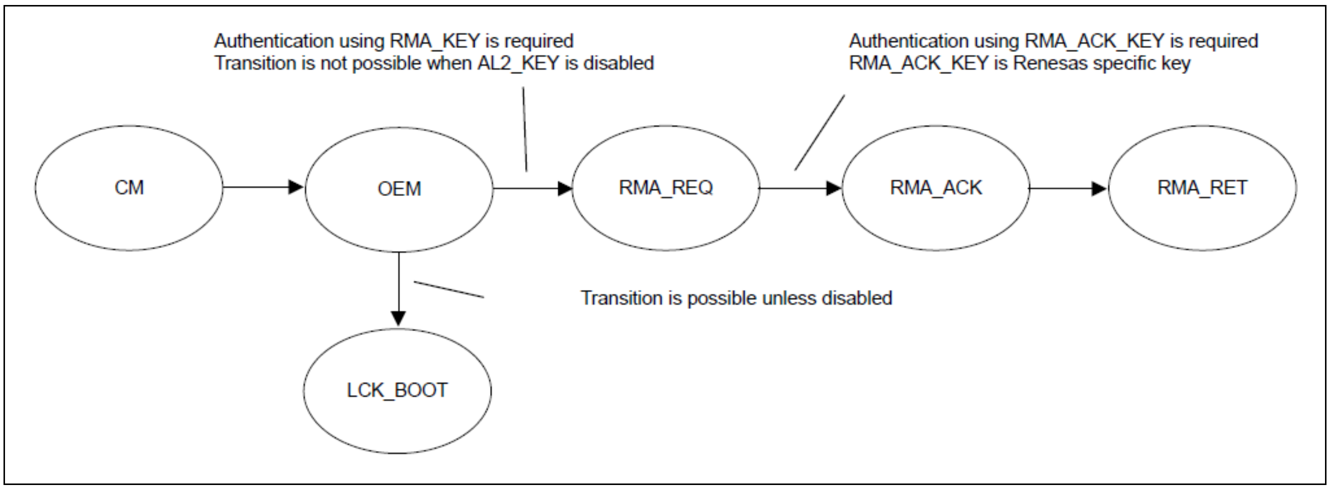
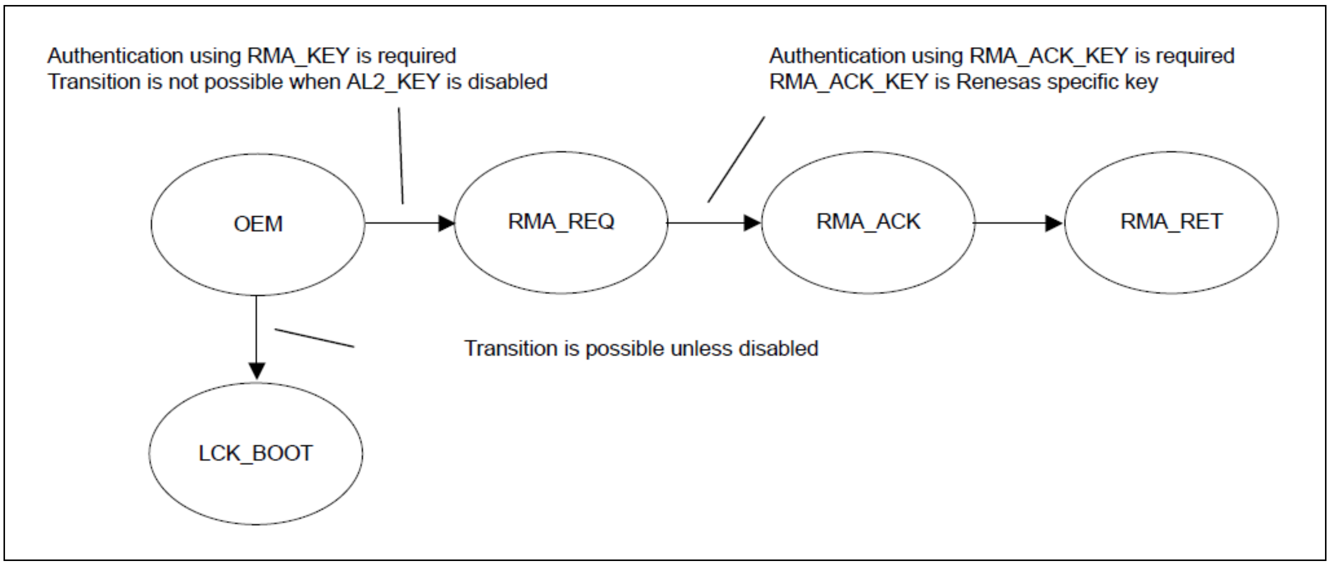

Authentication using RMA_KEY is required
Transition is not possible when AL2_KEY is disabled
Authentication using RMA_ACK_KEY is required
RMA_ACK_KEY is Renesas specific key
CM
OEM
RMA_REQ
RMA_ACK
RMA_RET
Transition is possible unless disabled
LCK_BOOT

Figure 1. Device Lifecycle Management on RA8M1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Authentication using RMA_ACK_KEY is required
RMA_ACK_KEY is Renesas specific key
OEM
RMA_REQ
RMA_ACK
RMA_RET
Transition is possible unless disabled
LCK_BOOT

Figure 2. Device Lifecycle Management on RA8P1

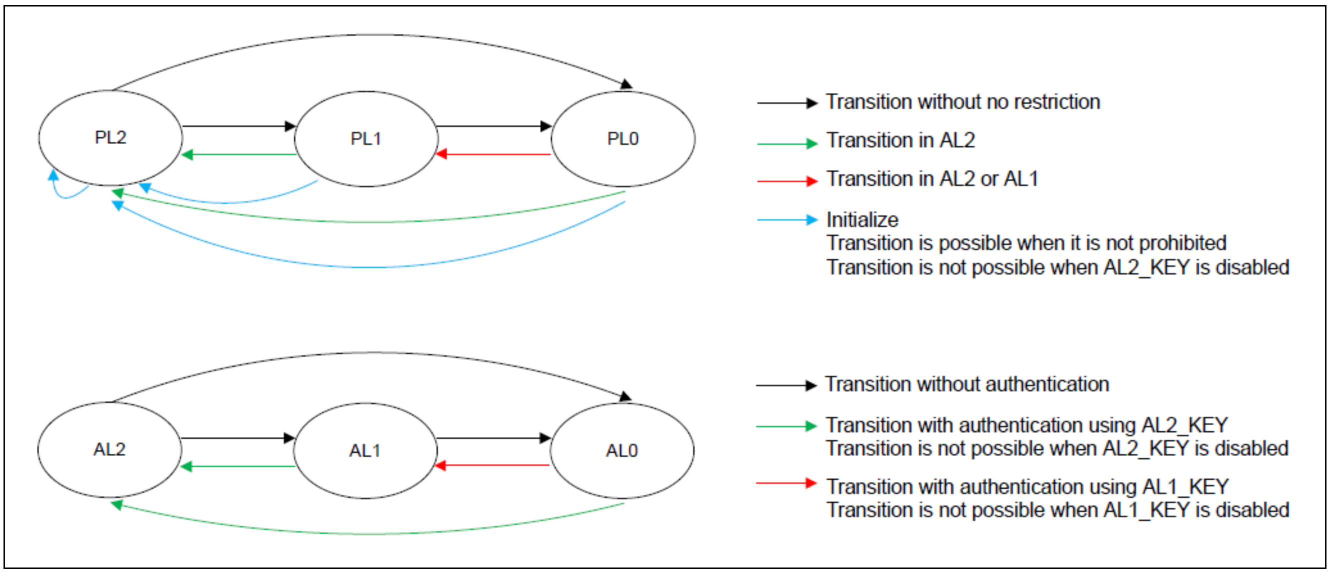

PL2
PL1
PL0
Transition without no restriction
Transition in AL2
Transition in AL2 or AL1
Initialize
Transition is possible when it is not prohibited
Transition is not possible when AL2_KEY is disabled
AL2
AL1
AL0
Transition without authentication
Transition with authentication using AL2_KEY
Transition is not possible when AL2_KEY is disabled
Transition with authentication using AL1_KEY
Transition is not possible when AL1_KEY is disabled

Figure 3. PL and AL states and transitions on RA8 MCU Groups

For production programming, the tool must move a device from CM to OEM for MCUs that are delivered from the factory. The tool may alternatively need to transit the DLM state back to OEM using an “Initialize” command for MCUs that have been used in the past. At the end of the sequence, the tool may also need to support locking down of the device—to prevent user’s proprietary code and data being read back—by moving the DLM state into LCK_BOOT or moving to RMA_REQ state in case of customers need Renesas support. Boot mode also provides a command to disable the “Initialize” command, preventing future erasing of flash/MRAM and resetting of DLM state, Protection Level and Authentication Level.

Authenticated transitions are possible using AL keys. These user-defined keys are injected during specific device lifecycle states to allow authenticated regression back to that state.

The primary keys that most applications will use are:

- AL2_KEY
  - The Authentication Level 2 Key can be injected when the MCU is in the OEM state. It can be used when the MCU is in the OEM_PL1 or OEM_PL2 state to regress back to the OEM_PL2 state without erasing flash memory. This key is used in green arrow of Figure 3.
- AL1_KEY
  - The Authentication Level 1 Key can be injected when the MCU is in the OEM state. It can be used when the MCU is in the OEM_PL0 state to regress back to the OEM_PL1 state without erasing flash memory. This key is used in red arrow of Figure 3.

Note that an AL key injected during production allows a user to change the DLM/PL state post-production if and only if they have access to the original key.

1.5 Secure / Non-secure /Non-secure Callable Regions

Arm TrustZone technology is a core security technology developed by Arm and included as part of the v8-M architecture. It is typically implemented on a wide range of Cortex-M85 based devices, including Renesas' RA8 Family MCUs. The key point about TrustZone technology is that it provides and enforces a partition between trusted and non-trusted portions of the system, which provides the designer of a product with a building block towards producing a more secure MCU application. At a basic level, the way this partitioning is implemented is by use of memory regions, which effectively covers code, data, and peripherals within the overall memory map.

First, we have Secure memory regions. These are the trusted regions covering overall system boot as well as trusted or protected IP such as key storage and data decryption.

Secondly, we have non-secure memory regions, which are used for our normal application code and data, which do not require direct access to the trusted data. The important point here is that non-secure operations are only allowed to access non-secure regions, thereby preventing unapproved access to trusted information or operations.

Finally, we have Non-Secure Callable regions, which are used to provide a gateway between the secure and non-secure worlds.

RA Cortex-M85 based MCUs with DLM implement a logic called an Implementation Defined Attribution Unit (IDAU) to establish partition of the Flash and SRAM into Secure and Non-Secure regions. In addition to IDAU, the Master Security Attribution Unit (MSAU) provides a security map for bus masters other than the CPU. Finally, the Security Attribution Unit (SAU) is programmable in Secure state, allowing firmware to define up to 8 regions as Secure, NSC, or Non-Secure. If an address falls under both IDAU and SAU, the stricter label applies, and SAU's region numbers let software verify areas share the same security attributes.

For more details, refer to The MCU User's Manual: Hardware (for the MCU that is under consideration), section Arm Security Features; or refer to Security Design using Arm TrustZone - Cortex M85 (R11AN0897).

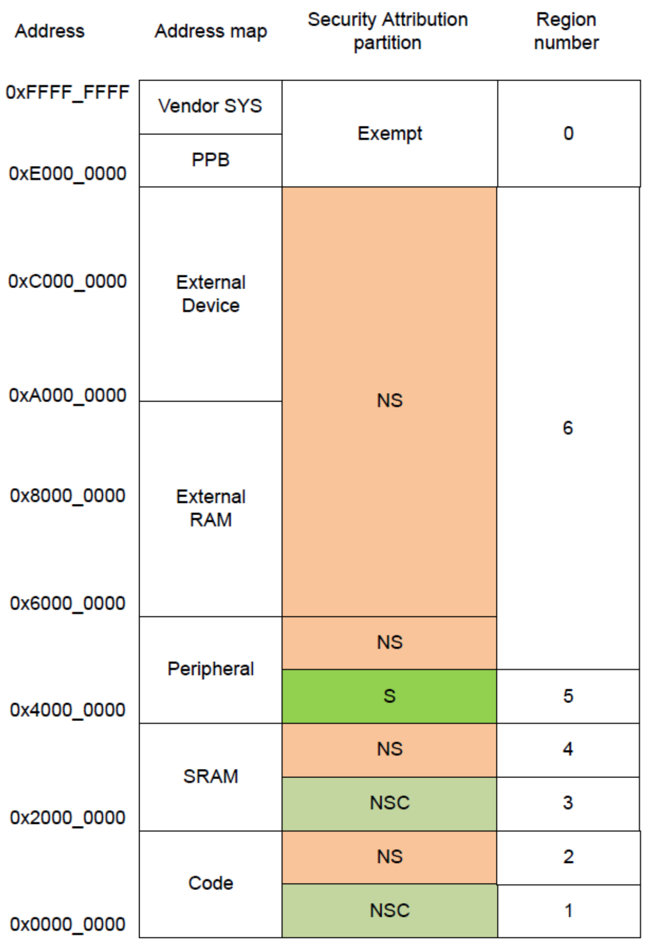


Figure 4. TrustZone Configurations Example using RA8M1

The IDAU provides a fixed, hardware-defined security map for code, SRAM, peripheral regions, and MSAU extended that map for other bus masters, which cannot be changed at runtime. Additional TrustZone boundaries as Secure, NSC, Non-Secure regions will be programmed into the SAU through boot mode. Therefore, as part of the production programming sequence, appropriate values for these registers need to be configured by the tools.

When a secure application is built, Renesas tools generate a file (.rpd) that contains details of the required split between Secure/Non-Secure memory. The .rpd file can be used by the production programming tool to configure the appropriate values into the security attributes register through boot mode.

1.5.1 SAU Registers and Non-TrustZone-using Software

Renesas tools also generate the .rpd file for applications that do not use TrustZone technology. In most cases, the SAU registers could theoretically be left set to the default (maximal) values that will be set by running an Initialize command.

However, in some cases, this is not appropriate. Some applications need some areas of memory set to be Non-Secure. Configuring the SAU regions is necessary for such use cases.

In general, to ensure correct application execution, we recommend always setting up security attributes as part of the production programming process.

2. MCU Hardware Setup for Boot Mode Use

This section describes the hardware requirements for setting up the production environment, including the power, clock, communication interface connections, and the signals that control the MCU operation mode.

2.1 Boot Mode Communication Interfaces Overview

Boot mode is entered when the MCU is reset with the MD pin on the device pulled low. Boot mode can then be accessed using one of the following communication methods:

- 2-wire serial communication (often referred to in Renesas documentation as SCI/UART)
- Universal Serial Bus (USB) communication (over a virtual COM port)
- Multiplex Serial Wire Debug (SWD) Interface and SCI/UART Interface on the SWD debug header

Communication with boot mode is not carried out directly over SWD. Instead, Renesas has defined a specification for reusing certain pins from an SWD debug header as UART pins. This enables production programming tools to communicate over a single physical connector using either SWD (for programming flash) or UART (for communication with boot mode).

The hardware requirements of these communication methods are described in the following sections. These sections use the RA8M1 MCU group as an example. For production support, confirm details for the specific MCU being used in the Hardware User's Manual Section "Pin Functions".

2.2 Power

The production hardware setup needs to provide proper power and ground to the MCU. The example guidelines shown in Table 2 and Table 3 are based on the RA8M1 MCU.

Table 2. RA8M1 MCU Operating Voltage Range

Operating voltage	VCC = 1.68 to 3.6 V When using USB communication: VCC = 3.0 to 3.6V

Table 3. RA8M1 MCU Power Signals

Function Name	Signal	IO	Comments
Power supply	VCC, VCC2	Input	Power supply pin. Connect it to the system power supply. Connect this pin to VSS by a 0.1-μF capacitor. The capacitor should be placed close to the pin.
	VCC_DCDC	Input	Switching regulator power supply pin.
	VLO	I/O	Switching regulator pin.
	VCL	Input	Connect this pin to the VSS pin by the smoothing capacitor used to stabilize the internal power supply. Place the capacitor close to the pin.
	VBATT	Input	Battery Backup power pin.
	VSS, VSS_DCDC	Input	Ground pin. Connect it to the system power supply (0 V).

2.3 Clock

The clock signal is also mandatory for the MCU and the boot firmware to function. To use the boot mode firmware, there are specific requirements on the main oscillator frequency. Table 4 shows the requirement for the RA8 MCU.

Table 4. Clock Source for Boot Mode Operation

Clock Source	RA8M1/D1/T1/E1/E2, RA8P1: Main Oscillator Frequency of 8, 10, 12, 15, 16, 20, 24, 32, 48 MHz can be used by boot mode firmware. Otherwise, HOCO will be used.

Table 5. Clock Signals

Function Name	Signal	IO	Comments
Clock	XTAL	Output	Pins for a crystal resonator. Input an external clock signal through the EXTAL pin.
	EXTAL	Input	

* When performing USB communication with HOCO, Sub-OSC must be oscillating stably.

2.4 MCU System Mode Control Signals

As mentioned in section 1.1, boot mode is entered when the MCU is reset with the MD pin on the device pulled low. Table 6 describes some more details on these two signals.

Table 6. General Signals for Accessing the Boot Mode

Function Name	Signal	IO	Comments
Operating mode control	MD	Input	Pin for setting the operating mode. The signal level on MD must not be changed during operation mode transition on release from the reset state. For the MCU groups covered in this application note, the MD pin is P201.
MCU Reset control	RES	Input	Reset signal input pin. The MCU enters the reset state when the RES signal goes low.

2.5 Using the 2-wire Serial Communication

The Serial Communication Interface (SCI) hardware block used for UART communication has several channels. For boot mode use, channel 9 is used to enumerate a COM port. Table 7 provides more details on the UART signals.

Table 7. UART Boot Mode Pins

Function Name	Signal	IO	Comments
SCI (channel 9)	RXD9	Input	RA8M1/D1/T1/E1/E2, RA8P1: P208
	TXD9	Output	RA8M1/D1/T1/E1/E2, RA8P1: P209

2.6 Using the Universal Serial Bus (USB) Communication

USB communication with boot mode can be used by all the supported MCU groups. Table 8 describes the details on the USB signals. The production programming fixture development team can refer to the Renesas evaluation board schematic to provide the signal conditioning circuit for the USB connections.

Table 8. USB Interface and Configurations

Function Name	Signal	IO	Comments
USB Full Speed	VCC_USB	Input	USB Full-speed power supply pin. Connect this pin to VCC. Connect this pin to VSS_USB through a 0.1 uF capacitor placed close to the VCC_USB pin.
	VSS_USB	Input	USB Full-speed ground pin. Connect this pin to VSS.
	USB_DP	I/O	D+ pin of the USB on-chip transceiver. Connect this pin to the D+ pin of the USB bus.
	USB_DM	I/O	D- pin of the USB on-chip transceiver. Connect this pin to the D- pin of the USB bus.
	USB_VBUS (P407)	Input	USB cable connection monitor pin. Connect this pin to VBUS of the USB bus. Designers should scale down the 5V VBUS input to the MCU's operating VCC voltage range with ESD projection. The VBUS pin status (connected or disconnected) can be detected when the USB module is operating as a function controller.
	USB_VBUSEN	Output	VBUS (5V) supply enable signal for external power supply chip.

2.7 Using Serial Wire Debug Interface (SWD)

For performance reasons, a production programming tool may prefer to program flash memory over an SWD connection, rather than using the boot mode interface.

SCI/UART and SWD can both be used to access the boot mode through the debug connector. A separate serial interface could be added, but by sharing the same header, board complexity is reduced, and the user experience is greatly improved. To support this, Renesas has standardized on an extended configuration of the SWD header. This is achieved by reusing pins on the standard debug connector as shown in Figure 5. Refer to the RA8 MCU Family Quick Design Guide (R01AN7087) section "Emulator Support" for more details on the specification of this interface.

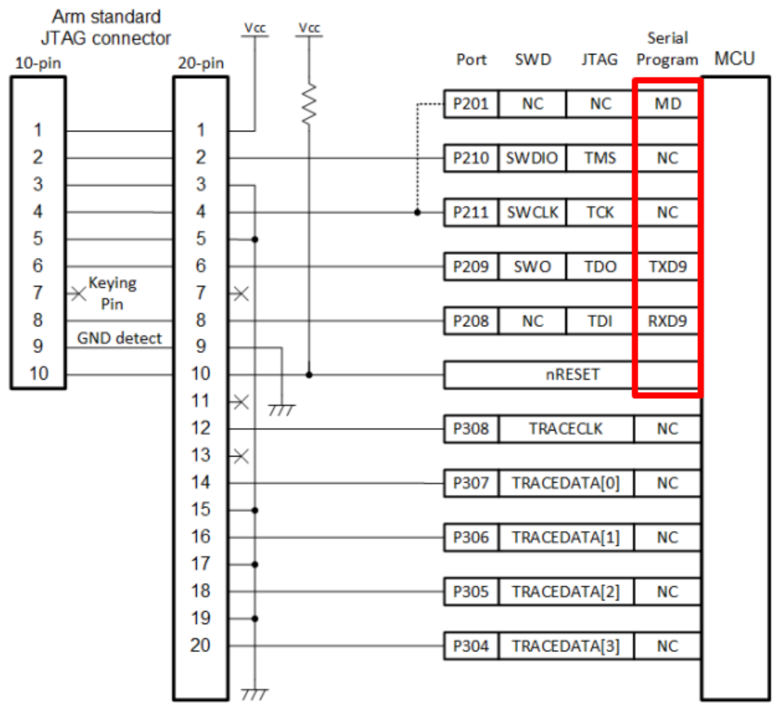


Figure 5. Access the Boot Mode through the Multi-emulator Interface Header

The setup shown in Figure 5 allows the production programming tools to control whether the target MCU will be accessed through serial communications or SWD, based on whether it pulls MD low or not when asserting reset. If boot mode access is in use, pins on the SWD header can be used as SCI/UART RXD/TXD pins by the production programming tool hardware.

This configuration of the SWD header is also commonly used for debugging purposes, where boot mode operations are also required (for example, to inject TrustZone partition boundaries).

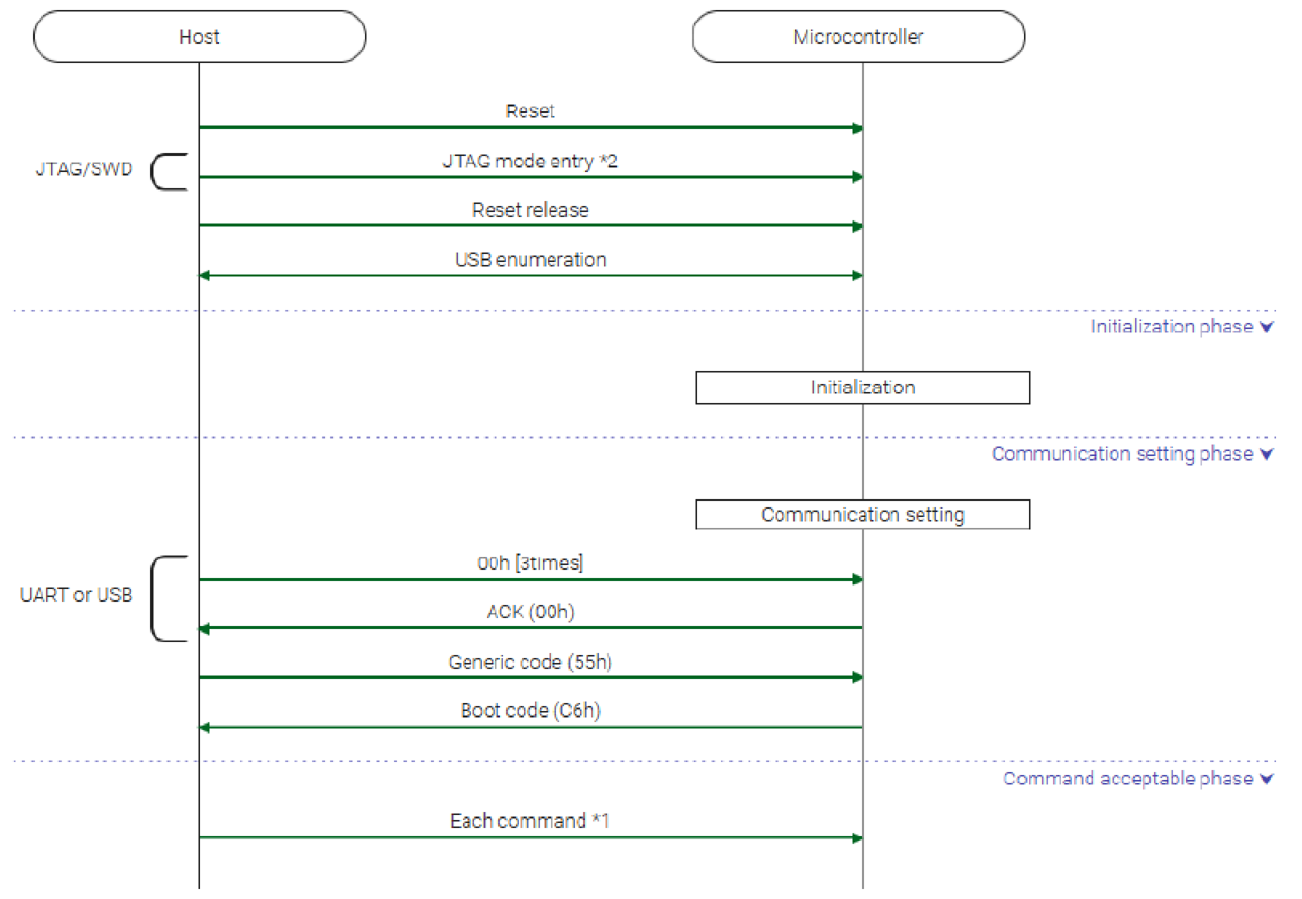
3. Connecting to Boot Mode

This section explains the procedure to establish communications with the boot mode.

3.1 Boot mode operational phases

When the MCU is reset with MD pulled low, the MCU enters a sequence of operational phases, as shown in Figure 6:

1. Initialization phase.
2. Communication setting phase.
3. Command acceptable phase

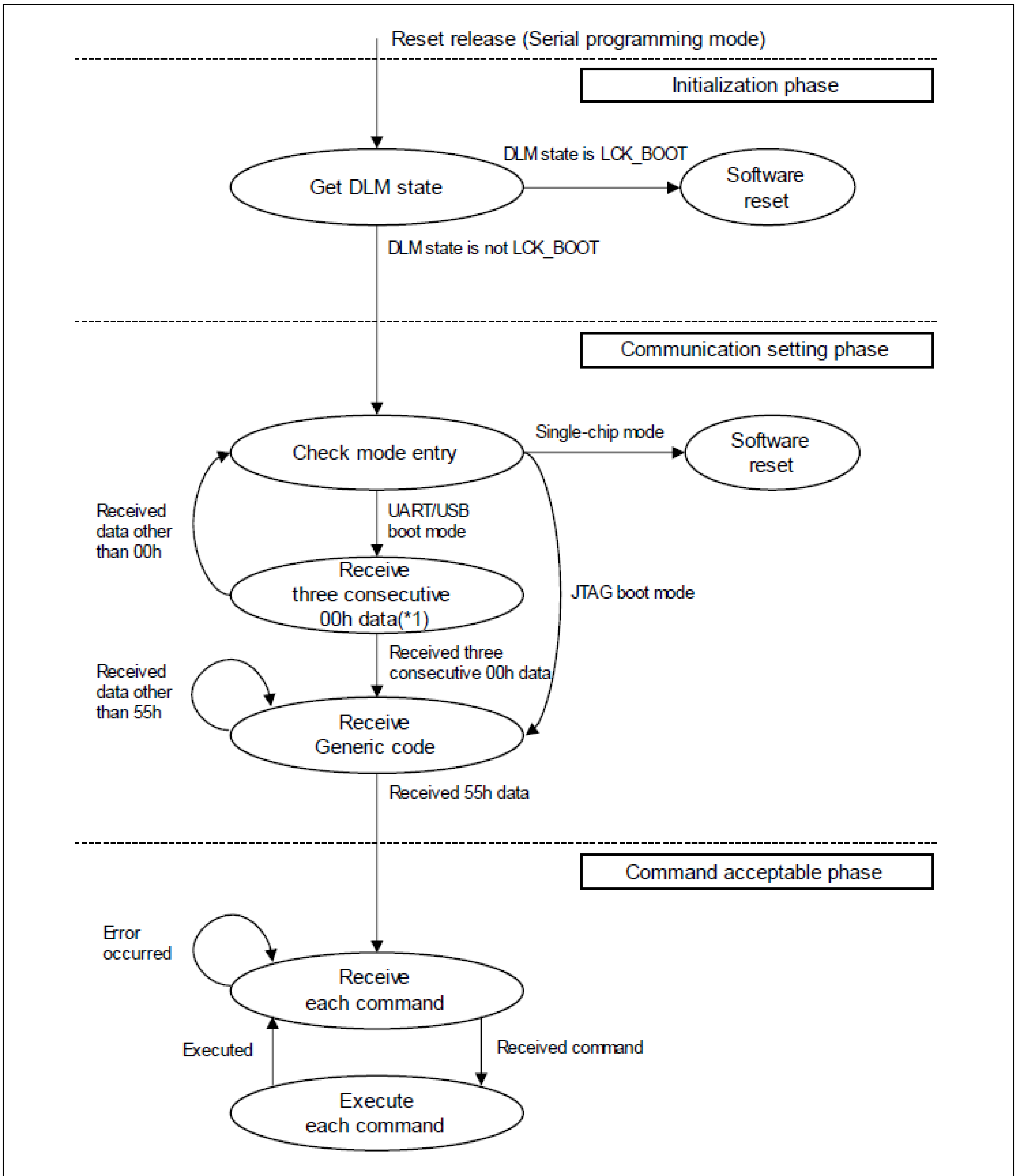


*1: From the Command acceptable phase, the host and microcontroller send data in turn unless otherwise noted. The host shall execute the data transmission after receiving the data from the microcontroller.
*2: If the magic code “A5H” is set in the JBMDR register during a pin reset, the microcontroller will boot into JTAG mode.

Figure 6. Boot Mode Operational Phases

Figure 7 shows this in more detail, in relation to the MCU DLM state.

The rest of this section examines how production programming tools can make the connection to boot mode, moving the MCU through the Initialization and Communication setting phases, and then entering the Command acceptance phase.



*1: Boot firmware adopts IP (SCI or USBFS) that received 00h consecutively three times earlier as the communication method.

Figure 7. Command Execution State Transition Diagram

3.2 Initialization Phase

Production programming tools do not need to carry out any actions during the Initialization phase. Once boot mode is entered after release of the reset pin with MD in low state, the boot mode firmware initializes the required hardware modules (including UART or USB) and then transits to the Communication setting phase.

3.2.1 Serial Settings

When using serial communication to boot mode, the following default settings are in use:

Bit rate	9600 bps (minimum, until the baud rate setting command) 6Mbps (maximum)
Data length	8 bits (LSB first)
Parity bit	None
Stop bit	1 bit

Communication is performed at 9600 bps until the baud rate setting command is invoked (in the Command acceptable phase). After the baud rate setting command has completely successfully, communication is then performed at the desired baud rate. The maximum bit rate that can be communicated with the device is returned by “RMB” of the “signature request” command.

- If communication with the MCU is interrupted during an active boot mode session - for example, due to cable disconnection, host-side timeout, or power loss - the MCU may enter an undefined state. Reset the MCU and reenter the boot mode may be required under certain conditions. The production programming tools should implement timeout handling and retry mechanisms to recover from communication failures whenever possible.
- Communication with the boot firmware through UART is demonstrated in this application note. However, the “Baud rate setting” command is not demonstrated. Refer to Boot Firmware application note, e.g. R01AN7140 for more details of commands. For production use cases requiring custom baud rates, refer to that document for implementation guidance.

3.2.2 USB Settings

When using USB communication to boot mode, the following settings are in use:

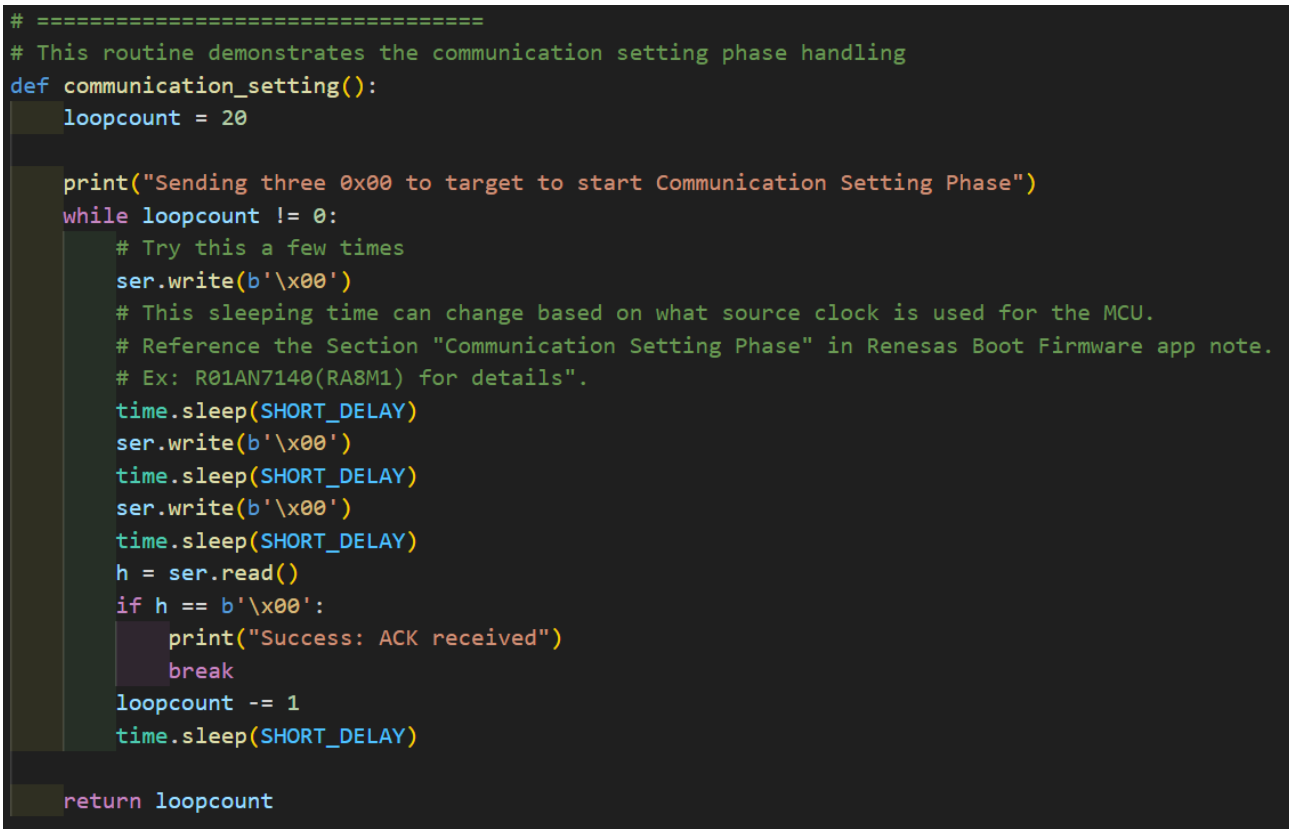
Transfer rate	12 Mbps (USB 2.0 Full Speed)
Device class	Communication Device Class (CDC) • SubClass: Abstract Control Mode (ACM) • Protocol: Common AT commands
Vender ID	0x045B (Renesas)
Product ID	0x0261
Transfer mode	Control (in/out) Bulk (in, out) Interrupt (in)

3.3 Communication Setting Phase

Once the system enters the Communication setting phase, boot mode polls the selected communication interface looking for a sequence of 3 consecutive 0x00 characters being transmitted by the production programming tools. When 3 consecutive 0x00 characters are received, boot mode sends an ‘ACK’ (another 0x00) back to the production programming tools to indicate that communication is being established.

Figure 8 shows an example function, `communication_setting()`, that could be used within the production programming tool to implement the Communication setting phase sequence. In this example, the code will attempt to start communication with boot mode 20 times.

The production programming tools should hold MD low throughout this process.

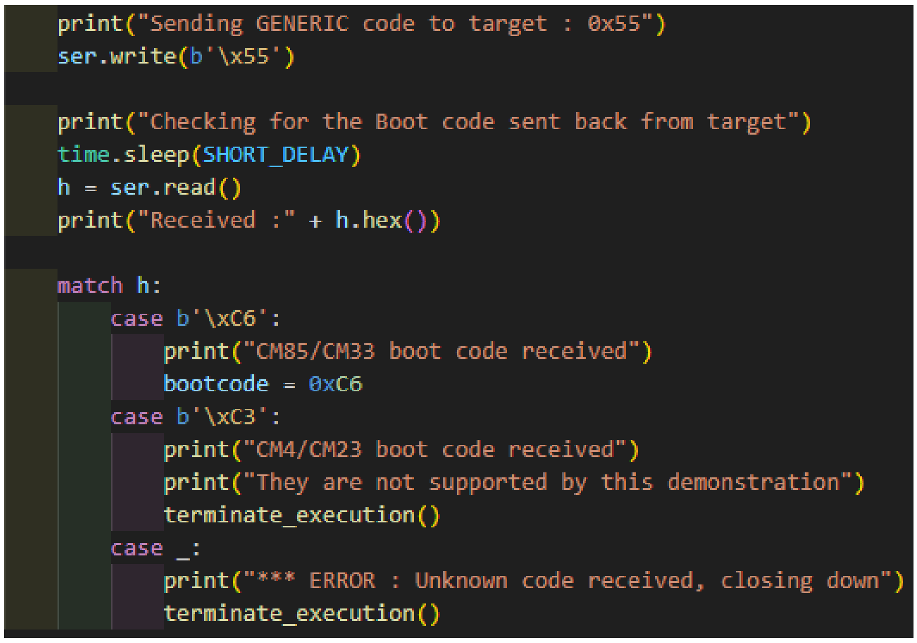


```python
# ==================================
# This routine demonstrates the communication setting phase handling
def communication_setting():
    loopcount = 20

    print("Sending three 0x00 to target to start Communication Setting Phase")
    while loopcount != 0:
        # Try this a few times
        ser.write(b'\x00')
        # This sleeping time can change based on what source clock is used for the MCU.
        # Reference the Section "Communication Setting Phase" in Renesas Boot Firmware app note.
        # Ex: R01AN7140(RA8M1) for details".
        time.sleep(SHORT_DELAY)
        ser.write(b'\x00')
        time.sleep(SHORT_DELAY)
        ser.write(b'\x00')
        time.sleep(SHORT_DELAY)
        h = ser.read()
        if h == b'\x00':
            print("Success: ACK received")
            break
        loopcount -= 1
        time.sleep(SHORT_DELAY)

    return loopcount
```

Figure 8. Communication Setting – Making the initial connection

If no ACK is received, it can be because a previous boot mode connection is still active. This can be verified using a boot mode Inquiry command. This is explained in section 5.2.

Once the production programming tools have received the ACK code, they should then transmit the “generic code” (0x55) to which boot mode will reply with the “boot code”, as shown in Figure 9. For the MCUs described in this application note, the boot code is 0xC6.



```python
    print("Sending GENERIC code to target : 0x55")
    ser.write(b'\x55')

    print("Checking for the Boot code sent back from target")
    time.sleep(SHORT_DELAY)
    h = ser.read()
    print("Received :" + h.hex())

    match h:
        case b'\xC6':
            print("CM85/CM33 boot code received")
            bootcode = 0xC6
        case b'\xC3':
            print("CM4/CM23 boot code received")
            print("They are not supported by this demonstration")
            terminate_execution()
        case _:
            print("*** ERROR : Unknown code received, closing down")
            terminate_execution()
```

Figure 9. Completing the connection - retrieving the boot code

In a real production programming tool, the boot code alone is not sufficient to completely identify the MCU type being communicated with and the capabilities available through its boot mode. The "Signature" command should be used to obtain additional details and determine such information.

4. Boot Mode Commands

This section describes how production programming tools can interact with boot mode, after they have retrieved the boot code and the MCU boot mode has entered the Command acceptable phase.

4.1 Command Acceptable Phase

Once in Command Acceptable Phase, the MCU's boot mode expects to receive command packets from the production programming tools, telling it which boot mode operation is to be carried out. Boot mode responds back to the production programming tools using data packets. Some commands also require data packets to be sent from the production programming tools back to boot mode providing additional information for use in the operation.

Sequence diagrams showing the transmission of packets for each command can be found in Boot Firmware application note, e. g. R01AN7140, R01AN7290.

4.1.1 Command Packet Format

Production programming tools send information for the required operation to the MCU's boot mode in the form of a command packet in format shown in Table 9.

Table 9. Command Packet

Symbol	Size	Value	Description
SOH	1 byte	01h	Start of command packet.
LNH	1 byte	-	Packet length (length of "CMD + Command information") [High].
LNL	1 byte	-	Packet length (length of "CMD + Command information") [Low].
CMD	1 byte	-	Command code, as described in section 4.1.3.
Command information	0 to 255 bytes	-	Command information. Examples: • For Write command: Start/End address. • For Baudrate setting command: UART baudrate.
SUM	1 byte	-	Sum data of "LNH + LNL + CMD + Command information" (expressed as two's complement). For example: LNH + LNL + CMD + Command information (1) + Command information (2) + … + Command information(n) + SUM = 00h.
ETX	1 byte	03h	End of packet.

Note: If the host sends data that exceeds 261 bytes, subsequent operations are not guaranteed.

4.1.2 Data Packet

The production programming tools and the boot mode firmware send additional data to each other in the format shown in Table 10.

Table 10. Data Packet

Symbol	Size	Value	Description
SOD	1 byte	81h	Start of data packet.
LNH	1 byte	-	Packet length (length of “RES + Data”) [High] (*1).
LNL	1 byte	-	Packet length (length of “RES + Data”) [Low] (*1).
RES	1 byte	-	Refer to Boot Firmware application note - section “RES: Response code” for all the supported response codes.
Data	(*3)	-	Transmit data. Examples: • For Write data transmission: Write data. • For Status transmission: Status code (STS), Status details (ST2) and Failure address (ADR).
SUM	1 byte	-	Sum data of “LNH + LNL + RES + Data” (expressed as two's complement). For example: LNH + LNL + RES + Data(1) + Data(2) + ... + Data(n) + SUM = 00h.
ETX	1 byte	03h	End of packet.

*1: If the host sends a packet whose length is 0 byte or over 1025 bytes, the microcontroller returns a packet with an indefinite RES value.
*2: If the host sends data that exceeds 1030 bytes, subsequent operations are not guaranteed.
*3: The size is 1-1024 bytes. As an exception, the maximum is 1040 bytes only for the Encrypted data write command.

4.1.3 Summary of Boot Mode Commands

Table 11 is the summary of all the boot mode commands available on the MCUs described in this application note. For the commands that are not demonstrated in this application project, refer to application note R01AN7140 to understand the command format details, response, and error handling.

Table 11. Boot Command Code Summary

Value	Device		Name	Comment
	RA8M1, RA8D1, RA8T1, RA8E1, RA8E2	RA8P1		
71h	○	○	DLM state transit command	Demonstrated
2Ch	○	○	DLM state request command	Demonstrated
72h	○	○	Protection level transit command	Demonstrated
73h	○	○	Protection level request command	Demonstrated
75h	○	○	Authentication level request command	Demonstrated
30h	○	○	Authentication command	Demonstrated
28h	○	○	Key setting command	Demonstrated
2Ah	○	○	User key setting command	Not demonstrated
29h	○	○	Key verify command	Demonstrated
2Bh	○	○	User key verify command	Not demonstrated
50h	○	○	Initialize command	Demonstrated
4Eh	○	○	Boundary setting command	Demonstrated
4Fh	○	○	Boundary request command	Demonstrated
51h	○	○	Parameter setting command	Not demonstrated
52h	○	○	Parameter request command	Not demonstrated
4Ah	○		Lock bit setting command	Not demonstrated
4Bh	○		Lock bit request command	Not demonstrated
4Ch	○	○	ARC configuration setting command	Not demonstrated
4Dh	○	○	ARC configuration request command	Not demonstrated
00h	○	○	Inquiry command	Demonstrated
3Ah	○	○	Signature request command	Demonstrated
3Bh	○	○	Area information request command	Not demonstrated
34h	○	○	Baudrate setting command	Not demonstrated
12h	○	○	Erase command	Not demonstrated
13h	○	○	Write command	Not demonstrated
15h	○	○	Read command	Not demonstrated
18h	○	○	CRC command	Not demonstrated
2Eh	○	○	OEM root public key setting command	Not demonstrated
2Fh		○	OEM root public key verify command	Not demonstrated
26h	○	○	Code certificate update command	Not demonstrated
27h	○	○	Code certificate check command	Not demonstrated
36h	○	○	External flash memory setting command	Not demonstrated
1Ah	○	○	Encrypted data write command	Not demonstrated

4.1.4 Boot Mode Firmware Operation

When the boot mode firmware receives a command packet, it performs packet analysis:

- The boot mode firmware recognizes the start of the command packet by receiving SOH. If the boot mode firmware receives something other than SOH, it waits until SOH is received.
- If ETX is not added to the received command packet, the boot mode firmware sends a “Packet error”.
- If the SUM of the received command packet is different from the sum value, the boot mode firmware sends a “Checksum error”.
- If the received command packets of LNH and LNL are different from the values specified in the packet format, the boot mode firmware sends a “Packet error”.
- If the CMD command in the received command packet is an undefined code, the boot mode firmware sends an “Unsupported command error”.
- If the received command packets of LNH and LNL are different from the values specified in each command, the boot mode firmware sends a “Packet error”.
- When an error described above occurs, the boot mode firmware does not process and returns to the command waiting state.

When the packet analysis has successfully completed, the boot mode firmware executes command processing. Refer to the explanation of each command for specific details.

When a command completes successfully, the boot mode firmware stays in the “Command acceptable phase”.

5. Typical Use Cases of Boot Mode Commands

This section describes several typical use cases of the boot mode commands. The command format and example code are provided.

5.1 Overview of Use cases

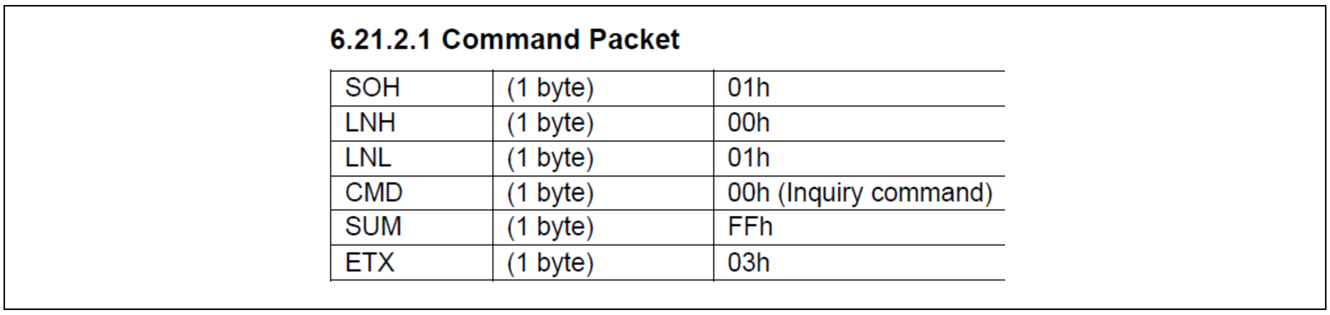
For more details on the use cases described in this section, refer to the section *Command List* in Boot Firmware application note. Table 12 details the specific subsections from Boot Firmware that match the following use cases from this application note.

Table 12. Boot Mode Command Use Cases

Section in this application note	Corresponding section in Boot Firmware AN
Boot Mode Inquiry Command	Inquiry command
Initialize MCU Command	Initialize command
Disable Initialize Command	Parameter setting command
Check Whether Initialize Command is Disabled	Parameter request command
Inject AL keys	Key setting command
Verify AL keys	Key verifying command
DLM State Request	DLM state request command
DLM State Transition	DLM state transition command
TrustZone Boundary Setting Command	Boundary setting command
TrustZone Boundary Request Command	Boundary request command

5.2 Inquiry Command

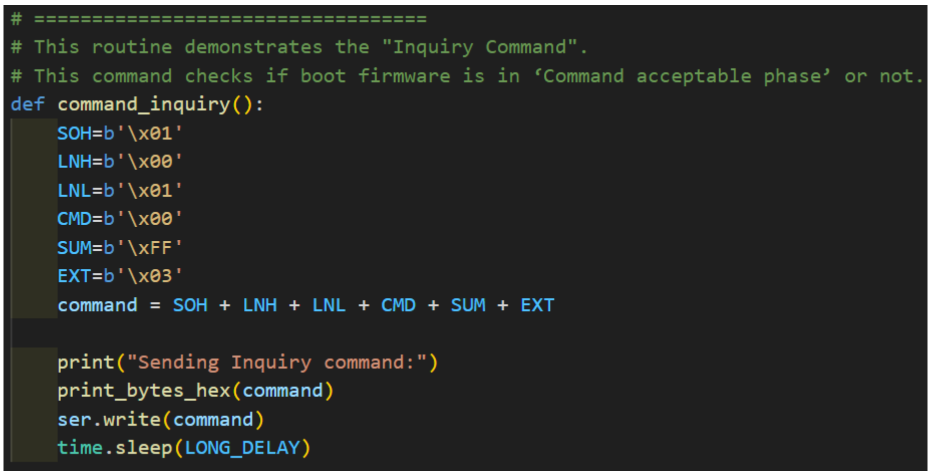
The Inquiry command checks whether a previous boot mode connection is still alive.



6.21.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	01h
CMD	(1 byte)	00h (Inquiry command)
SUM	(1 byte)	FFh
ETX	(1 byte)	03h

Figure 10. Inquiry Command Packet



```
# ================================
# This routine demonstrates the "Inquiry Command".
# This command checks if boot firmware is in ‘Command acceptable phase’ or not.
def command_inquiry():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x01'
    CMD=b'\x00'
    SUM=b'\xFF'
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SUM + EXT

    print("Sending Inquiry command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)
```

Figure 11. Inquiry Command Example Code

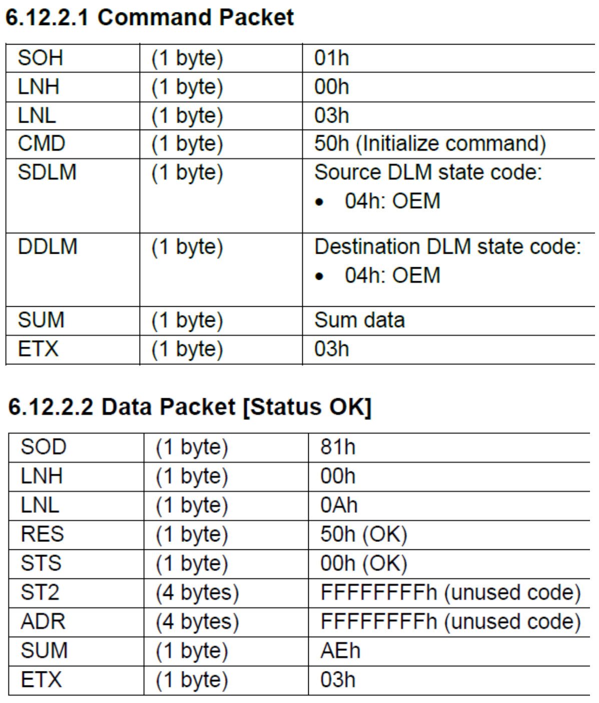
5.3 Initialize the MCU

The commands introduced in this section are used to ensure that the MCU is in the OEM DLM state and Protection Level is PL2 state to ready for other operations, such as flash programming.

5.3.1 Initialize Command

The Initialize command can be executed in the OEM state with PL2, PL1, PL0 of the Protection Level state. It clears the User area, Data area, Config area, EEP config area, Boundary setting, and Key index (Wrapped keys). In addition, the PL state transitions to PL2 from PL1 and PL0. Erase processing is performed unaffected by the flash block protection settings (BPS, BPS_SEC). However, if PBPS and PBPS_SEC are set, then the Initialize command cannot be processed. This command is typically not used in the production programming environment unless the MCU has been previously used (for example, an evaluation board being used for testing purposes).

The Initialize command takes the current DLM state as an input parameter. So, prior to executing the Initialize command, the production programming tools need to acquire the current DLM state using the DLM State Request Command (see demonstration in section 5.6.1).



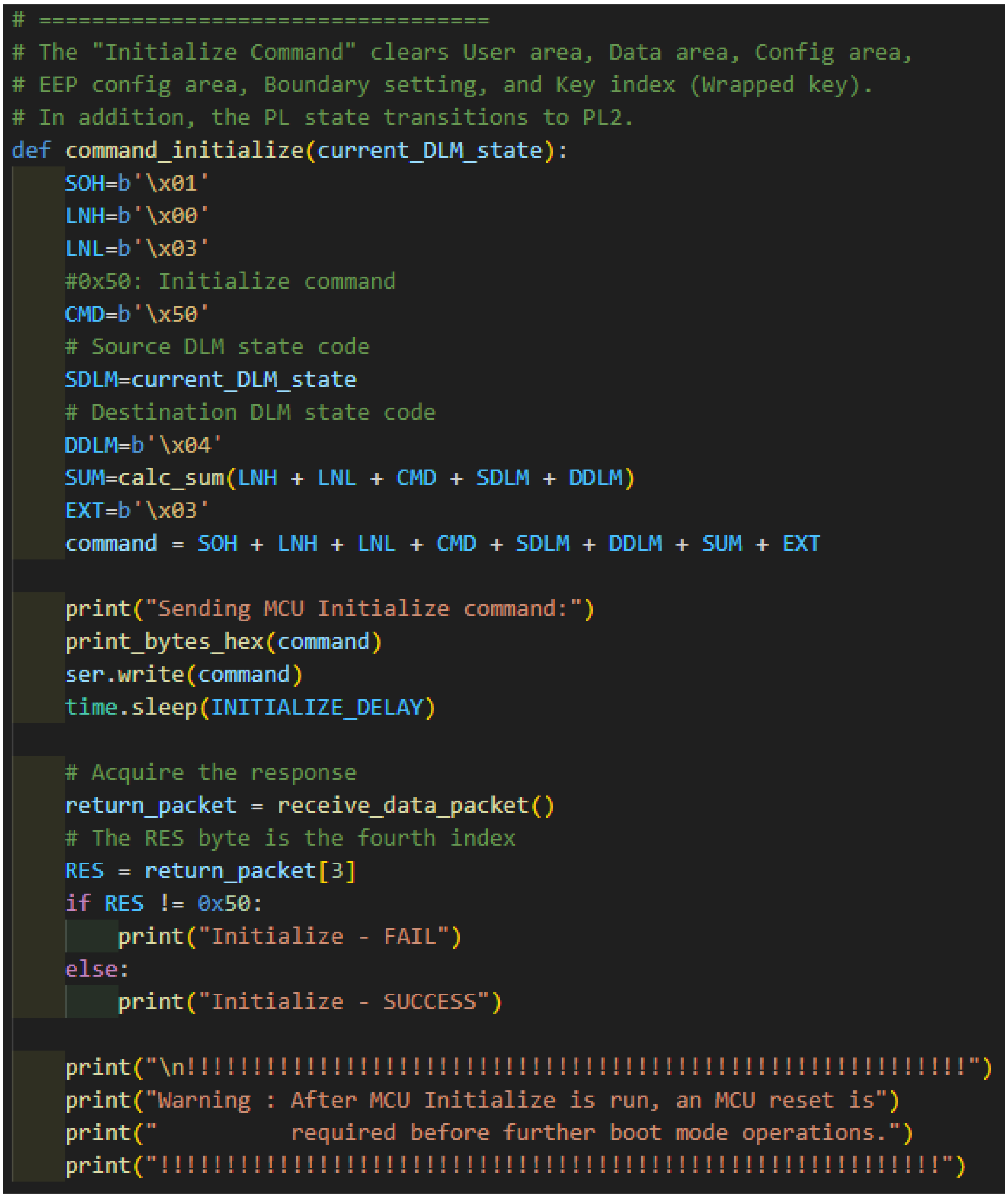
6.12.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	03h
CMD	(1 byte)	50h (Initialize command)
SDLM	(1 byte)	Source DLM state code: • 04h: OEM
DDLM	(1 byte)	Destination DLM state code: • 04h: OEM
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

6.12.2.2 Data Packet [Status OK]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	0Ah
RES	(1 byte)	50h (OK)
STS	(1 byte)	00h (OK)
ST2	(4 bytes)	FFFFFFFFh (unused code)
ADR	(4 bytes)	FFFFFFFFh (unused code)
SUM	(1 byte)	AEh
ETX	(1 byte)	03h

Figure 12. Initialize Command Packets

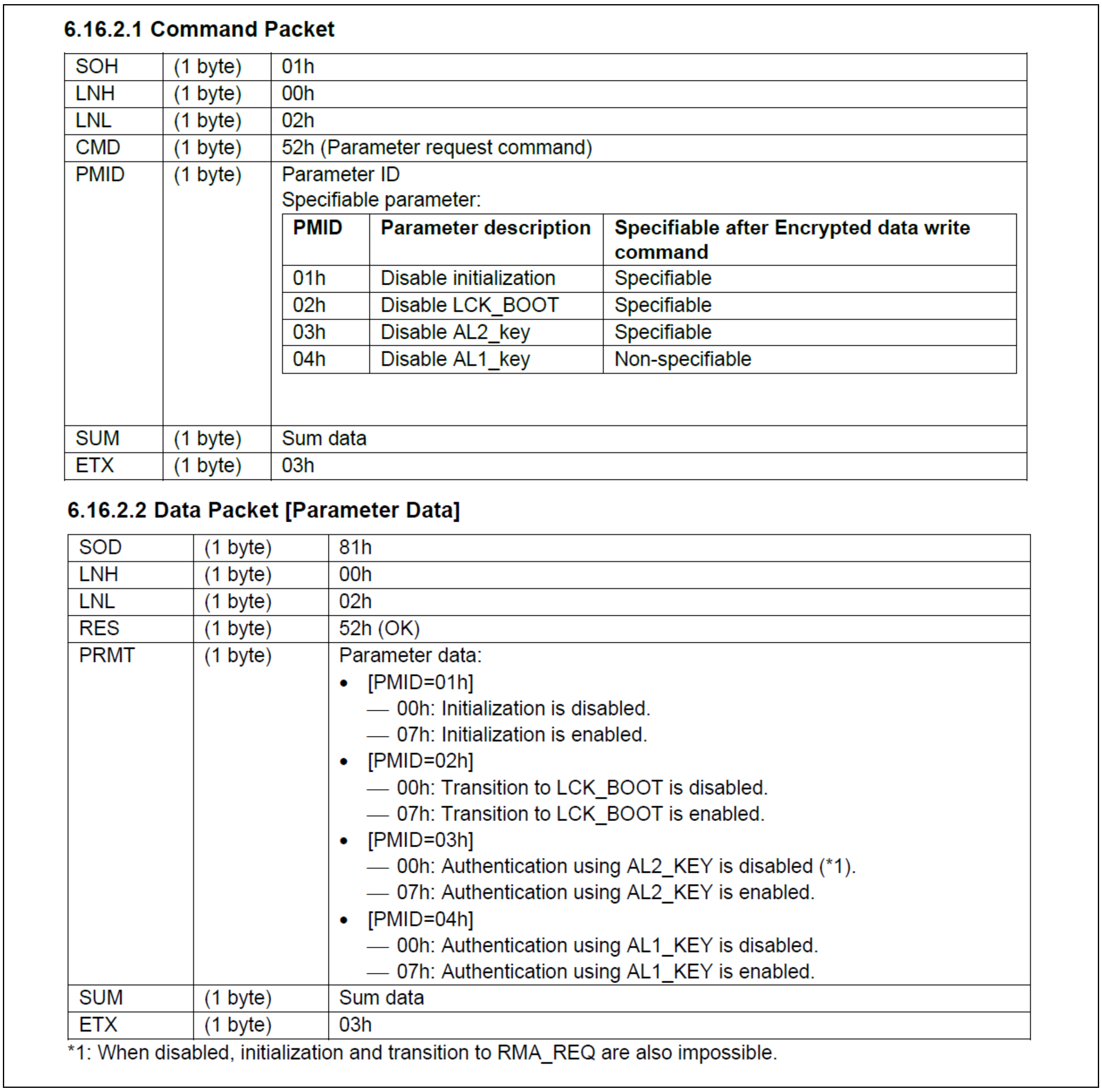


```
# ===================================
# The "Initialize Command" clears User area, Data area, Config area,
# EEP config area, Boundary setting, and Key index (Wrapped key).
# In addition, the PL state transitions to PL2.
def command_initialize(current_DLM_state):
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x03'
    #0x50: Initialize command
    CMD=b'\x50'
    # Source DLM state code
    SDLM=current_DLM_state
    # Destination DLM state code
    DDLM=b'\x04'
    SUM=calc_sum(LNH + LNL + CMD + SDLM + DDLM)
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SDLM + DDLM + SUM + EXT

    print("Sending MCU Initialize command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(INITIALIZE_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x50:
        print("Initialize - FAIL")
    else:
        print("Initialize - SUCCESS")

    print("\n!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!")
    print("Warning : After MCU Initialize is run, an MCU reset is")
    print("          required before further boot mode operations.")
    print("!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!")
```

Figure 13. Initialize Command Example Code

5.3.2 Check Whether Initialize Command is Disabled

For a non-factory fresh device (for example, a device previously used for development/testing purposes), it is possible that boot mode Initialize command might have been disabled (and other changes made). Checking whether the MCU Initialize command is disabled or not can be achieved by using the Parameter Request command.



6.16.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
CMD	(1 byte)	52h (Parameter request command)
PMID	(1 byte)	Parameter ID Specifiable parameter:

PMID	Parameter description	Specifiable after Encrypted data write command
01h	Disable initialization	Specifiable
02h	Disable LCK_BOOT	Specifiable
03h	Disable AL2_key	Specifiable
04h	Disable AL1_key	Non-specifiable

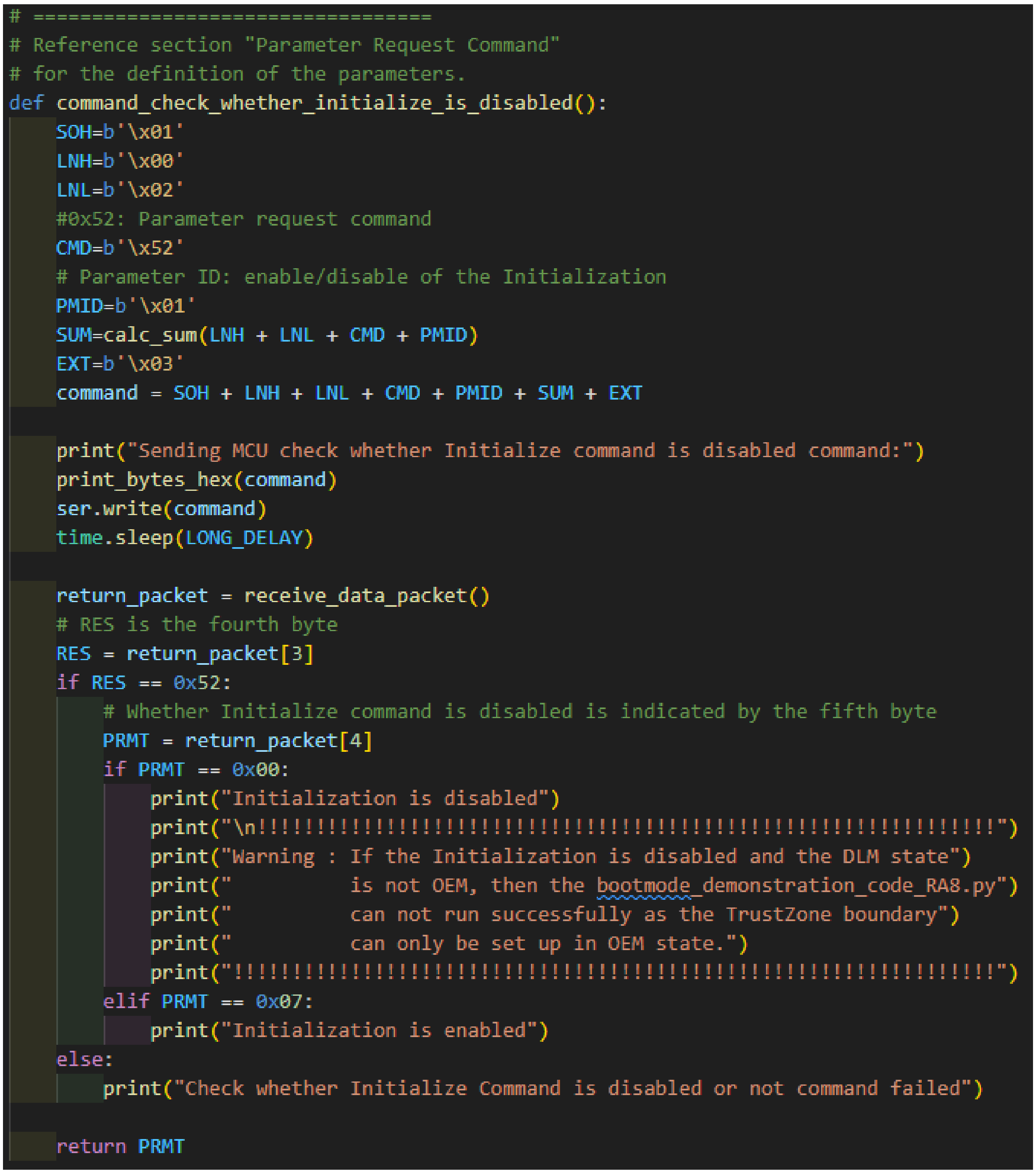
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

6.16.2.2 Data Packet [Parameter Data]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
RES	(1 byte)	52h (OK)
PRMT	(1 byte)	Parameter data: • [PMID=01h] — 00h: Initialization is disabled. — 07h: Initialization is enabled. • [PMID=02h] — 00h: Transition to LCK_BOOT is disabled. — 07h: Transition to LCK_BOOT is enabled. • [PMID=03h] — 00h: Authentication using AL2_KEY is disabled (*1). — 07h: Authentication using AL2_KEY is enabled. • [PMID=04h] — 00h: Authentication using AL1_KEY is disabled. — 07h: Authentication using AL1_KEY is enabled.
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

*1: When disabled, initialization and transition to RMA_REQ are also impossible.

Figure 14. Command Packet: Check whether Initialize Command is Disabled



```python
# ==================================
# Reference section "Parameter Request Command"
# for the definition of the parameters.
def command_check_whether_initialize_is_disabled():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x02'
    #0x52: Parameter request command
    CMD=b'\x52'
    # Parameter ID: enable/disable of the Initialization
    PMID=b'\x01'
    SUM=calc_sum(LNH + LNL + CMD + PMID)
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + PMID + SUM + EXT

    print("Sending MCU check whether Initialize command is disabled command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    return_packet = receive_data_packet()
    # RES is the fourth byte
    RES = return_packet[3]
    if RES == 0x52:
        # Whether Initialize command is disabled is indicated by the fifth byte
        PRMT = return_packet[4]
        if PRMT == 0x00:
            print("Initialization is disabled")
            print("\n!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!")
            print("Warning : If the Initialization is disabled and the DLM state")
            print("          is not OEM, then the bootmode_demonstration_code_RA8.py")
            print("          can not run successfully as the TrustZone boundary")
            print("          can only be set up in OEM state.")
            print("!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!")
        elif PRMT == 0x07:
            print("Initialization is enabled")
    else:
        print("Check whether Initialize Command is disabled or not command failed")

    return PRMT
```

Figure 15. Example Code: Check whether Initialize Command is Disabled

5.3.3 Disable Initialize Command

As part of the final production programming process, the Initialize command can be disabled if required.

NOTE: This step is **non-reversable, so exercise with caution!**

This command is included in the `bootmode_demonstration_code_RA8.py` code, but the section of the code is not enabled due to the risk of locking up the MCU during the development of tools for production programming. Refer to section 6.6 for details on enabling this command in the demonstration code.

6.15.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	03h
CMD	(1 byte)	51h (Parameter setting command)
PMID	(1 byte)	Parameter ID Specifiable parameter:

PMID	Parameter description	Specifiable at	Specifiable after Encrypted data write command
01h	Disable initialization	AL2/AL1/AL0	Specifiable
02h	Disable LCK_BOOT	AL2/AL1	Specifiable
03h	Disable AL2_key	AL2	Specifiable
04h	Disable AL1_key	AL2/AL1	Non-specifiable

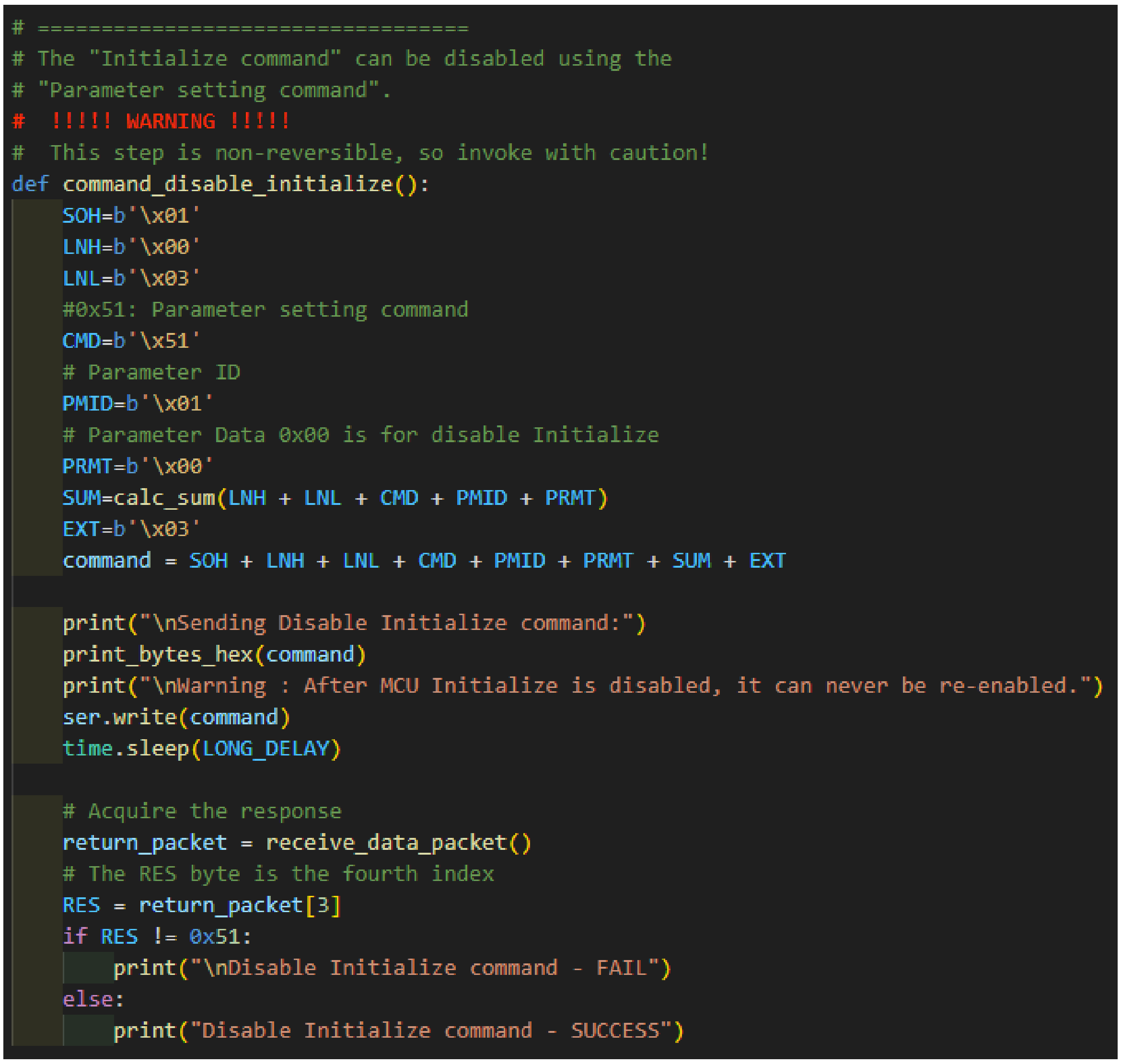
PRMT	(1 byte)	Parameter data: • [PMID=01h] — 00h: Disable initialization • [PMID=02h] — 00h: Disable transition to LCK_BOOT • [PMID=03h] — 00h: Disable of authentication using AL2_KEY (*1) • [PMID=04h] — 00h: Disable of authentication using AL1_KEY
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

*1: When disabled, initialization and transition to RMA_REQ are also impossible.

6.15.2.2 Data Packet [Status OK]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	0Ah
RES	(1 byte)	51h (OK)
STS	(1 byte)	00h (OK)
ST2	(4 bytes)	FFFFFFFFh (unused code)
ADR	(4 bytes)	FFFFFFFFh (unused code)
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 16. Disable the 'Initialize Command' Command Packet



```python
# ==================================
# The "Initialize command" can be disabled using the
# "Parameter setting command".
#  !!!!! WARNING !!!!!
#  This step is non-reversible, so invoke with caution!
def command_disable_initialize():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x03'
    #0x51: Parameter setting command
    CMD=b'\x51'
    # Parameter ID
    PMID=b'\x01'
    # Parameter Data 0x00 is for disable Initialize
    PRMT=b'\x00'
    SUM=calc_sum(LNH + LNL + CMD + PMID + PRMT)
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + PMID + PRMT + SUM + EXT

    print("\nSending Disable Initialize command:")
    print_bytes_hex(command)
    print("\nWarning : After MCU Initialize is disabled, it can never be re-enabled.")
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x51:
        print("\nDisable Initialize command - FAIL")
    else:
        print("Disable Initialize command - SUCCESS")
```

Figure 17. Example Code: Disable the 'Initialize Command'

5.4 TrustZone Boundary Region Setup

This section explains the operational flow of the TrustZone boundary setup and introduces the command packet and the example code.

5.4.1 Operational Flow

The recommended flow when setting up the TrustZone partition boundary regions is:

1. Acquire the TrustZone partition boundary information from the application.
2. Check DLM state and AL as necessary. The TrustZone partition boundaries can only be set up in OEM with PL2 state.
3. Set up boundaries.
4. Verify the boundaries set up properly.

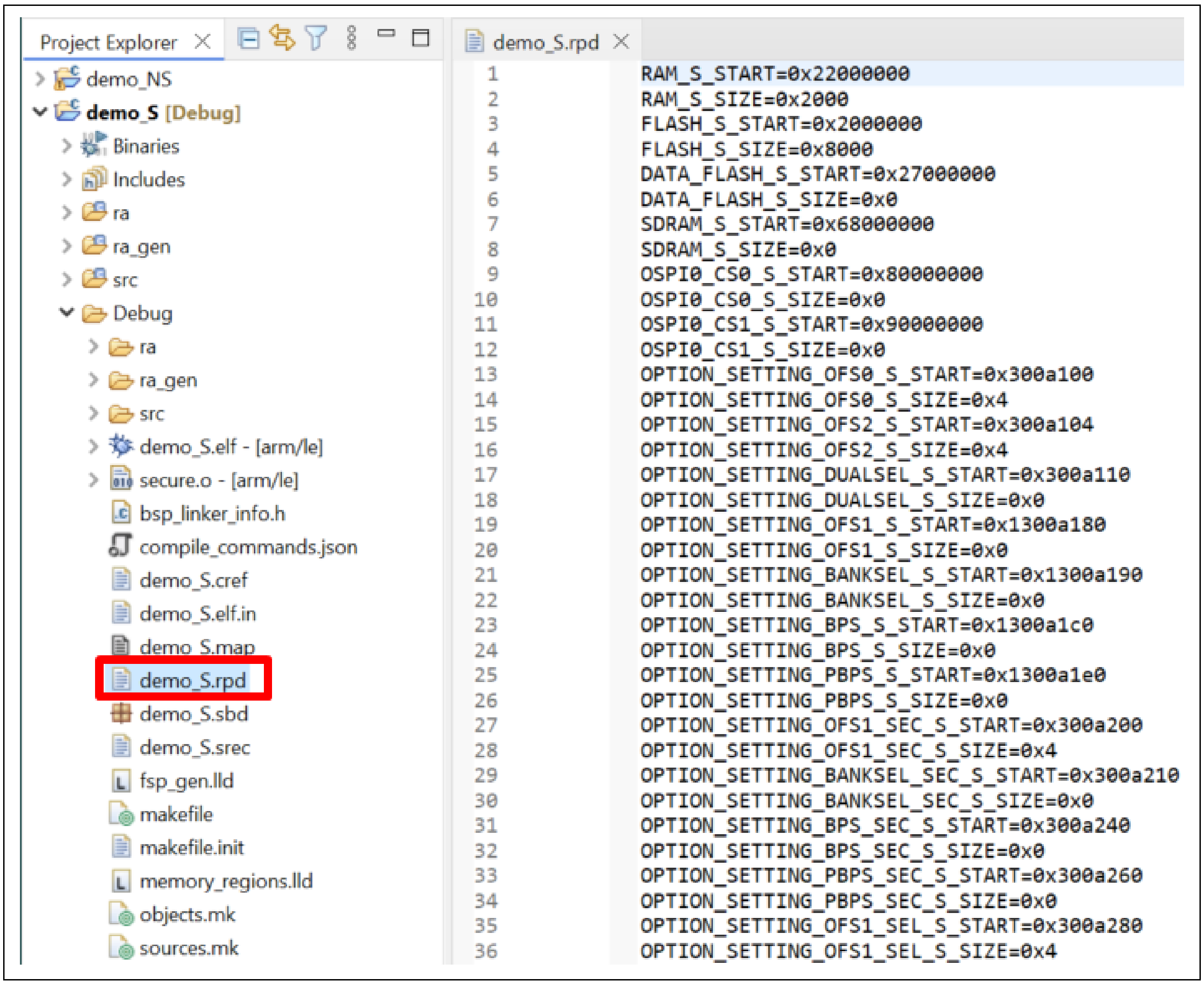
5.4.2 Acquire the Boundary Information from an Application

The security attribute regions information is stored in a .rpd file generated as a post-build step in an RA project in e^2 studio, or a RASC-generated EWARM / MDK project. Table 13 shows how to find the .rpd file based on the IDE.

Table 13. The . rpd File Location Based on IDE

IDE	Location of the .rpd file
e^2 studio	Secure project root folder: <secure_project_name>\Debug\<secure_project_name>. rpd
EWARM	Secure project root folder: <secure_project_name>\Debug\exe\<secure_project_name>.rpd
MDK	Secure project root folder: <secure_project_name>\Objects\<secure_project_name>.rpd

The format of the .rpd file is identical across the IDEs. Figure 18 shows the contents of the rpd file.



```
RAM_S_START=0x22000000
RAM_S_SIZE=0x2000
FLASH_S_START=0x2000000
FLASH_S_SIZE=0x8000
DATA_FLASH_S_START=0x27000000
DATA_FLASH_S_SIZE=0x0
SDRAM_S_START=0x68000000
SDRAM_S_SIZE=0x0
OSPI0_CS0_S_START=0x80000000
OSPI0_CS0_S_SIZE=0x0
OSPI0_CS1_S_START=0x90000000
OSPI0_CS1_S_SIZE=0x0
OPTION_SETTING_OFS0_S_START=0x300a100
OPTION_SETTING_OFS0_S_SIZE=0x4
OPTION_SETTING_OFS2_S_START=0x300a104
OPTION_SETTING_OFS2_S_SIZE=0x4
OPTION_SETTING_DUALSEL_S_START=0x300a110
OPTION_SETTING_DUALSEL_S_SIZE=0x0
OPTION_SETTING_OFS1_S_START=0x1300a180
OPTION_SETTING_OFS1_S_SIZE=0x0
OPTION_SETTING_BANKSEL_S_START=0x1300a190
OPTION_SETTING_BANKSEL_S_SIZE=0x0
OPTION_SETTING_BPS_S_START=0x1300a1c0
OPTION_SETTING_BPS_S_SIZE=0x0
OPTION_SETTING_PBPS_S_START=0x1300a1e0
OPTION_SETTING_PBPS_S_SIZE=0x0
OPTION_SETTING_OFS1_SEC_S_START=0x300a200
OPTION_SETTING_OFS1_SEC_S_SIZE=0x4
OPTION_SETTING_BANKSEL_SEC_S_START=0x300a210
OPTION_SETTING_BANKSEL_SEC_S_SIZE=0x0
OPTION_SETTING_BPS_SEC_S_START=0x300a240
OPTION_SETTING_BPS_SEC_S_SIZE=0x0
OPTION_SETTING_PBPS_SEC_S_START=0x300a260
OPTION_SETTING_PBPS_SEC_S_SIZE=0x0
OPTION_SETTING_OFS1_SEL_S_START=0x300a280
OPTION_SETTING_OFS1_SEL_S_SIZE=0x4
```

Figure 18. Obtain the IDAU Region Size using EWARM

The FLASH_S_SIZE is the size of the Secure Code Flash region. The production programming tools need to convert this value to KB (kilobytes) and then assign this value to the CFS as shown in Figure 21.

The DATA_FLASH_S_SIZE is the size of the Secure Data Flash region. The production programming tools needs to convert this value to KB and then assign this value to DFS as shown in Figure 21.

Production programming tools can ignore the other fields.

5.4.3 TrustZone Boundary Request Command

Reading the configured security attribute regions setup can be achieved using the command in Figure 19. The example code to perform this function is shown in Figure 20.

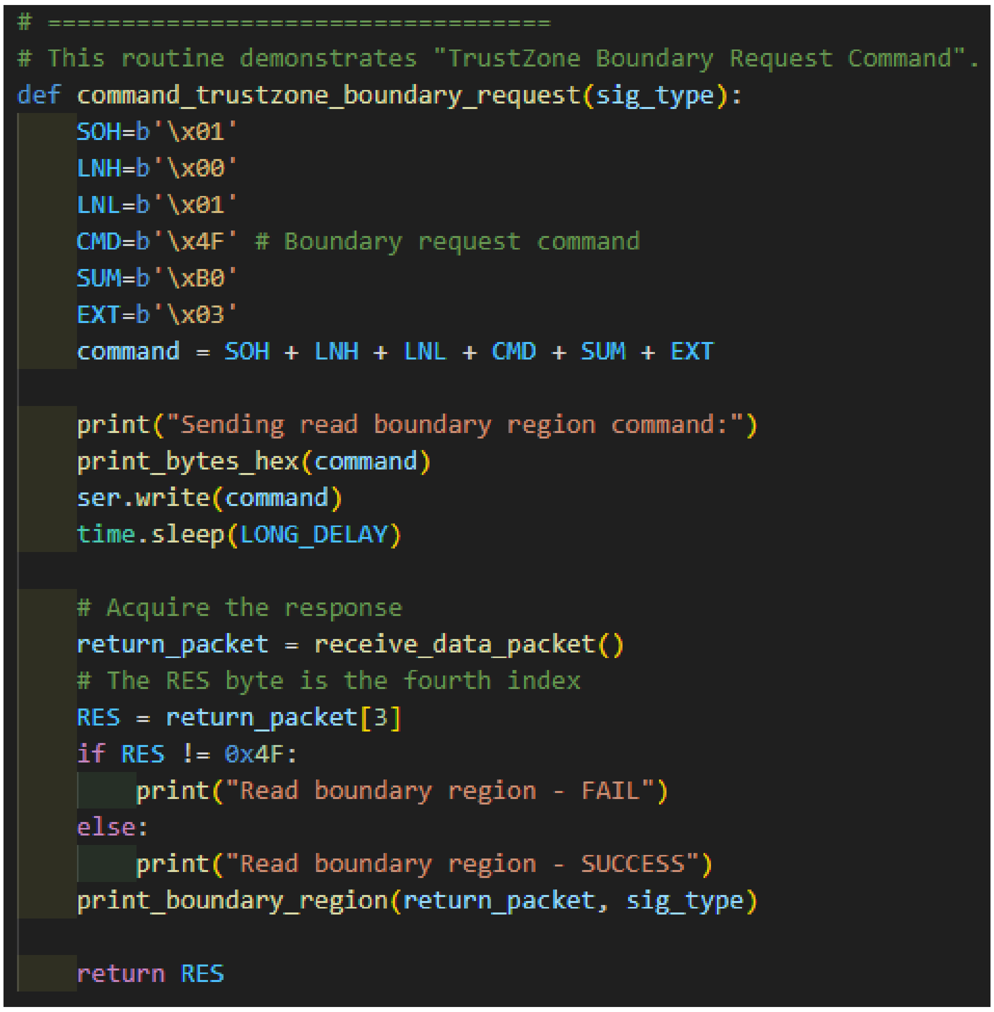
6.14.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	01h
CMD	(1 byte)	4Fh (Boundary request command)
SUM	(1 byte)	B0h
ETX	(1 byte)	03h

6.14.2.2 Data packet [Boundary Setting Data]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	0Bh
RES	(1 byte)	4Fh (OK)
RSV	(2 bytes)	0000h (unused code)
CFS	(2 bytes)	Size of Code Flash Secure region [KB] For example: 0100h -> 01h, 00h (256 KB)
DFS	(2 bytes)	Size of Data Flash Secure region [KB] For example: 0004h -> 00h, 04h (4 KB)
RSV	(2 bytes)	0000h (unused code)
RSV	(2 bytes)	0000h (unused code)
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 19. Command Packet for Reading Security Region Setup

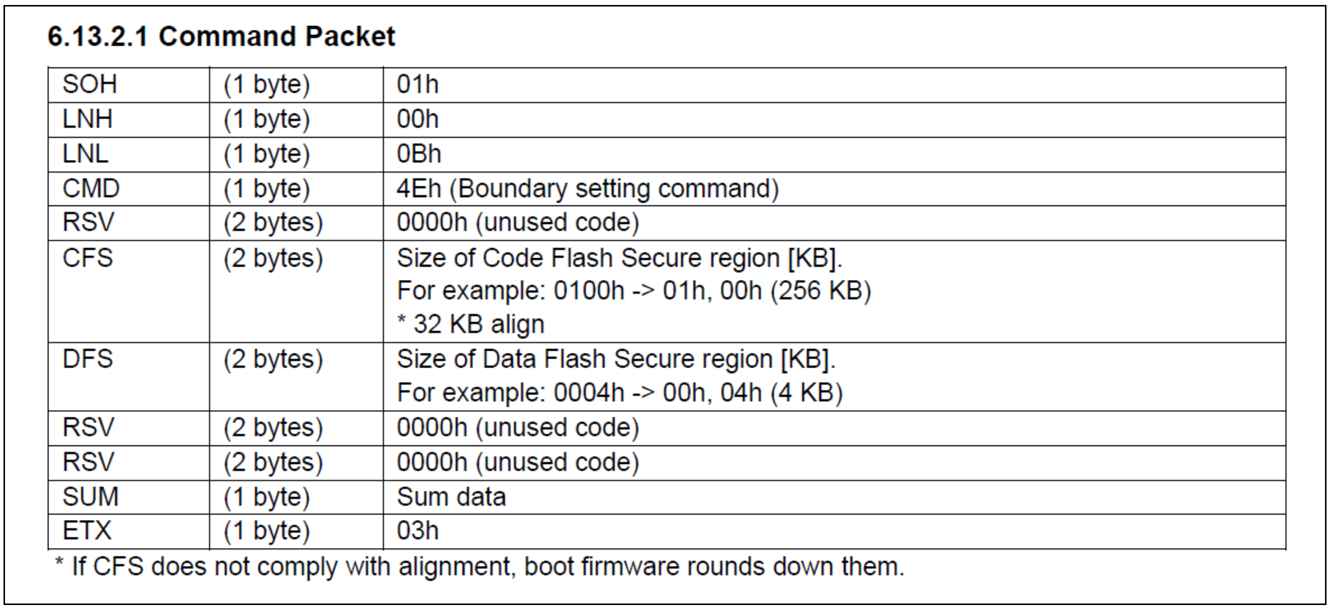


```
# ==================================
# This routine demonstrates "TrustZone Boundary Request Command".
def command_trustzone_boundary_request(sig_type):
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x01'
    CMD=b'\x4F' # Boundary request command
    SUM=b'\xB0'
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SUM + EXT

    print("Sending read boundary region command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x4F:
        print("Read boundary region - FAIL")
    else:
        print("Read boundary region - SUCCESS")
    print_boundary_region(return_packet, sig_type)

    return RES
```

Figure 20. Example Code: Request TrustZone Boundary

5.4.4 TrustZone Boundary Setting Command

Figure 21 is the command packet for setting up the TrustZone boundary. The new stored boundary setting becomes effective after resetting the device.



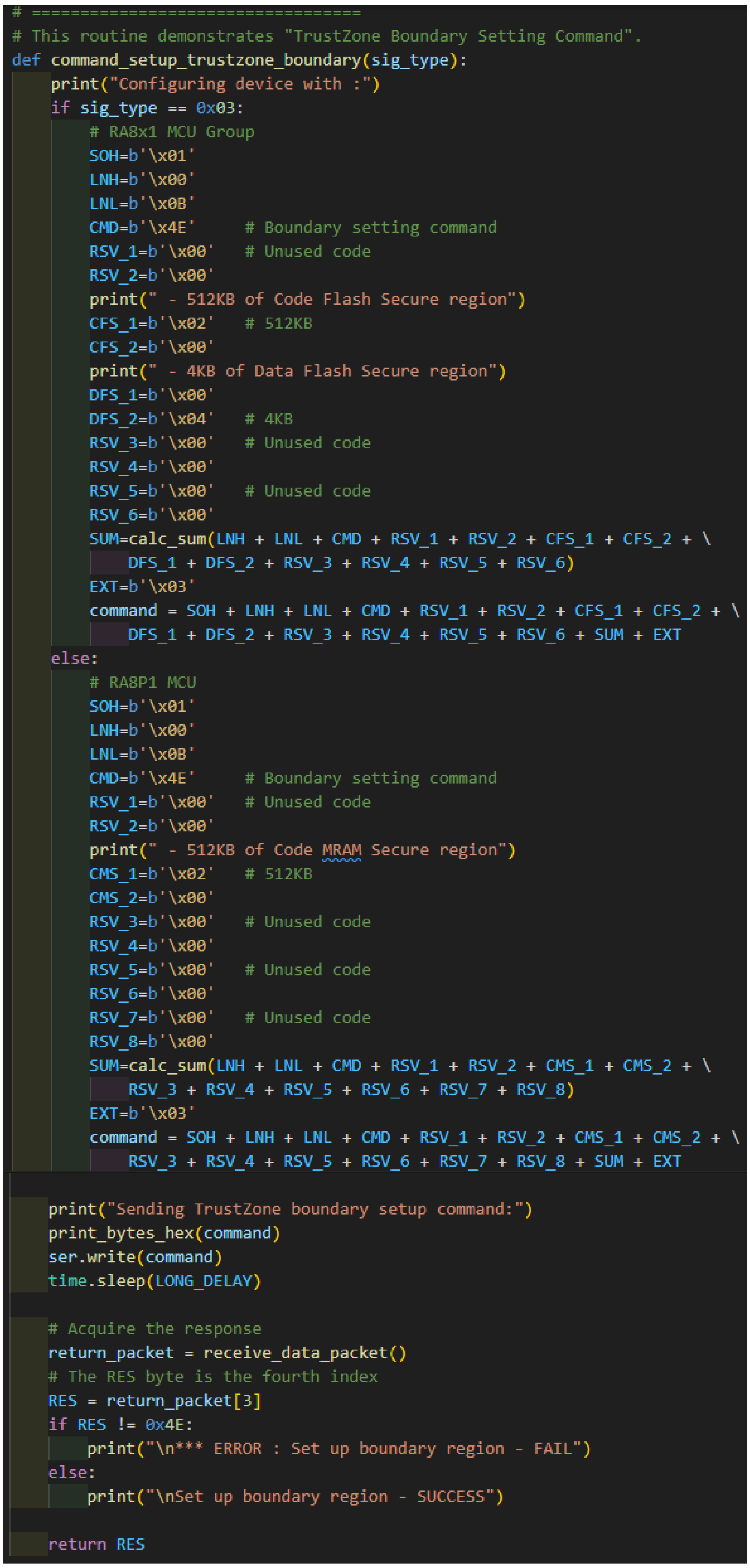
6.13.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	0Bh
CMD	(1 byte)	4Eh (Boundary setting command)
RSV	(2 bytes)	0000h (unused code)
CFS	(2 bytes)	Size of Code Flash Secure region [KB]. For example: 0100h -> 01h, 00h (256 KB) * 32 KB align
DFS	(2 bytes)	Size of Data Flash Secure region [KB]. For example: 0004h -> 00h, 04h (4 KB)
RSV	(2 bytes)	0000h (unused code)
RSV	(2 bytes)	0000h (unused code)
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

* If CFS does not comply with alignment, boot firmware rounds down them.

Figure 21. Command Packet for TrustZone Boundary Setup

Figure 22 shows the example code for setting up the TrustZone boundary cover for both RA8x1 and RA8P1 Groups.



```
# ==================================
# This routine demonstrates "TrustZone Boundary Setting Command".
def command_setup_trustzone_boundary(sig_type):
    print("Configuring device with :")
    if sig_type == 0x03:
        # RA8x1 MCU Group
        SOH=b'\x01'
        LNH=b'\x00'
        LNL=b'\x0B'
        CMD=b'\x4E'     # Boundary setting command
        RSV_1=b'\x00'   # Unused code
        RSV_2=b'\x00'
        print(" - 512KB of Code Flash Secure region")
        CFS_1=b'\x02'   # 512KB
        CFS_2=b'\x00'
        print(" - 4KB of Data Flash Secure region")
        DFS_1=b'\x00'
        DFS_2=b'\x04'   # 4KB
        RSV_3=b'\x00'   # Unused code
        RSV_4=b'\x00'
        RSV_5=b'\x00'   # Unused code
        RSV_6=b'\x00'
        SUM=calc_sum(LNH + LNL + CMD + RSV_1 + RSV_2 + CFS_1 + CFS_2 + \
            DFS_1 + DFS_2 + RSV_3 + RSV_4 + RSV_5 + RSV_6)
        EXT=b'\x03'
        command = SOH + LNH + LNL + CMD + RSV_1 + RSV_2 + CFS_1 + CFS_2 + \
            DFS_1 + DFS_2 + RSV_3 + RSV_4 + RSV_5 + RSV_6 + SUM + EXT
    else:
        # RA8P1 MCU
        SOH=b'\x01'
        LNH=b'\x00'
        LNL=b'\x0B'
        CMD=b'\x4E'     # Boundary setting command
        RSV_1=b'\x00'   # Unused code
        RSV_2=b'\x00'
        print(" - 512KB of Code MRAM Secure region")
        CMS_1=b'\x02'   # 512KB
        CMS_2=b'\x00'
        RSV_3=b'\x00'   # Unused code
        RSV_4=b'\x00'
        RSV_5=b'\x00'   # Unused code
        RSV_6=b'\x00'
        RSV_7=b'\x00'   # Unused code
        RSV_8=b'\x00'
        SUM=calc_sum(LNH + LNL + CMD + RSV_1 + RSV_2 + CMS_1 + CMS_2 + \
            RSV_3 + RSV_4 + RSV_5 + RSV_6 + RSV_7 + RSV_8)
        EXT=b'\x03'
        command = SOH + LNH + LNL + CMD + RSV_1 + RSV_2 + CMS_1 + CMS_2 + \
            RSV_3 + RSV_4 + RSV_5 + RSV_6 + RSV_7 + RSV_8 + SUM + EXT

    print("Sending TrustZone boundary setup command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x4E:
        print("\n*** ERROR : Set up boundary region - FAIL")
    else:
        print("\nSet up boundary region - SUCCESS")

    return RES
```

Figure 22.   Example Command Setting up TrustZone Boundary

5.5 DLM Authentication Key Handling

DLM Authentication keys are stored in dedicated, non-user-accessible memory within the MCU, with one slot dedicated to each Authentication Level transition. Therefore, when injecting the key, it is necessary to specify which target AL key, so that the key is placed into the correct slot.

Key injection for AL2 and AL1 states is demonstrated in this application note. Injection of the RMA key can follow similar sequence but is not demonstrated in this application note.

Note: The injection of user keys is very similar to AL keys, except that additional address information is required in the corresponding command, as these keys are stored in user flash.

Keys can be generated using the following systems:

- The “Security Key Management Tool”
- The Renesas Device Lifecycle Management server available from the Renesas website

The procedure for generating the DLM Authentication keys is described in R11AN0785.

5.5.1 Inject DLM Authentication Keys

Injecting a DLM AL key requires a two-stage sequence, as shown in Figure 23.

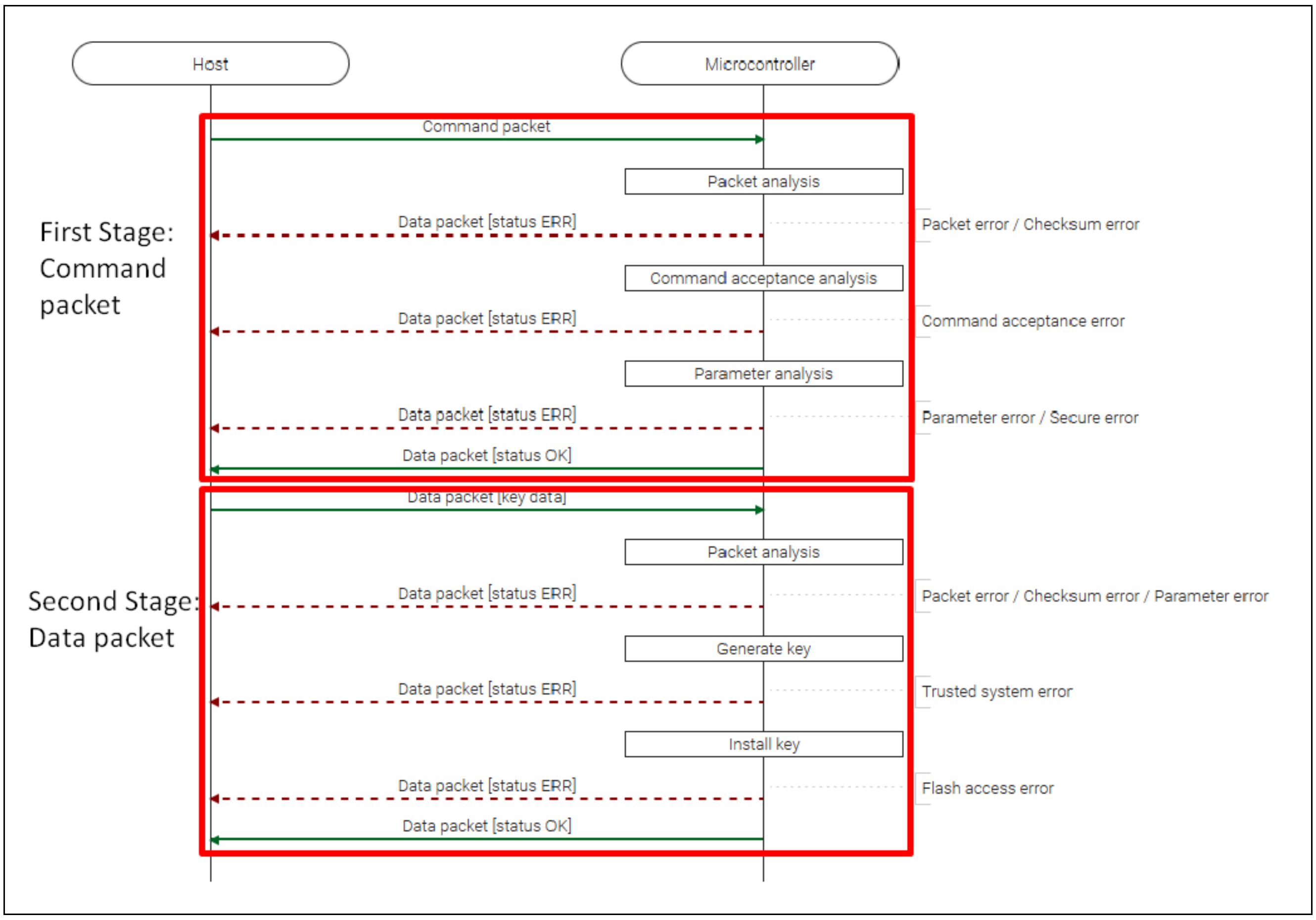
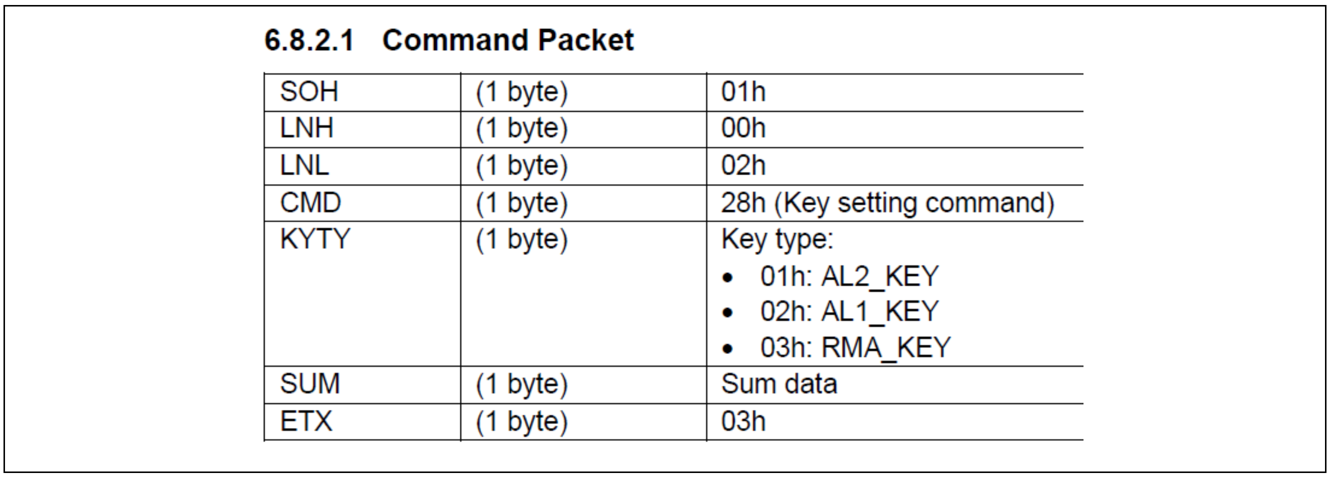


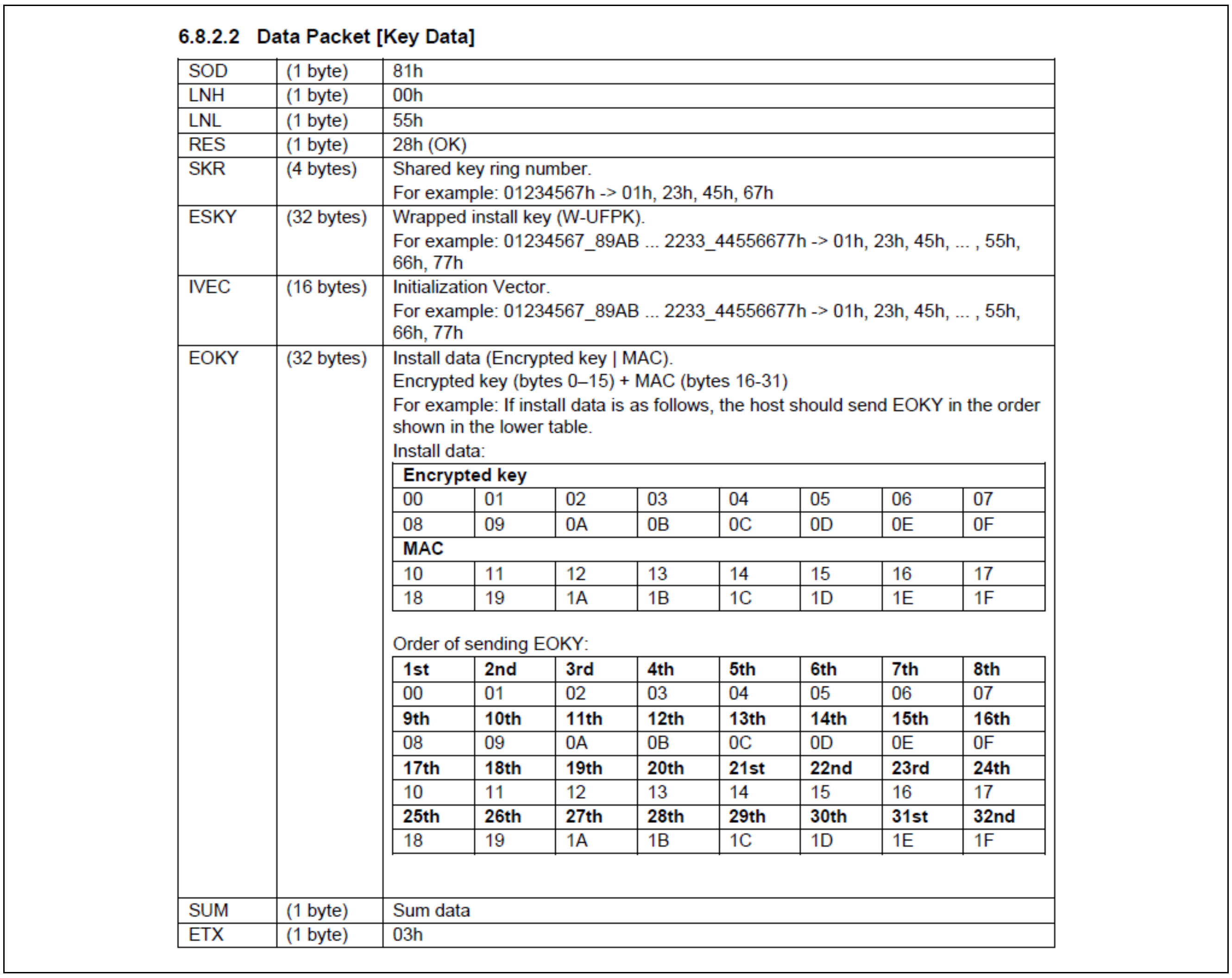
Figure 23. DLM Key Injection Flow



6.8.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
CMD	(1 byte)	28h (Key setting command)
KYTY	(1 byte)	Key type: • 01h: AL2_KEY • 02h: AL1_KEY • 03h: RMA_KEY
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 24. DLM Key Injection Command Packet



6.8.2.2 Data Packet [Key Data]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	55h
RES	(1 byte)	28h (OK)
SKR	(4 bytes)	Shared key ring number. For example: 01234567h -> 01h, 23h, 45h, 67h
ESKY	(32 bytes)	Wrapped install key (W-UFPK). For example: 01234567_89AB ... 2233_44556677h -> 01h, 23h, 45h, ... , 55h, 66h, 77h
IVEC	(16 bytes)	Initialization Vector. For example: 01234567_89AB ... 2233_44556677h -> 01h, 23h, 45h, ... , 55h, 66h, 77h
EOKY	(32 bytes)	Install data (Encrypted key | MAC). Encrypted key (bytes 0–15) + MAC (bytes 16-31) For example: If install data is as follows, the host should send EOKY in the order shown in the lower table. Install data:
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Install data:

Encrypted key							
00	01	02	03	04	05	06	07
08	09	0A	0B	0C	0D	0E	0F
MAC							
10	11	12	13	14	15	16	17
18	19	1A	1B	1C	1D	1E	1F

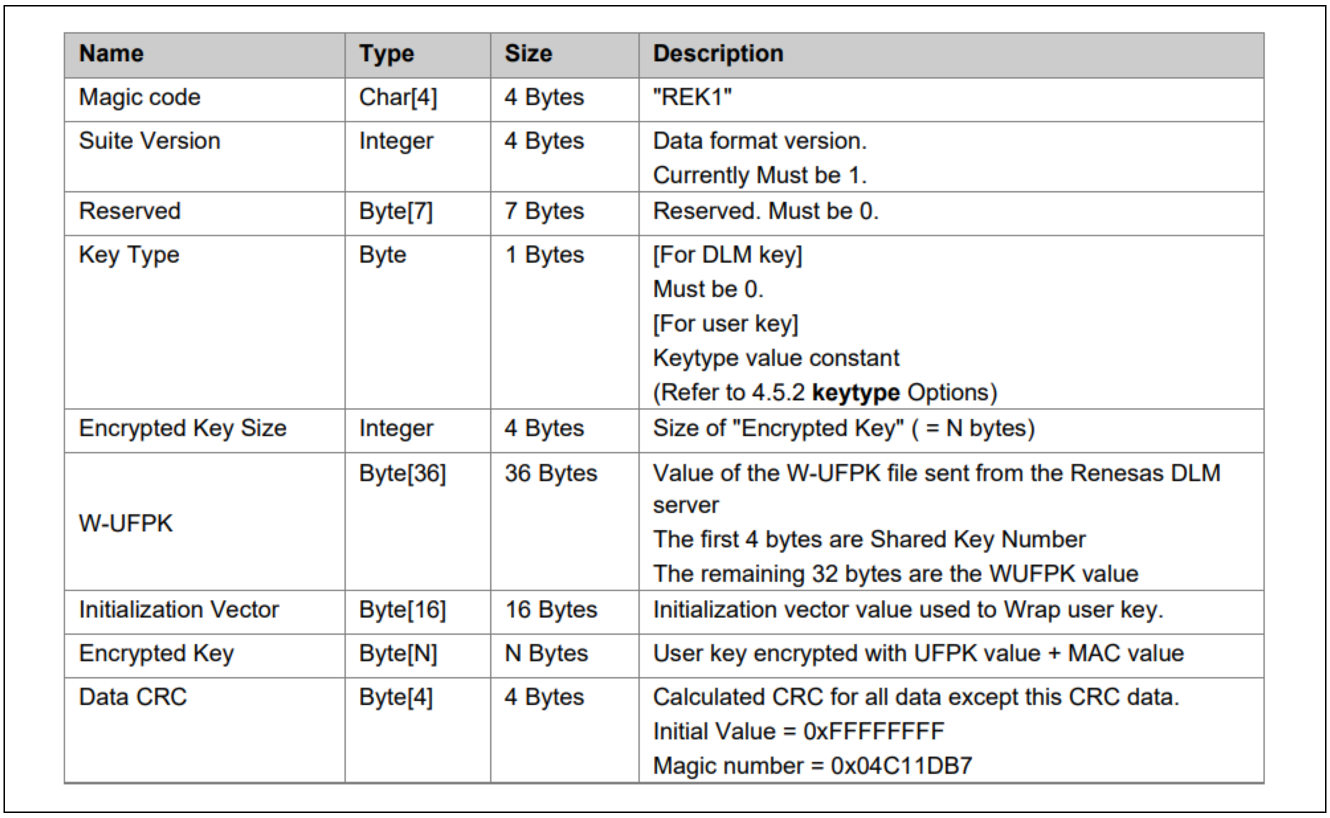
Order of sending EOKY:

1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
00	01	02	03	04	05	06	07
9th	**10th**	**11th**	**12th**	**13th**	**14th**	**15th**	**16th**
08	09	0A	0B	0C	0D	0E	0F
17th	**18th**	**19th**	**20th**	**21st**	**22nd**	**23rd**	**24th**
10	11	12	13	14	15	16	17
25th	**26th**	**27th**	**28th**	**29th**	**30th**	**31st**	**32nd**
18	19	1A	1B	1C	1D	1E	1F

Figure 25. DLM Key Injection Data Packet

To properly prepare for the DLM key injection, the production programming tools need to understand the .rkey file format. The .rkey file is also base64 encoded, so the production programming tools need to first decode the data prior to accessing the fields. Once the .rkey file is decoded, the .rkey file data fields can then be accessed. The format of the fields is shown in Figure 26, and is further explained in the user manual of Secure Key Management Tool.

Key Data is stored in order and size shown in Figure 26. The byte order is big-endian.



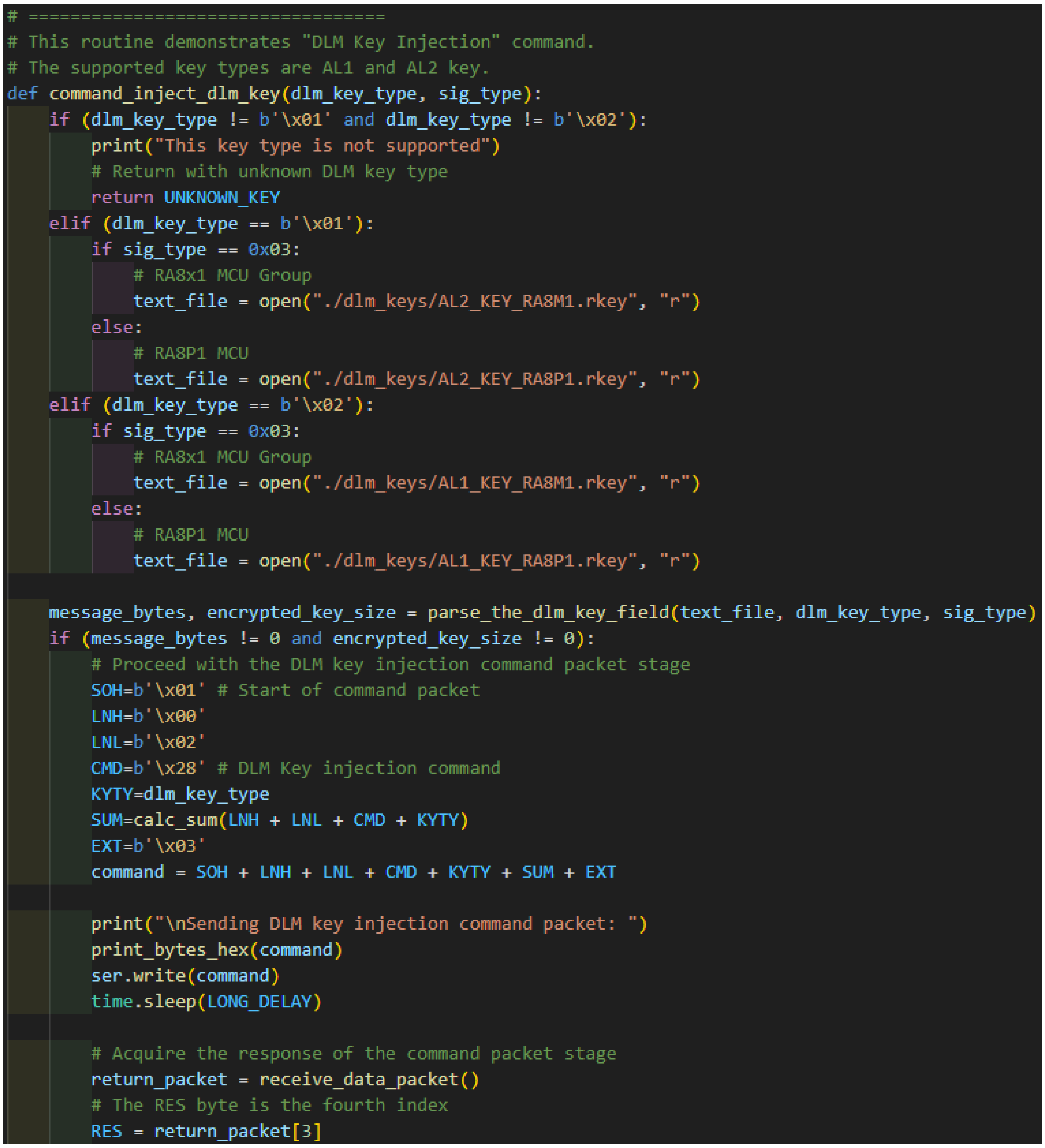
Name	Type	Size	Description
Magic code	Char[4]	4 Bytes	"REK1"
Suite Version	Integer	4 Bytes	Data format version. Currently Must be 1.
Reserved	Byte[7]	7 Bytes	Reserved. Must be 0.
Key Type	Byte	1 Bytes	[For DLM key] Must be 0. [For user key] Keytype value constant (Refer to 4.5.2 **keytype** Options)
Encrypted Key Size	Integer	4 Bytes	Size of "Encrypted Key" (= N bytes)
W-UFPK	Byte[36]	36 Bytes	Value of the W-UFPK file sent from the Renesas DLM server The first 4 bytes are Shared Key Number The remaining 32 bytes are the WUFPK value
Initialization Vector	Byte[16]	16 Bytes	Initialization vector value used to Wrap user key.
Encrypted Key	Byte[N]	N Bytes	User key encrypted with UFPK value + MAC value
Data CRC	Byte[4]	4 Bytes	Calculated CRC for all data except this CRC data. Initial Value = 0xFFFFFFFF Magic number = 0x04C11DB7

Figure 26. DLM Key Data Structure

The demonstration code for DLM Authentication key injection is included in function `command_inject_dlm_key()`. The main operations carried out by this function are:

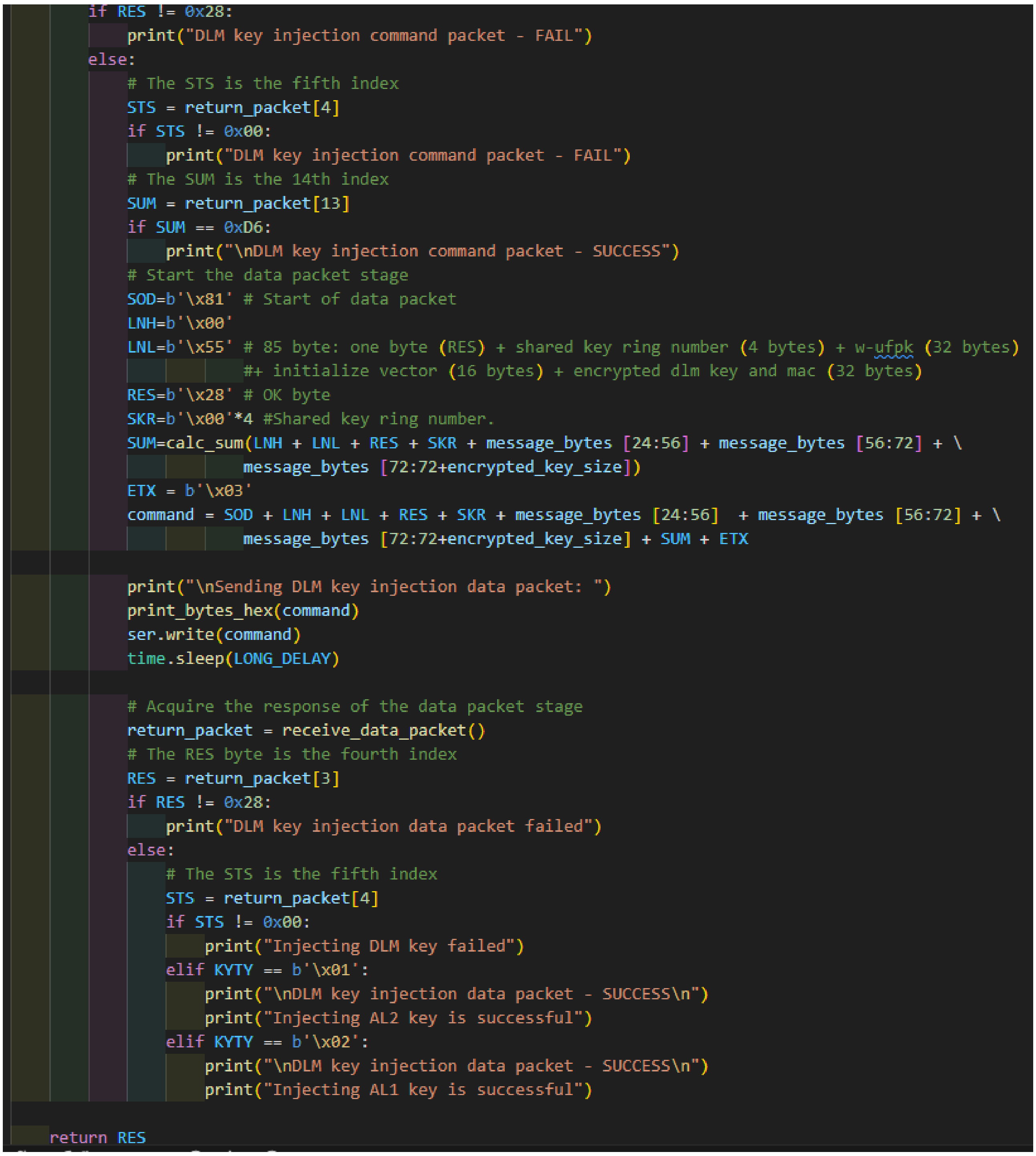
- Read the AL2 or AL1 key file (.rkey) to an array.
- Decode the base64 array so all the data fields can be accessed.
- Parse the .rkey file for the field of magic code, key type, w-ufpk, initialization vector, and the encrypted DLM key to ensure valid content.
- Issue DLM AL Key Injection command packet and verify the response.
- Issue DLM AL Key Injection data packet and verify the response using the decoded key data.

Figure 27 and Figure 28 show the example code.



```
# ==================================
# This routine demonstrates "DLM Key Injection" command.
# The supported key types are AL1 and AL2 key.
def command_inject_dlm_key(dlm_key_type, sig_type):
    if (dlm_key_type != b'\x01' and dlm_key_type != b'\x02'):
        print("This key type is not supported")
        # Return with unknown DLM key type
        return UNKNOWN_KEY
    elif (dlm_key_type == b'\x01'):
        if sig_type == 0x03:
            # RA8x1 MCU Group
            text_file = open("./dlm_keys/AL2_KEY_RA8M1.rkey", "r")
        else:
            # RA8P1 MCU
            text_file = open("./dlm_keys/AL2_KEY_RA8P1.rkey", "r")
    elif (dlm_key_type == b'\x02'):
        if sig_type == 0x03:
            # RA8x1 MCU Group
            text_file = open("./dlm_keys/AL1_KEY_RA8M1.rkey", "r")
        else:
            # RA8P1 MCU
            text_file = open("./dlm_keys/AL1_KEY_RA8P1.rkey", "r")

    message_bytes, encrypted_key_size = parse_the_dlm_key_field(text_file, dlm_key_type, sig_type)
    if (message_bytes != 0 and encrypted_key_size != 0):
        # Proceed with the DLM key injection command packet stage
        SOH=b'\x01' # Start of command packet
        LNH=b'\x00'
        LNL=b'\x02'
        CMD=b'\x28' # DLM Key injection command
        KYTY=dlm_key_type
        SUM=calc_sum(LNH + LNL + CMD + KYTY)
        EXT=b'\x03'
        command = SOH + LNH + LNL + CMD + KYTY + SUM + EXT

        print("\nSending DLM key injection command packet: ")
        print_bytes_hex(command)
        ser.write(command)
        time.sleep(LONG_DELAY)

        # Acquire the response of the command packet stage
        return_packet = receive_data_packet()
        # The RES byte is the fourth index
        RES = return_packet[3]
```

Figure 27. Example Code: DLM Key Injection – Part 1

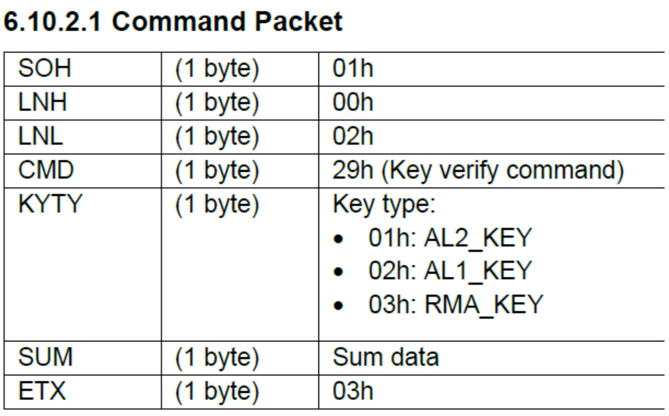


```
        if RES != 0x28:
            print("DLM key injection command packet - FAIL")
        else:
            # The STS is the fifth index
            STS = return_packet[4]
            if STS != 0x00:
                print("DLM key injection command packet - FAIL")
            # The SUM is the 14th index
            SUM = return_packet[13]
            if SUM == 0xD6:
                print("\nDLM key injection command packet - SUCCESS")
            # Start the data packet stage
            SOD=b'\x81' # Start of data packet
            LNH=b'\x00'
            LNL=b'\x55' # 85 byte: one byte (RES) + shared key ring number (4 bytes) + w-ufpk (32 bytes)
                        #+ initialize vector (16 bytes) + encrypted dlm key and mac (32 bytes)
            RES=b'\x28' # OK byte
            SKR=b'\x00'*4 #Shared key ring number.
            SUM=calc_sum(LNH + LNL + RES + SKR + message_bytes [24:56] + message_bytes [56:72] + \
                        message_bytes [72:72+encrypted_key_size])
            ETX = b'\x03'
            command = SOD + LNH + LNL + RES + SKR + message_bytes [24:56]  + message_bytes [56:72] + \
                        message_bytes [72:72+encrypted_key_size] + SUM + ETX

            print("\nSending DLM key injection data packet: ")
            print_bytes_hex(command)
            ser.write(command)
            time.sleep(LONG_DELAY)

            # Acquire the response of the data packet stage
            return_packet = receive_data_packet()
            # The RES byte is the fourth index
            RES = return_packet[3]
            if RES != 0x28:
                print("DLM key injection data packet failed")
            else:
                # The STS is the fifth index
                STS = return_packet[4]
                if STS != 0x00:
                    print("Injecting DLM key failed")
                elif KYTY == b'\x01':
                    print("\nDLM key injection data packet - SUCCESS\n")
                    print("Injecting AL2 key is successful")
                elif KYTY == b'\x02':
                    print("\nDLM key injection data packet - SUCCESS\n")
                    print("Injecting AL1 key is successful")

    return RES
```

Figure 28. Example Code: DLM Key Injection – Part 2

5.5.2 Verify DLM Authentication Keys

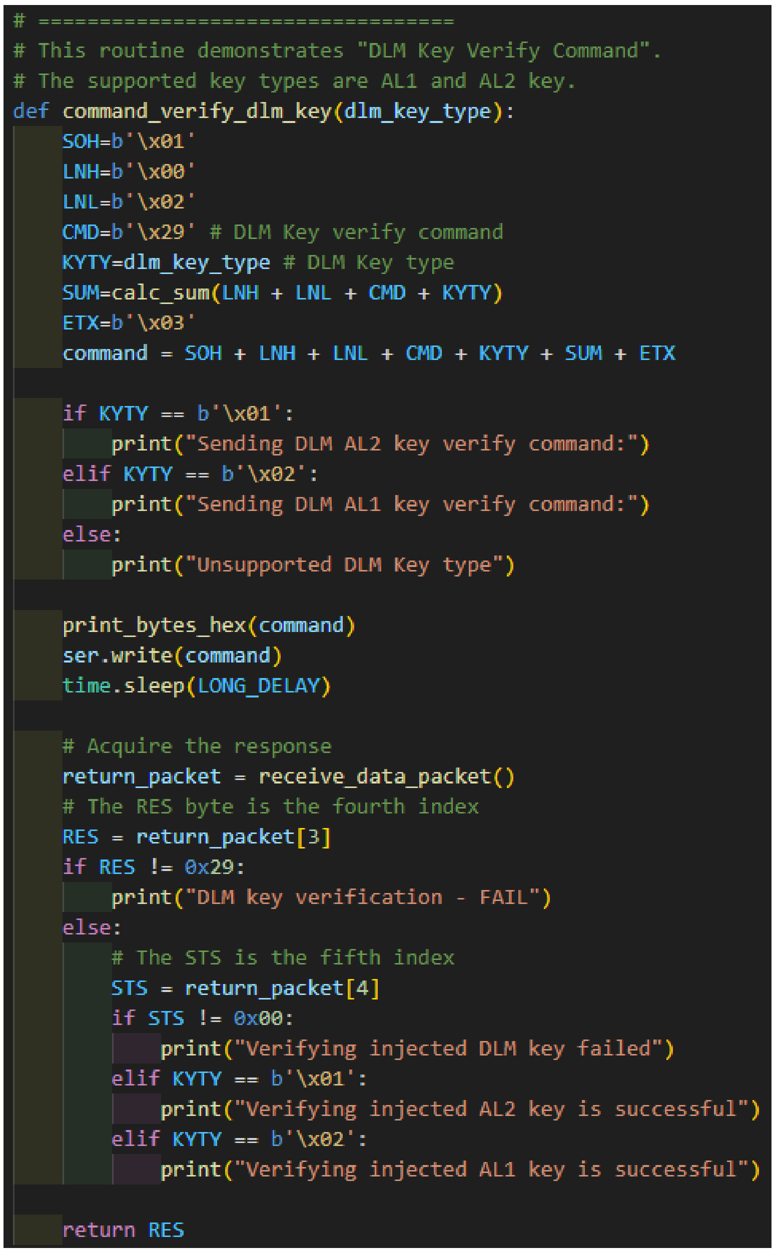
After injecting the DLM AL keys, the production programming tools should invoke a verify command to confirm correct injection. Figure 29 shows the command packet information for verifying the DLM AL keys.



6.10.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
CMD	(1 byte)	29h (Key verify command)
KYTY	(1 byte)	Key type: • 01h: AL2_KEY • 02h: AL1_KEY • 03h: RMA_KEY
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 29. DLM Key Verify Command Packet



```python
# ==================================
# This routine demonstrates "DLM Key Verify Command".
# The supported key types are AL1 and AL2 key.
def command_verify_dlm_key(dlm_key_type):
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x02'
    CMD=b'\x29' # DLM Key verify command
    KYTY=dlm_key_type # DLM Key type
    SUM=calc_sum(LNH + LNL + CMD + KYTY)
    ETX=b'\x03'
    command = SOH + LNH + LNL + CMD + KYTY + SUM + ETX

    if KYTY == b'\x01':
        print("Sending DLM AL2 key verify command:")
    elif KYTY == b'\x02':
        print("Sending DLM AL1 key verify command:")
    else:
        print("Unsupported DLM Key type")

    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x29:
        print("DLM key verification - FAIL")
    else:
        # The STS is the fifth index
        STS = return_packet[4]
        if STS != 0x00:
            print("Verifying injected DLM key failed")
        elif KYTY == b'\x01':
            print("Verifying injected AL2 key is successful")
        elif KYTY == b'\x02':
            print("Verifying injected AL1 key is successful")

    return RES
```

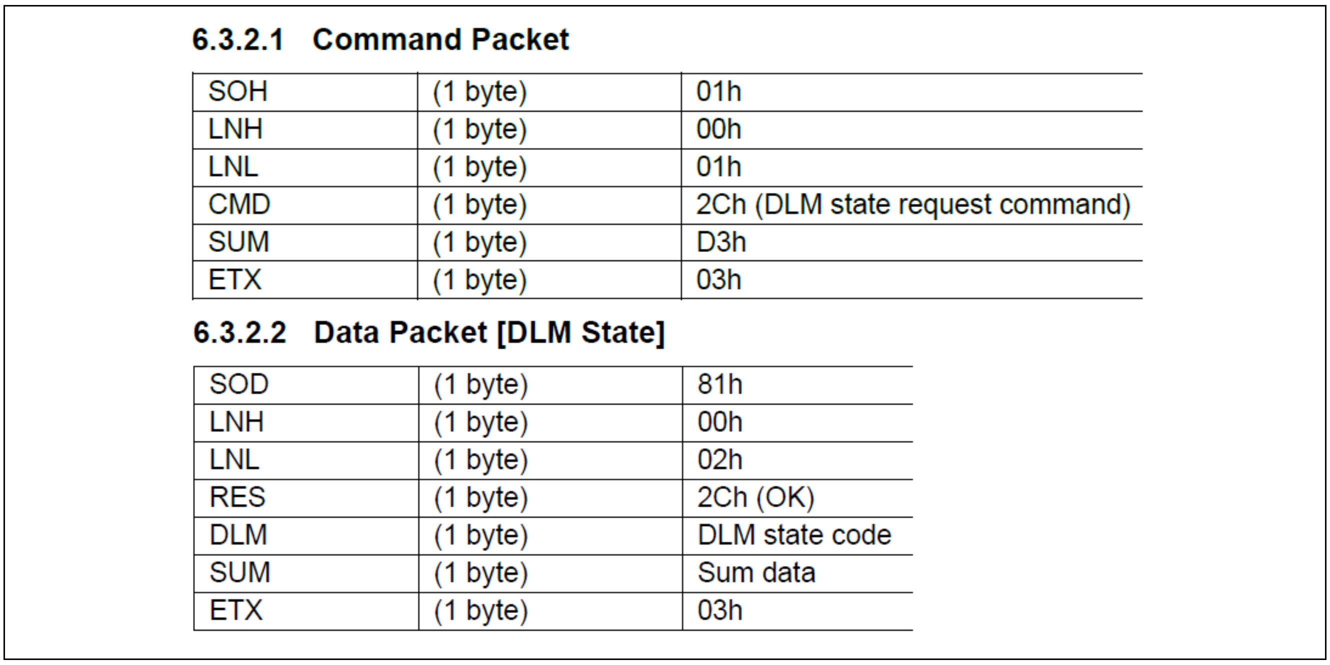
Figure 30. DLM Authentication Key Verify Command Example Code

5.6 DLM State, Protection Level and Authentication Level Handling

This section explains the DLM state, Protection Level (PL) and Authentication Level (AL) request command and the non-authenticated DLM state, PL and AL transition command.

5.6.1 DLM State Request

The state request command is demonstrated in the included example code. Figure 31 shows the state request command packet format. Figure 32 shows the example code.



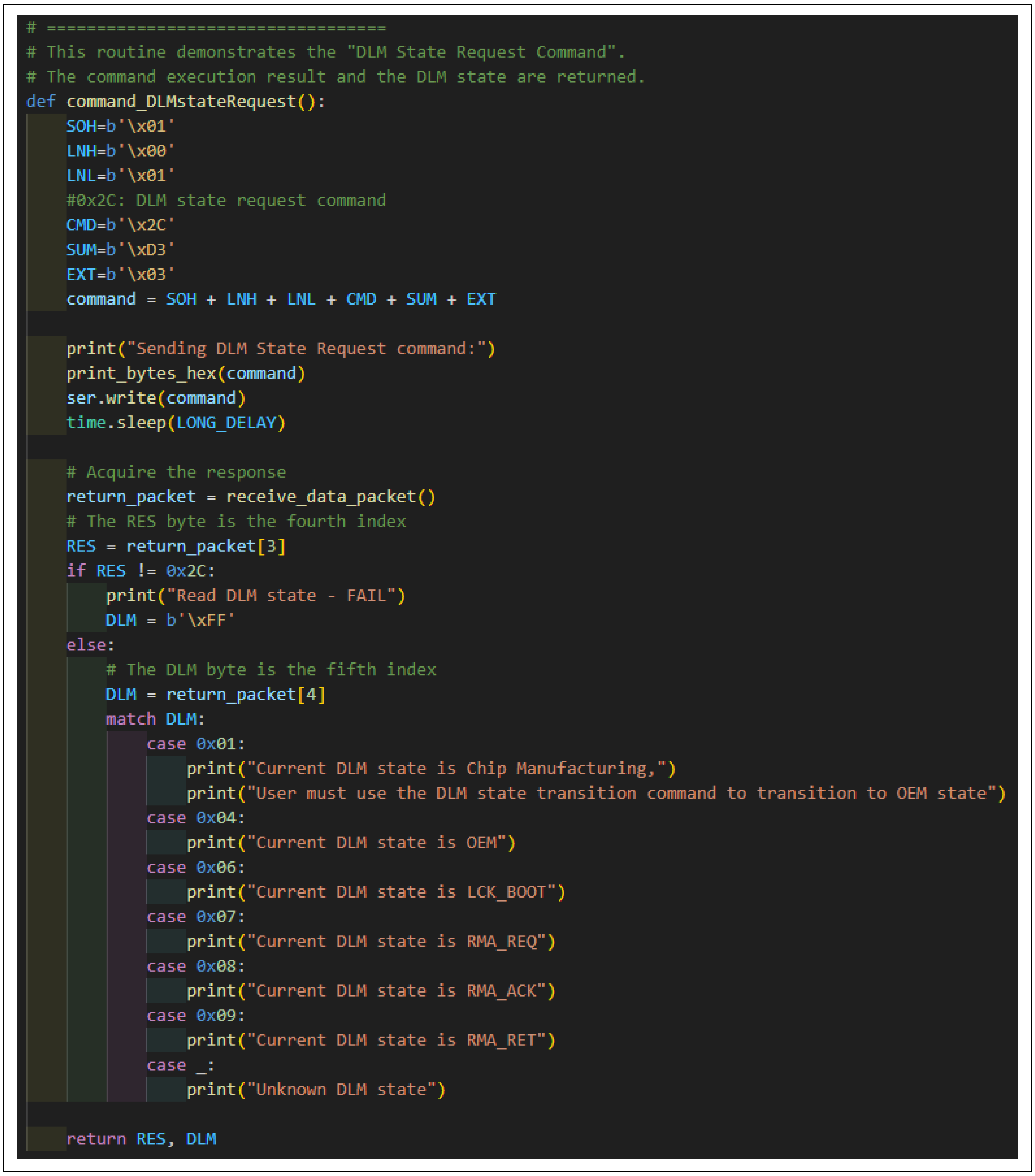
6.3.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	01h
CMD	(1 byte)	2Ch (DLM state request command)
SUM	(1 byte)	D3h
ETX	(1 byte)	03h

6.3.2.2 Data Packet [DLM State]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
RES	(1 byte)	2Ch (OK)
DLM	(1 byte)	DLM state code
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 31. DLM State Request Command Packet



```
# ==================================
# This routine demonstrates the "DLM State Request Command".
# The command execution result and the DLM state are returned.
def command_DLMstateRequest():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x01'
    #0x2C: DLM state request command
    CMD=b'\x2C'
    SUM=b'\xD3'
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SUM + EXT

    print("Sending DLM State Request command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x2C:
        print("Read DLM state - FAIL")
        DLM = b'\xFF'
    else:
        # The DLM byte is the fifth index
        DLM = return_packet[4]
        match DLM:
            case 0x01:
                print("Current DLM state is Chip Manufacturing,")
                print("User must use the DLM state transition command to transition to OEM state")
            case 0x04:
                print("Current DLM state is OEM")
            case 0x06:
                print("Current DLM state is LCK_BOOT")
            case 0x07:
                print("Current DLM state is RMA_REQ")
            case 0x08:
                print("Current DLM state is RMA_ACK")
            case 0x09:
                print("Current DLM state is RMA_RET")
            case _:
                print("Unknown DLM state")

    return RES, DLM
```

Figure 32. DLM State Request Command Example Code

5.6.2 DLM State Transition

This section covers the non-authenticated DLM state transition. Authenticated transitions are not generally required in production programming tools.

The recommended flow when performing DLM state transition is described in Figure 33. The current DLM state is a required parameter for the DLM state transition command and should be acquired first.

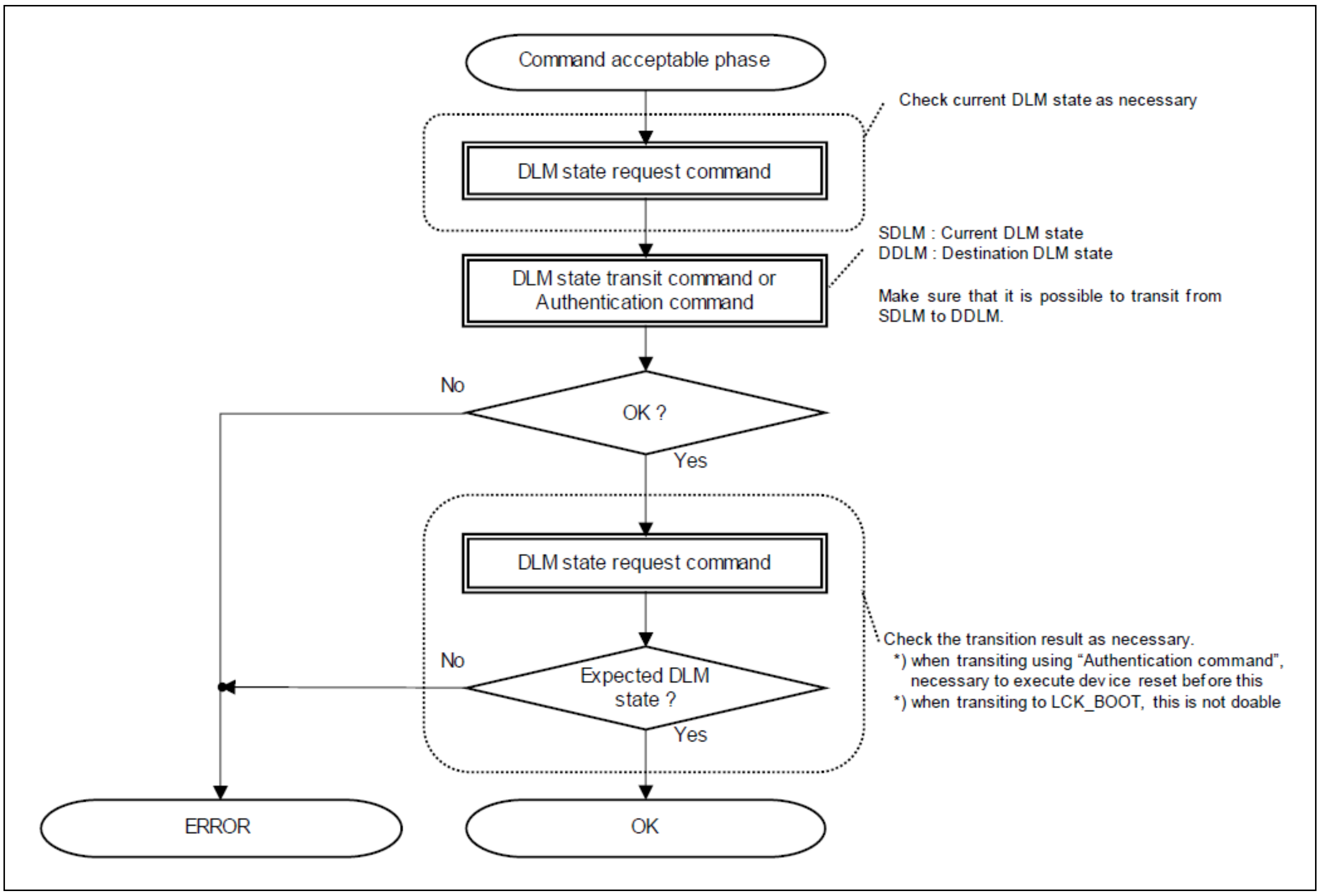

Command acceptable phase
Check current DLM state as necessary
DLM state request command
SDLM : Current DLM state
DDLM : Destination DLM state
DLM state transit command or Authentication command
Make sure that it is possible to transit from SDLM to DDLM.
No
OK ?
Yes
DLM state request command
Check the transition result as necessary.
*) when transiting using "Authentication command", necessary to execute device reset before this
*) when transiting to LCK_BOOT, this is not doable
No
Expected DLM state ?
Yes
ERROR
OK

Figure 33. Recommended Flow for Performing DLM State Transition

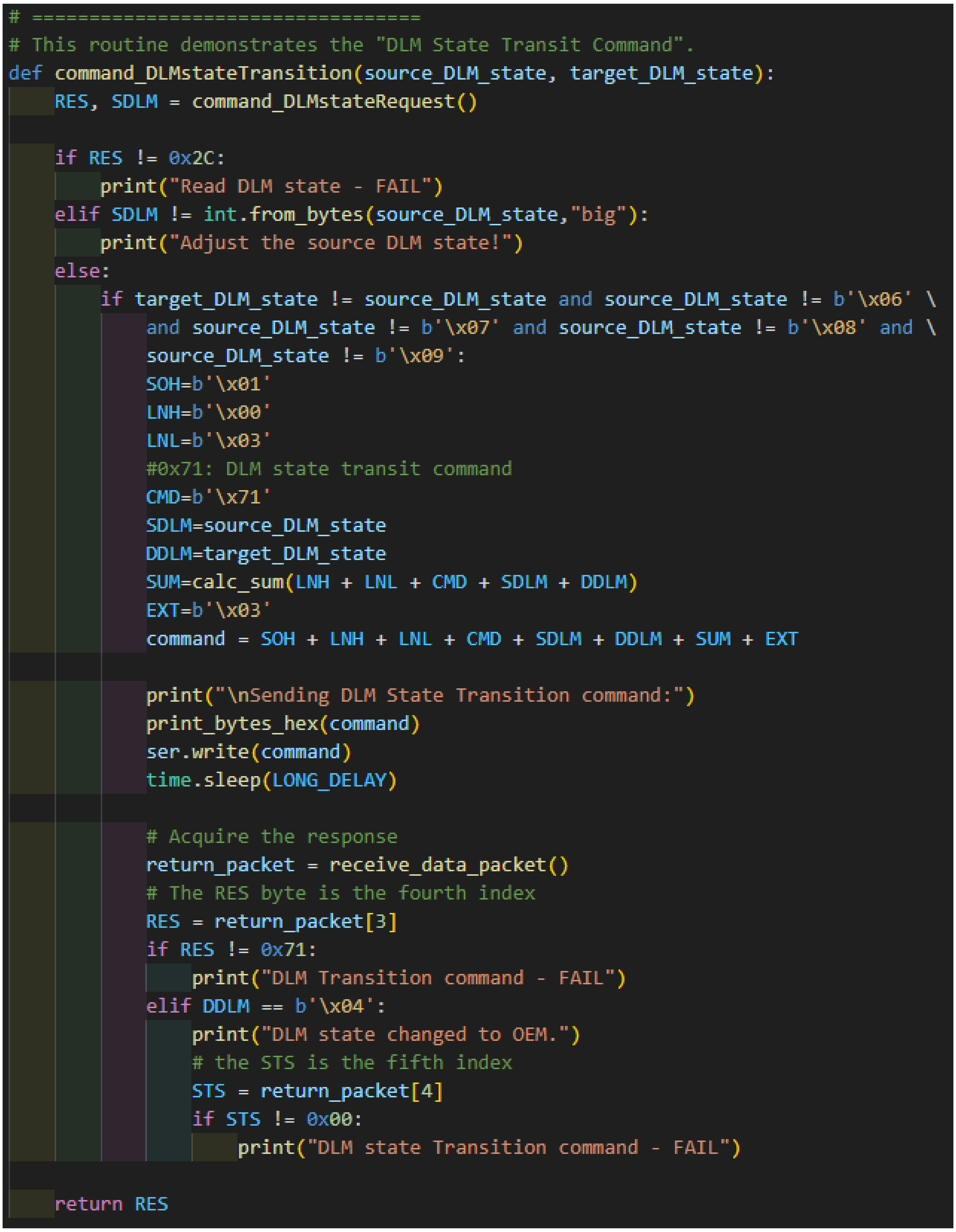
6.2.1.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	03h
CMD	(1 byte)	71h (DLM state transit command)
SDLM	(1 byte)	Source DLM state code: • 01h: CM • 04h: OEM • 08h: RMA_ACK
DDLM	(1 byte)	Destination DLM state code: • 04h: OEM • 06h: LCK_BOOT • 09h: RMA_RET
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

6.2.1.2 Data Packet [Status OK]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	0Ah
RES	(1 byte)	71h (OK)
STS	(1 byte)	00h (OK)
ST2	(4 bytes)	FFFFFFFFh (unused code)
ADR	(4 bytes)	FFFFFFFFh (unused code)
SUM	(1 byte)	8Dh
ETX	(1 byte)	03h

Figure 34. DLM State Transition Command Packet

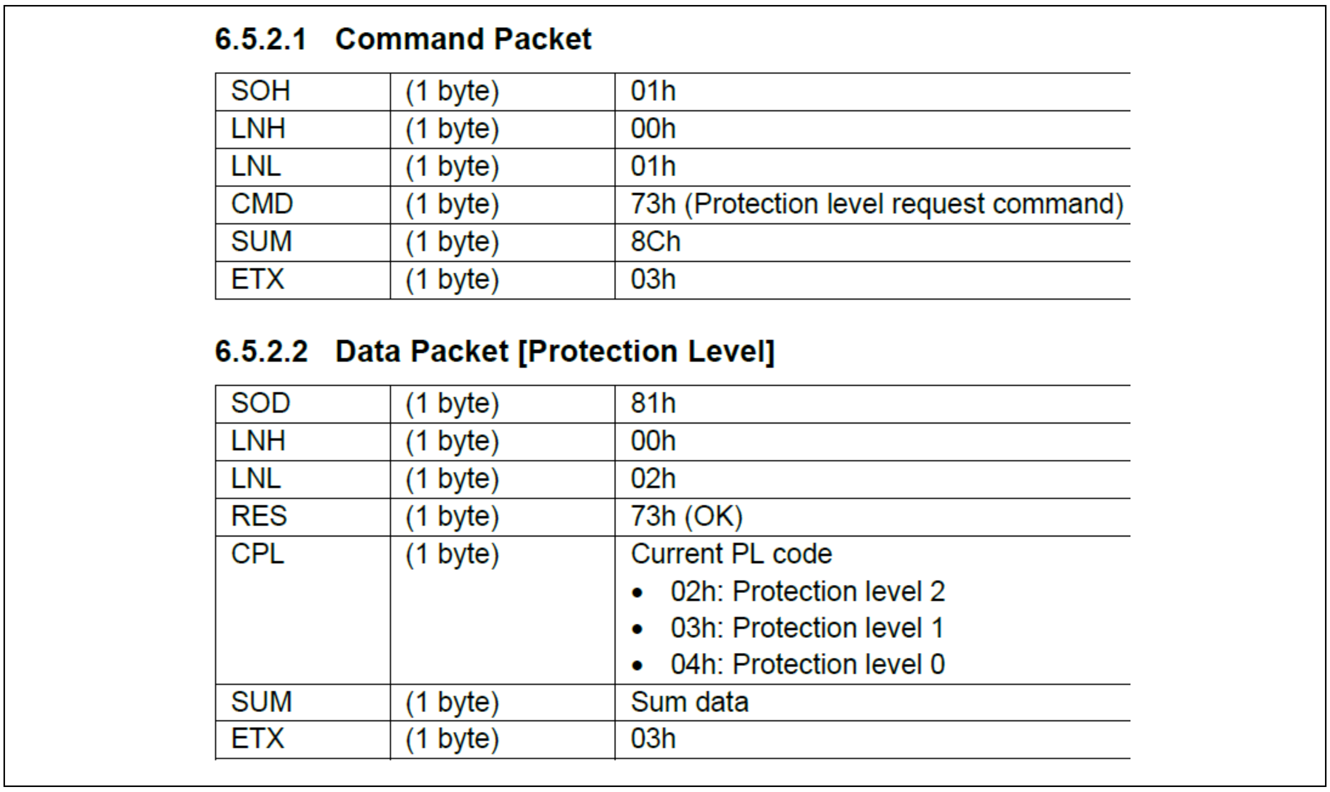


```
# ==================================
# This routine demonstrates the "DLM State Transit Command".
def command_DLMstateTransition(source_DLM_state, target_DLM_state):
    RES, SDLM = command_DLMstateRequest()

    if RES != 0x2C:
        print("Read DLM state - FAIL")
    elif SDLM != int.from_bytes(source_DLM_state,"big"):
        print("Adjust the source DLM state!")
    else:
        if target_DLM_state != source_DLM_state and source_DLM_state != b'\x06' \
            and source_DLM_state != b'\x07' and source_DLM_state != b'\x08' and \
            source_DLM_state != b'\x09':
            SOH=b'\x01'
            LNH=b'\x00'
            LNL=b'\x03'
            #0x71: DLM state transit command
            CMD=b'\x71'
            SDLM=source_DLM_state
            DDLM=target_DLM_state
            SUM=calc_sum(LNH + LNL + CMD + SDLM + DDLM)
            EXT=b'\x03'
            command = SOH + LNH + LNL + CMD + SDLM + DDLM + SUM + EXT

            print("\nSending DLM State Transition command:")
            print_bytes_hex(command)
            ser.write(command)
            time.sleep(LONG_DELAY)

            # Acquire the response
            return_packet = receive_data_packet()
            # The RES byte is the fourth index
            RES = return_packet[3]
            if RES != 0x71:
                print("DLM Transition command - FAIL")
            elif DDLM == b'\x04':
                print("DLM state changed to OEM.")
                # the STS is the fifth index
                STS = return_packet[4]
                if STS != 0x00:
                    print("DLM state Transition command - FAIL")

    return RES
```

Figure 35. Example Code for DLM State Transition Command

5.6.3 Protection Level Request

The PL request command is demonstrated in the included example code. Figure 36 shows the PL request command packet format. Figure 37 shows the example code.



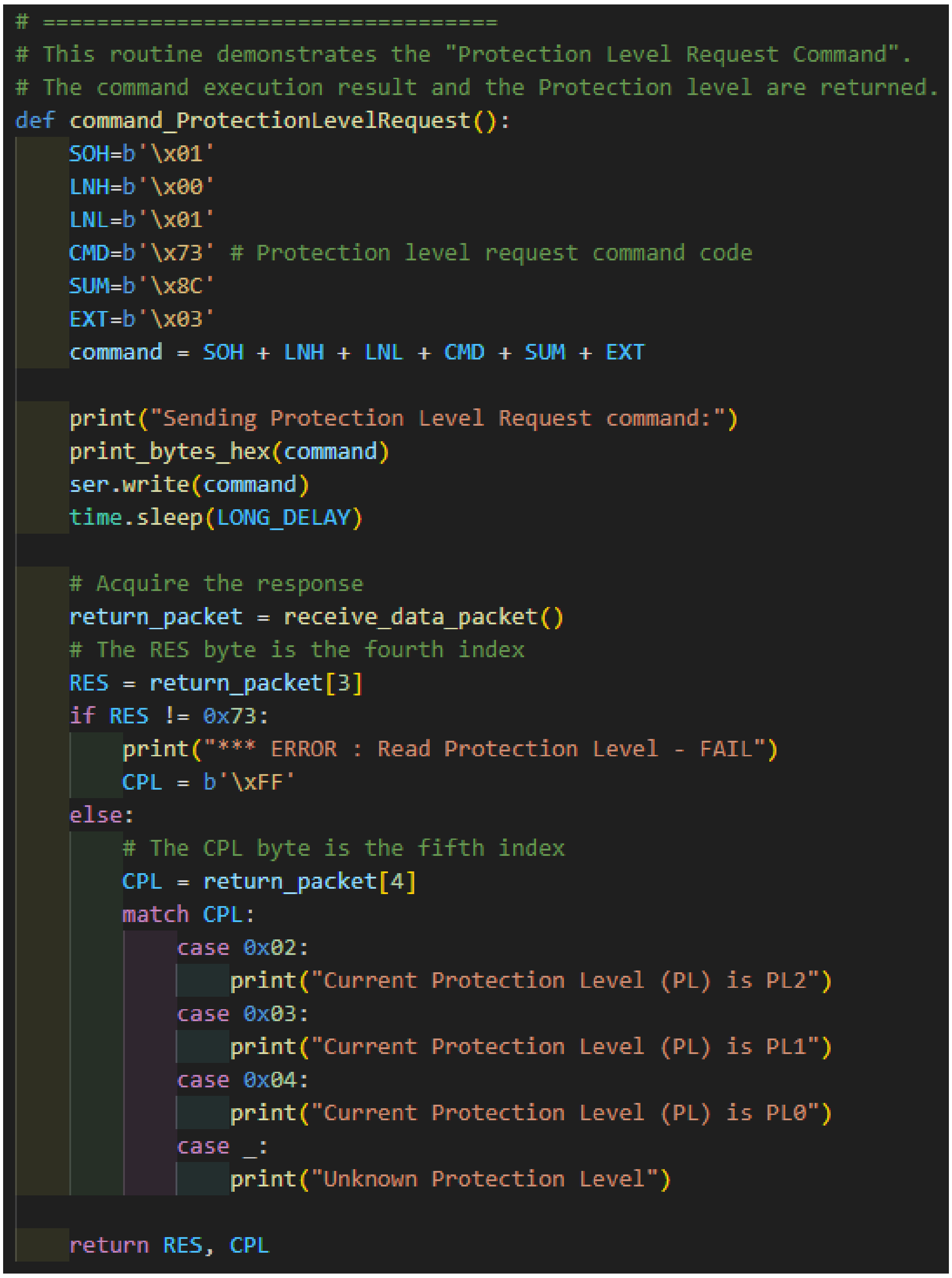
6.5.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	01h
CMD	(1 byte)	73h (Protection level request command)
SUM	(1 byte)	8Ch
ETX	(1 byte)	03h

6.5.2.2 Data Packet [Protection Level]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
RES	(1 byte)	73h (OK)
CPL	(1 byte)	Current PL code • 02h: Protection level 2 • 03h: Protection level 1 • 04h: Protection level 0
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 36. Protection Level Request Command Packet



```
# ==================================
# This routine demonstrates the "Protection Level Request Command".
# The command execution result and the Protection level are returned.
def command_ProtectionLevelRequest():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x01'
    CMD=b'\x73' # Protection level request command code
    SUM=b'\x8C'
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SUM + EXT

    print("Sending Protection Level Request command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x73:
        print("*** ERROR : Read Protection Level - FAIL")
        CPL = b'\xFF'
    else:
        # The CPL byte is the fifth index
        CPL = return_packet[4]
        match CPL:
            case 0x02:
                print("Current Protection Level (PL) is PL2")
            case 0x03:
                print("Current Protection Level (PL) is PL1")
            case 0x04:
                print("Current Protection Level (PL) is PL0")
            case _:
                print("Unknown Protection Level")

    return RES, CPL
```

Figure 37. Protection Level Request Command Example Code

5.6.4 Protection Level Transition

This section covers the non-authenticated PL transition. Authenticated transitions are not generally required in production programming tools.

The recommended flow when performing PL transition is described in Figure 38. The current DLM state, PL and AL are necessary for the PL transition command and should be acquired first.

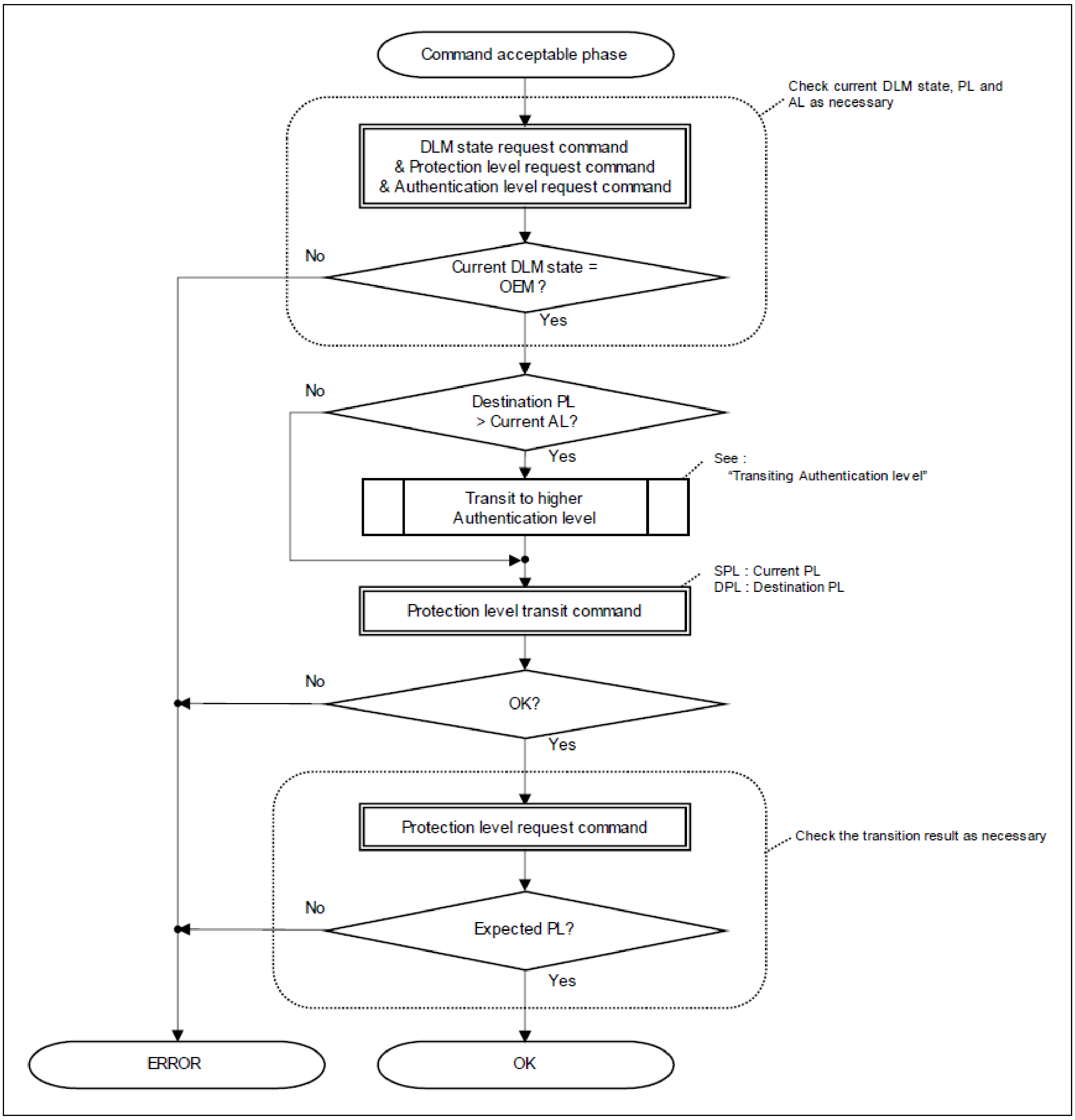
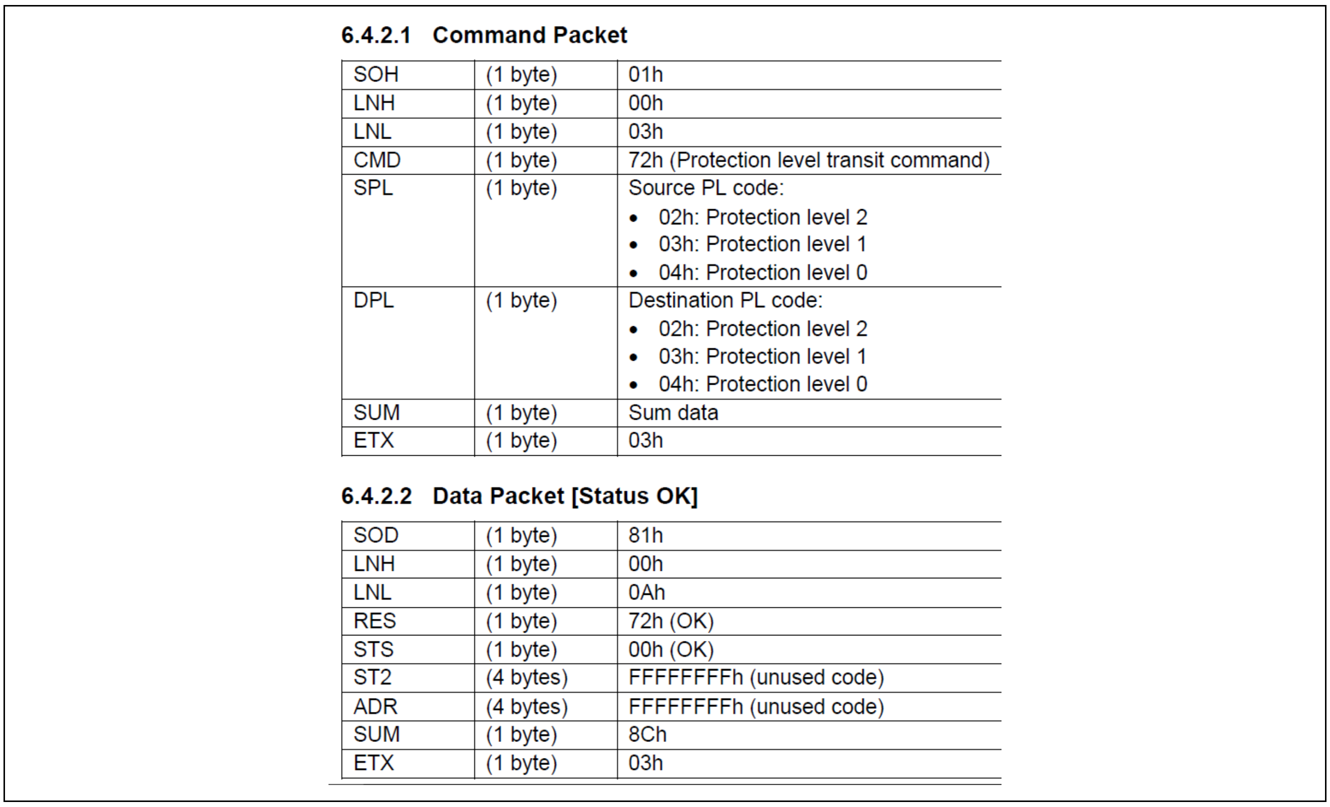

Command acceptable phase
Check current DLM state, PL and AL as necessary
DLM state request command & Protection level request command & Authentication level request command
No
Current DLM state = OEM ?
Yes
No
Destination PL > Current AL?
Yes
See : "Transiting Authentication level"
Transit to higher Authentication level
SPL : Current PL
DPL : Destination PL
Protection level transit command
No
OK?
Yes
Protection level request command
Check the transition result as necessary
No
Expected PL?
Yes
ERROR
OK

Figure 38. Recommended Flow for Performing Protection Level Transition



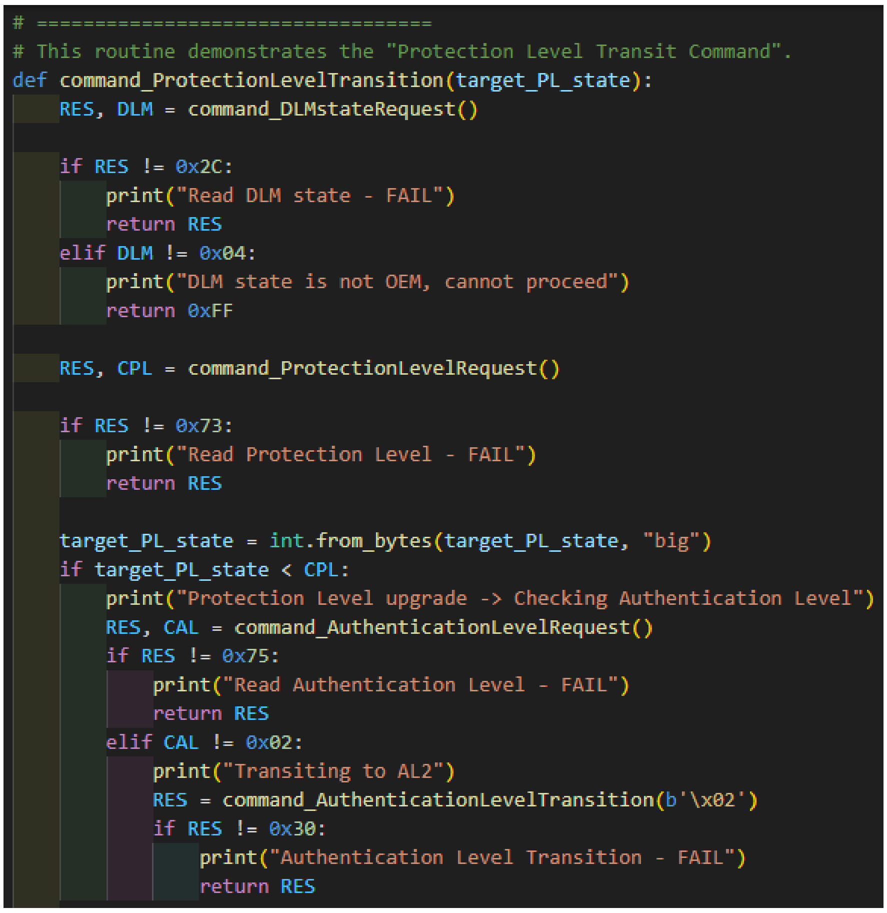
6.4.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	03h
CMD	(1 byte)	72h (Protection level transit command)
SPL	(1 byte)	Source PL code: • 02h: Protection level 2 • 03h: Protection level 1 • 04h: Protection level 0
DPL	(1 byte)	Destination PL code: • 02h: Protection level 2 • 03h: Protection level 1 • 04h: Protection level 0
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

6.4.2.2 Data Packet [Status OK]

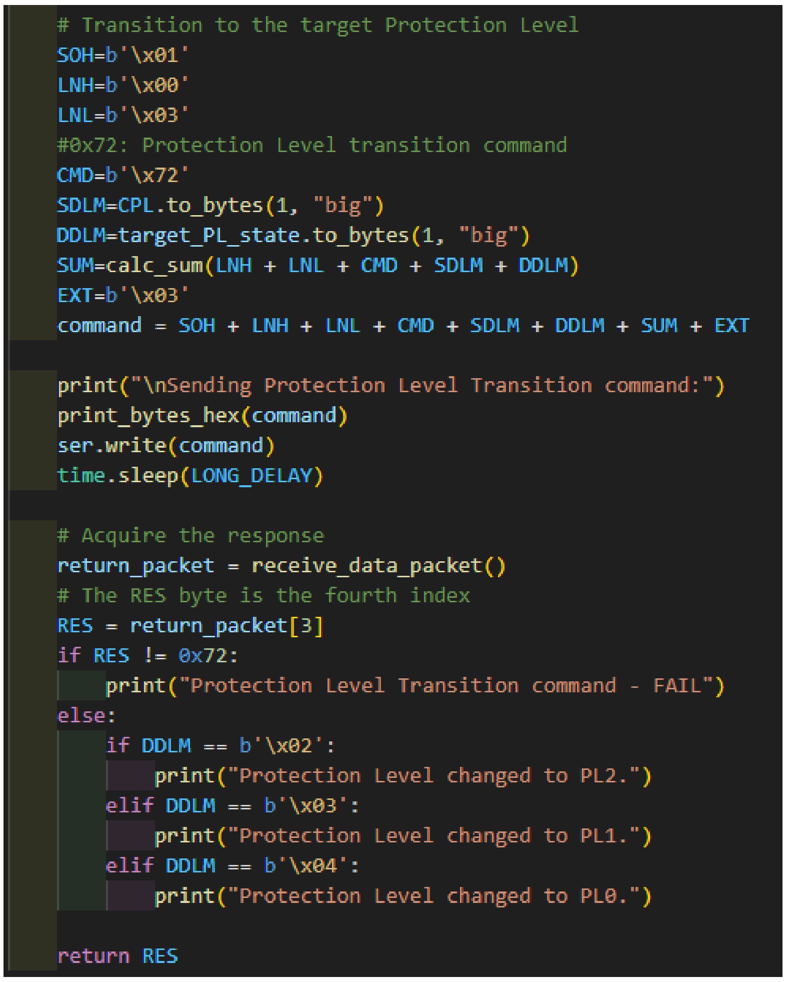
SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	0Ah
RES	(1 byte)	72h (OK)
STS	(1 byte)	00h (OK)
ST2	(4 bytes)	FFFFFFFFh (unused code)
ADR	(4 bytes)	FFFFFFFFh (unused code)
SUM	(1 byte)	8Ch
ETX	(1 byte)	03h

Figure 39. Protection Level Transition Command Packet



```python
# ==================================
# This routine demonstrates the "Protection Level Transit Command".
def command_ProtectionLevelTransition(target_PL_state):
    RES, DLM = command_DLMstateRequest()

    if RES != 0x2C:
        print("Read DLM state - FAIL")
        return RES
    elif DLM != 0x04:
        print("DLM state is not OEM, cannot proceed")
        return 0xFF

    RES, CPL = command_ProtectionLevelRequest()

    if RES != 0x73:
        print("Read Protection Level - FAIL")
        return RES

    target_PL_state = int.from_bytes(target_PL_state, "big")
    if target_PL_state < CPL:
        print("Protection Level upgrade -> Checking Authentication Level")
        RES, CAL = command_AuthenticationLevelRequest()
        if RES != 0x75:
            print("Read Authentication Level - FAIL")
            return RES
        elif CAL != 0x02:
            print("Transiting to AL2")
            RES = command_AuthenticationLevelTransition(b'\x02')
            if RES != 0x30:
                print("Authentication Level Transition - FAIL")
                return RES
```

Figure 40. Example Code for Protection Level Transition Command – part 1

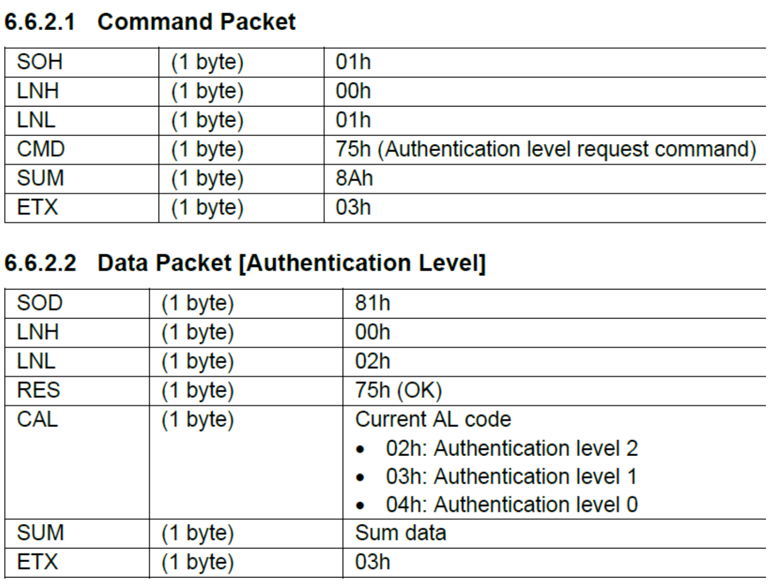


```
    # Transition to the target Protection Level
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x03'
    #0x72: Protection Level transition command
    CMD=b'\x72'
    SDLM=CPL.to_bytes(1, "big")
    DDLM=target_PL_state.to_bytes(1, "big")
    SUM=calc_sum(LNH + LNL + CMD + SDLM + DDLM)
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SDLM + DDLM + SUM + EXT

    print("\nSending Protection Level Transition command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x72:
        print("Protection Level Transition command - FAIL")
    else:
        if DDLM == b'\x02':
            print("Protection Level changed to PL2.")
        elif DDLM == b'\x03':
            print("Protection Level changed to PL1.")
        elif DDLM == b'\x04':
            print("Protection Level changed to PL0.")

    return RES
```

Figure 41. Example Code for Protection Level Transition Command – part 2

5.6.5 Authentication Level Request

The AL request command is demonstrated in the included example code. Figure 42 shows the AL request command packet format. Figure 43 shows the example code.



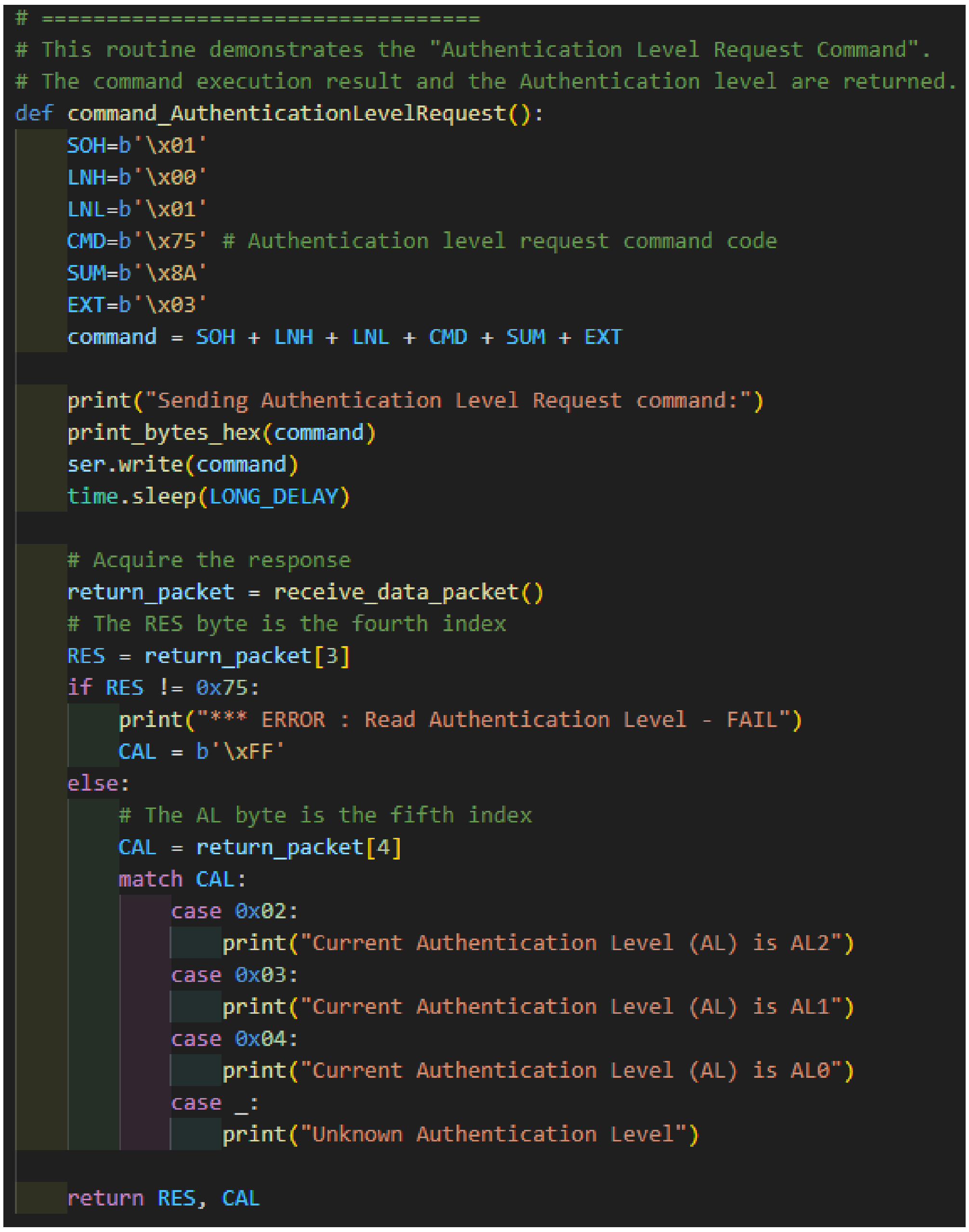
6.6.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	01h
CMD	(1 byte)	75h (Authentication level request command)
SUM	(1 byte)	8Ah
ETX	(1 byte)	03h

6.6.2.2 Data Packet [Authentication Level]

SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	02h
RES	(1 byte)	75h (OK)
CAL	(1 byte)	Current AL code • 02h: Authentication level 2 • 03h: Authentication level 1 • 04h: Authentication level 0
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 42. Authentication Level Request Command Packet



```
# ==================================
# This routine demonstrates the "Authentication Level Request Command".
# The command execution result and the Authentication level are returned.
def command_AuthenticationLevelRequest():
    SOH=b'\x01'
    LNH=b'\x00'
    LNL=b'\x01'
    CMD=b'\x75' # Authentication level request command code
    SUM=b'\x8A'
    EXT=b'\x03'
    command = SOH + LNH + LNL + CMD + SUM + EXT

    print("Sending Authentication Level Request command:")
    print_bytes_hex(command)
    ser.write(command)
    time.sleep(LONG_DELAY)

    # Acquire the response
    return_packet = receive_data_packet()
    # The RES byte is the fourth index
    RES = return_packet[3]
    if RES != 0x75:
        print("*** ERROR : Read Authentication Level - FAIL")
        CAL = b'\xFF'
    else:
        # The AL byte is the fifth index
        CAL = return_packet[4]
        match CAL:
            case 0x02:
                print("Current Authentication Level (AL) is AL2")
            case 0x03:
                print("Current Authentication Level (AL) is AL1")
            case 0x04:
                print("Current Authentication Level (AL) is AL0")
            case _:
                print("Unknown Authentication Level")

    return RES, CAL
```

Figure 43. Authentication Request Command Example Code

5.6.6 Authentication Level Transition

This section covers the AL transition. Authenticated transitions are not generally required in production programming tools.

The recommended flow when performing AL transition is described in Figure 44. The current DLM state and AL are necessary for the AL transition command and should be acquired first.

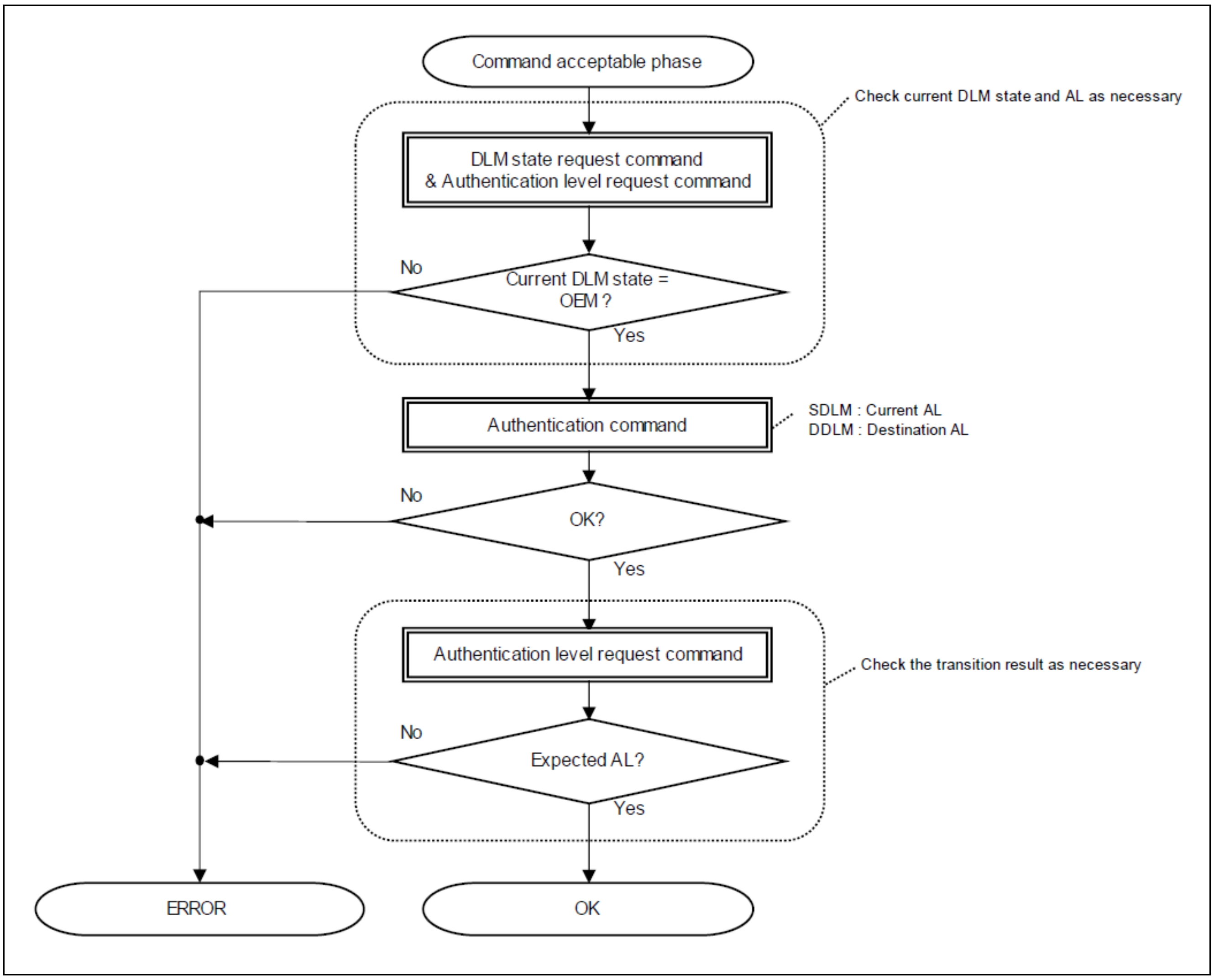
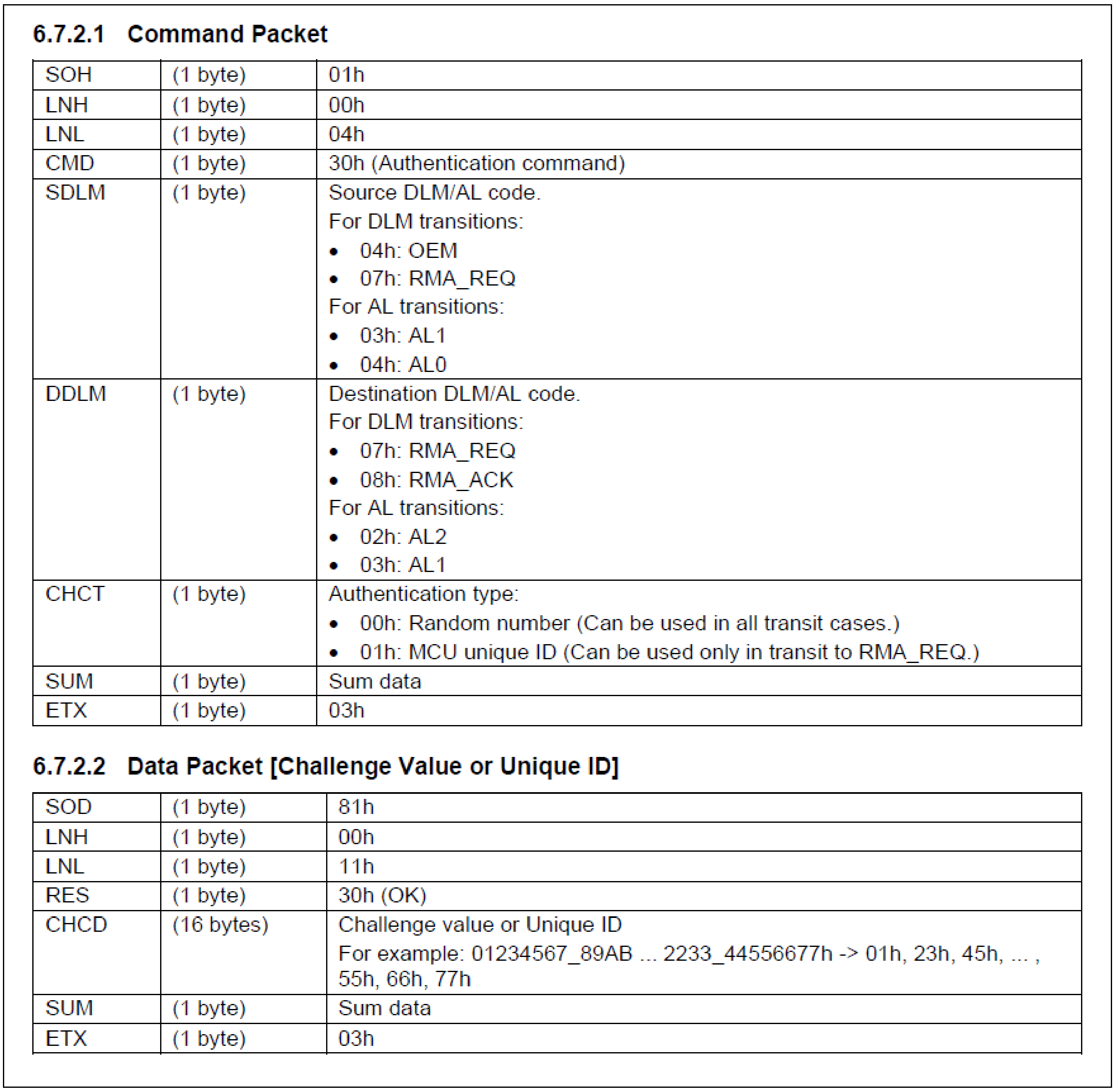

Command acceptable phase
Check current DLM state and AL as necessary
DLM state request command & Authentication level request command
No
Current DLM state = OEM ?
Yes
Authentication command
SDLM : Current AL
DDLM : Destination AL
No
OK?
Yes
Authentication level request command
Check the transition result as necessary
No
Expected AL?
Yes
ERROR
OK

Figure 44. Recommended Flow for Performing Authentication Level Transition



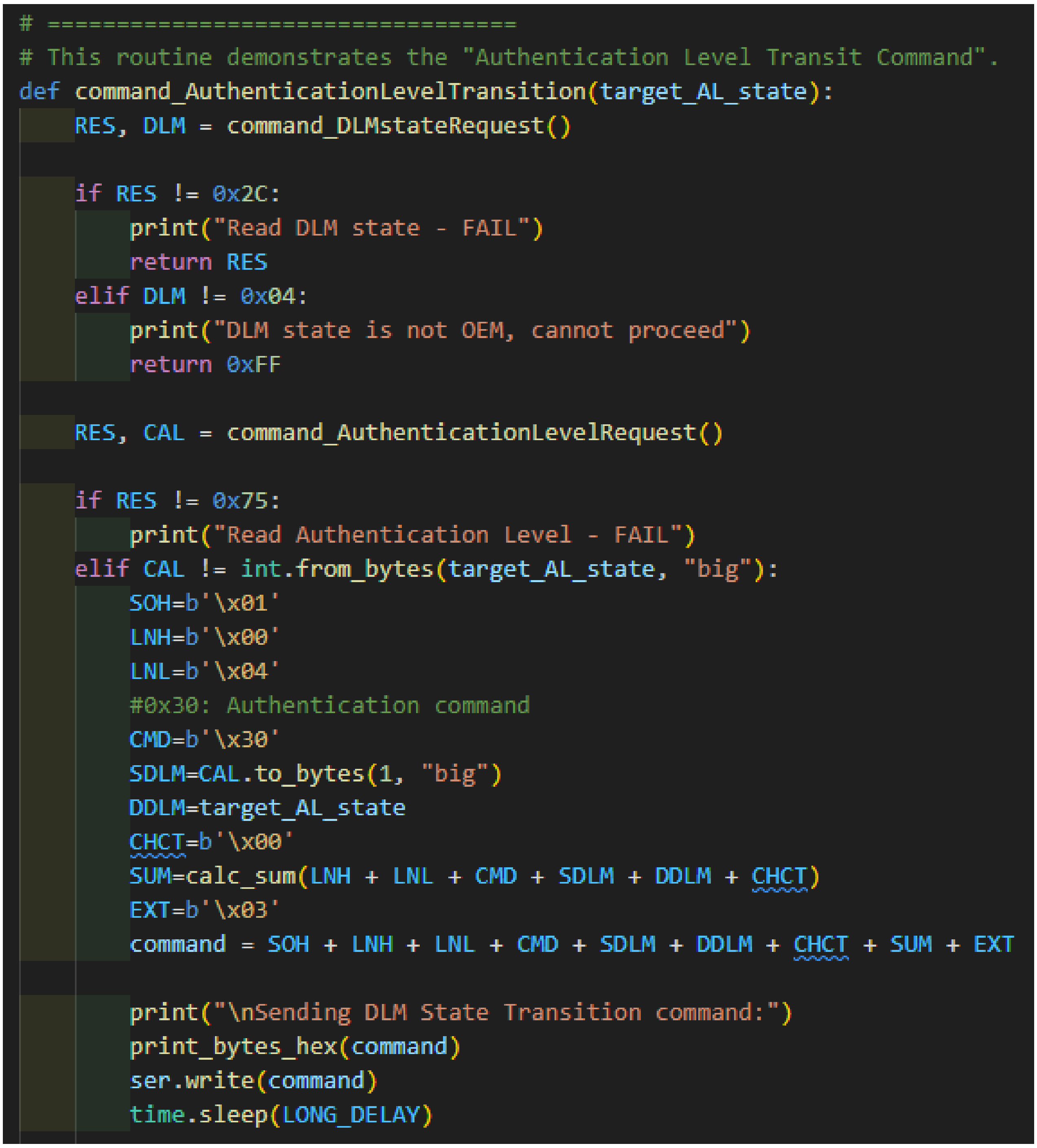
6.7.2.1 Command Packet

SOH	(1 byte)	01h
LNH	(1 byte)	00h
LNL	(1 byte)	04h
CMD	(1 byte)	30h (Authentication command)
SDLM	(1 byte)	Source DLM/AL code. For DLM transitions: • 04h: OEM • 07h: RMA_REQ For AL transitions: • 03h: AL1 • 04h: AL0
DDLM	(1 byte)	Destination DLM/AL code. For DLM transitions: • 07h: RMA_REQ • 08h: RMA_ACK For AL transitions: • 02h: AL2 • 03h: AL1
CHCT	(1 byte)	Authentication type: • 00h: Random number (Can be used in all transit cases.) • 01h: MCU unique ID (Can be used only in transit to RMA_REQ.)
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

6.7.2.2 Data Packet [Challenge Value or Unique ID]

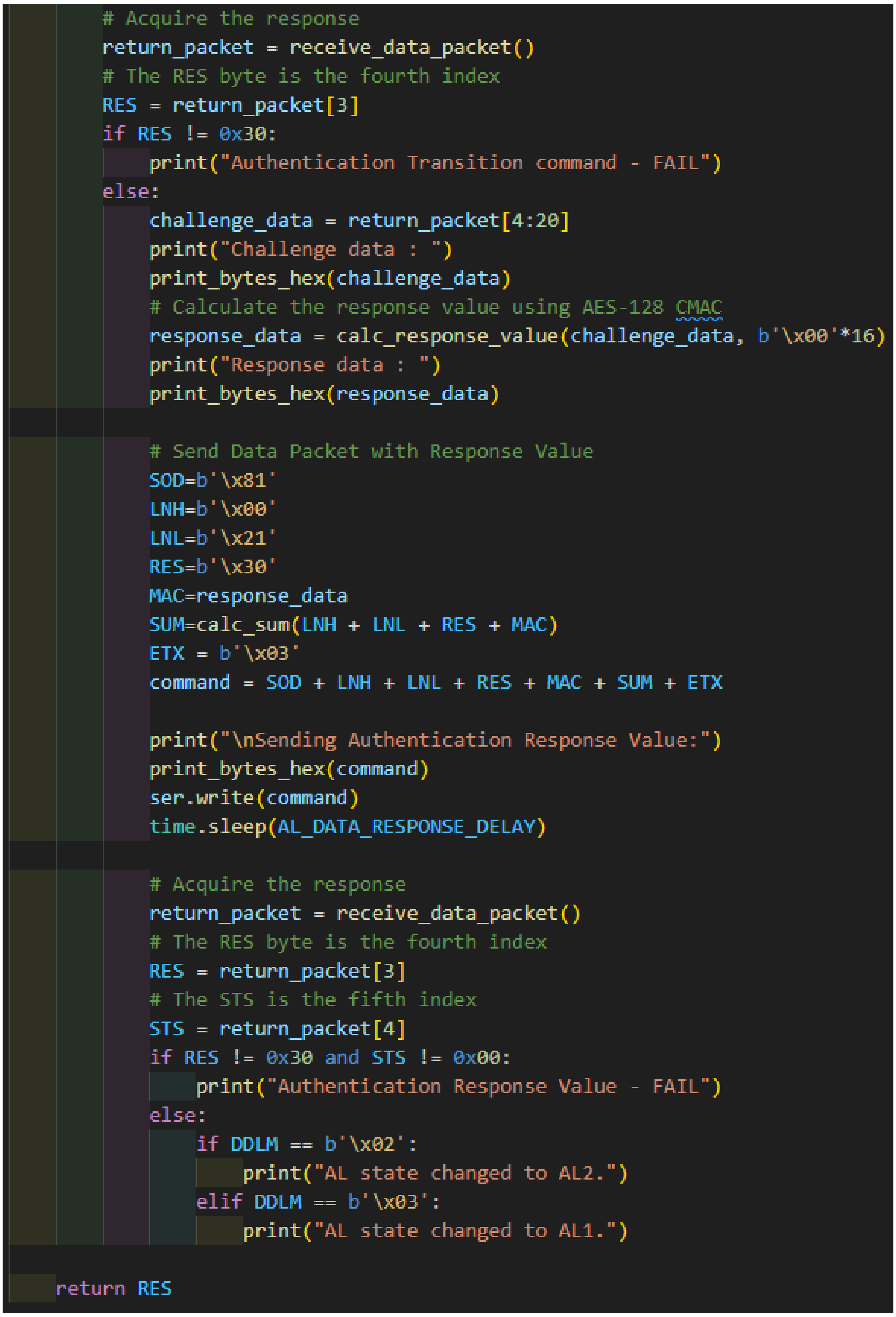
SOD	(1 byte)	81h
LNH	(1 byte)	00h
LNL	(1 byte)	11h
RES	(1 byte)	30h (OK)
CHCD	(16 bytes)	Challenge value or Unique ID For example: 01234567_89AB ... 2233_44556677h -> 01h, 23h, 45h, ... , 55h, 66h, 77h
SUM	(1 byte)	Sum data
ETX	(1 byte)	03h

Figure 45. Authentication Level Transition Command Packet



```python
# ==================================
# This routine demonstrates the "Authentication Level Transit Command".
def command_AuthenticationLevelTransition(target_AL_state):
    RES, DLM = command_DLMstateRequest()

    if RES != 0x2C:
        print("Read DLM state - FAIL")
        return RES
    elif DLM != 0x04:
        print("DLM state is not OEM, cannot proceed")
        return 0xFF

    RES, CAL = command_AuthenticationLevelRequest()

    if RES != 0x75:
        print("Read Authentication Level - FAIL")
    elif CAL != int.from_bytes(target_AL_state, "big"):
        SOH=b'\x01'
        LNH=b'\x00'
        LNL=b'\x04'
        #0x30: Authentication command
        CMD=b'\x30'
        SDLM=CAL.to_bytes(1, "big")
        DDLM=target_AL_state
        CHCT=b'\x00'
        SUM=calc_sum(LNH + LNL + CMD + SDLM + DDLM + CHCT)
        EXT=b'\x03'
        command = SOH + LNH + LNL + CMD + SDLM + DDLM + CHCT + SUM + EXT

        print("\nSending DLM State Transition command:")
        print_bytes_hex(command)
        ser.write(command)
        time.sleep(LONG_DELAY)
```

Figure 46. Example Code for Authentication Level Transition Command – Part 1



```
        # Acquire the response
        return_packet = receive_data_packet()
        # The RES byte is the fourth index
        RES = return_packet[3]
        if RES != 0x30:
            print("Authentication Transition command - FAIL")
        else:
            challenge_data = return_packet[4:20]
            print("Challenge data : ")
            print_bytes_hex(challenge_data)
            # Calculate the response value using AES-128 CMAC
            response_data = calc_response_value(challenge_data, b'\x00'*16)
            print("Response data : ")
            print_bytes_hex(response_data)

            # Send Data Packet with Response Value
            SOD=b'\x81'
            LNH=b'\x00'
            LNL=b'\x21'
            RES=b'\x30'
            MAC=response_data
            SUM=calc_sum(LNH + LNL + RES + MAC)
            ETX = b'\x03'
            command = SOD + LNH + LNL + RES + MAC + SUM + ETX

            print("\nSending Authentication Response Value:")
            print_bytes_hex(command)
            ser.write(command)
            time.sleep(AL_DATA_RESPONSE_DELAY)

            # Acquire the response
            return_packet = receive_data_packet()
            # The RES byte is the fourth index
            RES = return_packet[3]
            # The STS is the fifth index
            STS = return_packet[4]
            if RES != 0x30 and STS != 0x00:
                print("Authentication Response Value - FAIL")
            else:
                if DDLM == b'\x02':
                    print("AL state changed to AL2.")
                elif DDLM == b'\x03':
                    print("AL state changed to AL1.")

    return RES
```

Figure 47. Example Code for Authentication Level Transition Command – Part 2

6. Running the Python Example Code

Many of the typical boot mode commands are implemented in the included example code, which can be used as a starting point for writing a complete production programming tool. The code snippets provided in earlier sections are taken from the examples.

6.1 Set up the Python Environment

To execute the demonstration code supplied along with this application note, it is necessary to install the following software packages first. Follow the links below to acquire and install the software needed:

- Install Python:
  - Python 3.10 or later (https://www.python.org/downloads/)
- Install the pySerial package
  - pySerial 3.5 (https://pyserial.readthedocs.io/en/latest/pyserial.html#installation)
- Install PyCryptodome package
  - PyCryptodome (Installation — PyCryptodome 3.4.6 documentation)

6.2 Setting Up the Hardware

The demonstration code works with all the MCU groups covered in this application project. The example shown here uses an RA8M1/RA8P1 MCU fitted to an EK-RA8M1/EK-RA8P1 evaluation board.

To cause the RA8M1 MCU to enter boot mode on reset, first ensure that a jumper has been placed on the MD ("BOOT MODE") jumper, in this case J16, as shown in Figure 48.

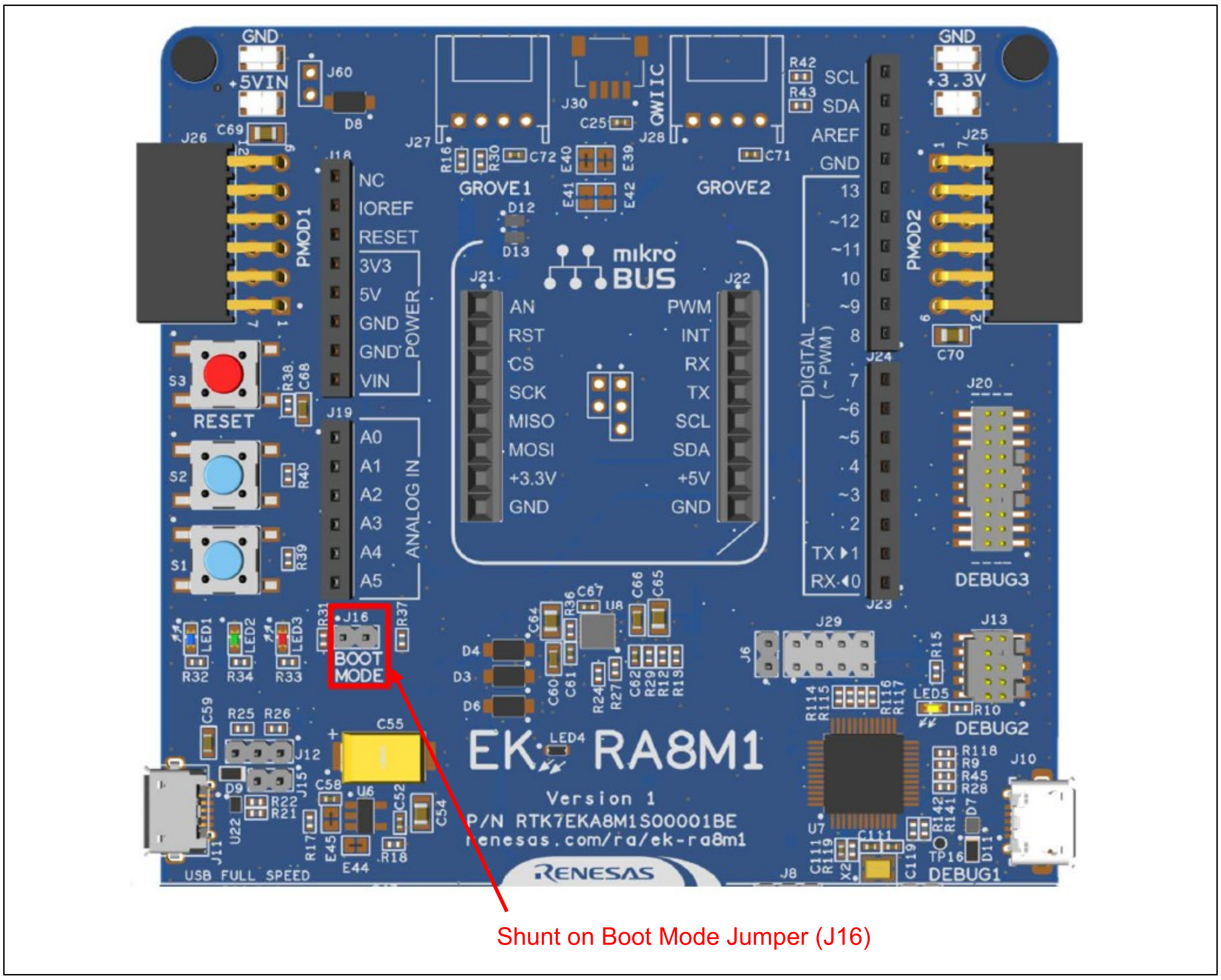


Figure 48. Shunt the MD Pin Jumper on EK-RA8M1

To cause the RA8P1 MCU to enter boot mode on reset, first ensure that a jumper has been placed on the MD (“BOOT MODE”) jumper, in this case J16 pins 1-2, as shown in Figure 49.

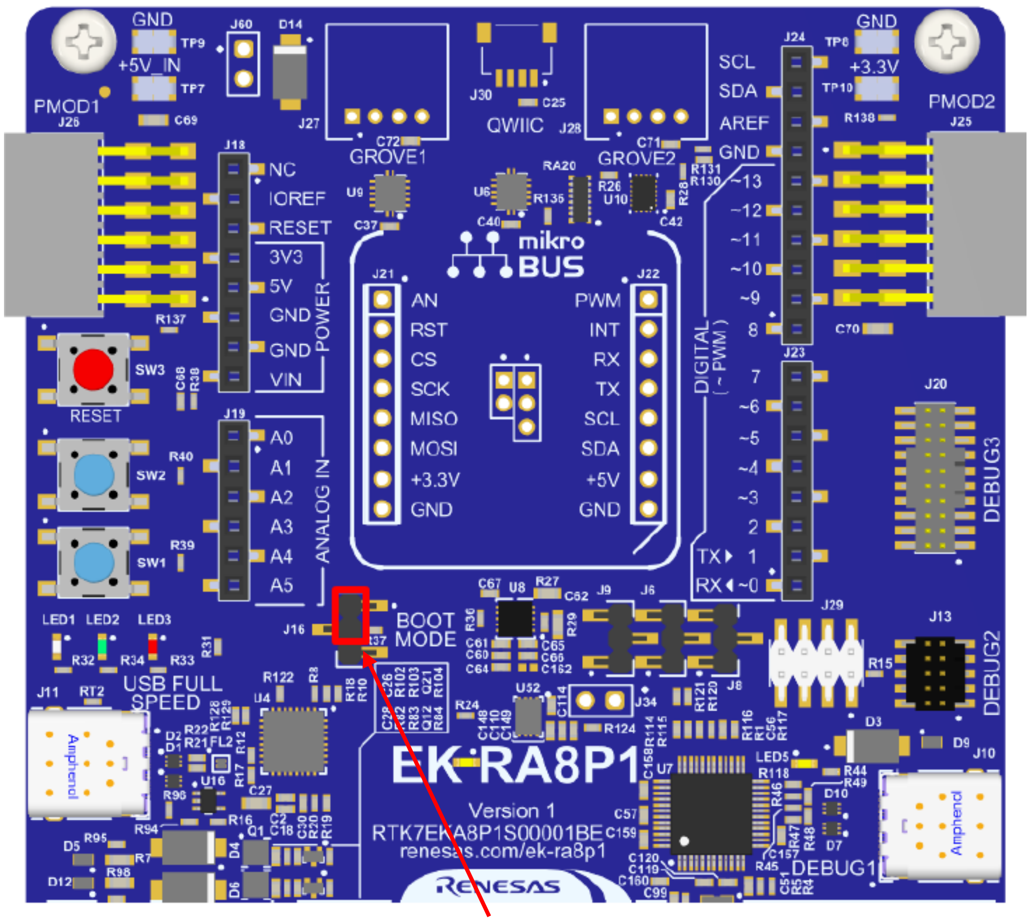


Figure 49. Shunt the MD Pin Jumper on EK-RA8P1

Next, decide whether the serial or USB interface will be used for boot mode communication.

If the USB interface is used:

- Using a USB micro to B cable, connect J11 (USB FS) from the EK-RA8M1/EK-RA8P1 to the development PC to provide USB Device connection.
- See Table 8 for more general details on the USB connection.

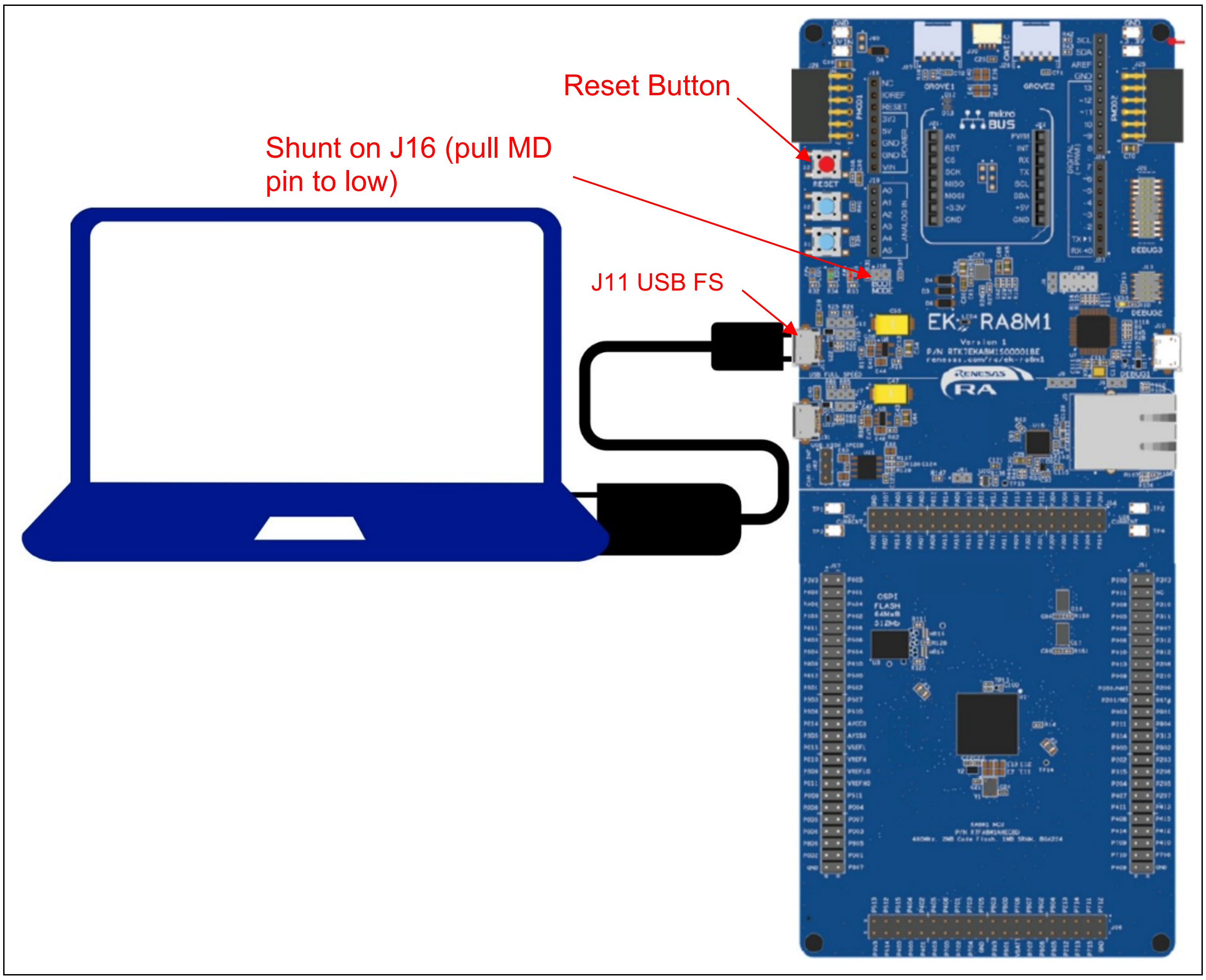


Figure 50. Hardware Setup using USB Full Speed Port

If the serial interface is used:

- Connect the four pins in Table 14 on the UART to USB converter to the EK-RA8M1 and connect the other end of the converter to the PC's USB port. Note that there may be variations on the voltage output from the converter cable. For the FTDI cable demonstrated in Figure 51, the voltage supply to the MCU is 5V. Another converter may output 3.3V, so the production programming tool should take this into consideration when setting up the hardware.
- See Table 7 for more details of the serial interface.

Table 14. Connection through the UART Interface

UART to USB Converter	EK-RA8M1	EK-RA8P1
RX	J51: Pin 20 (MCU P209 (TXD9))	J2: Pin 21 (MCU P209 (TXD9))
TX	J51: Pin 16 (MCU P208 (RXD9))	J2: Pin 37 (MCU P208 (RXD9))
+5V (FTDI cable power output voltage. Check the voltage output on the converter used.)	J51: Pin 01 (If +3.3V is provided from the converter, then connect to Pin 02 of J51). If the production programming board has stable power supply, then this pin connection is not needed.	J1: Pin 08 (If +3.3V is provided from the converter, then connect to Pin 01 of J2). If the production programming board has stable power supply, then this pin connection is not needed.
GND	J51: Pin 50 (MCU Ground)	J2: Pin 39 (MCU Ground)

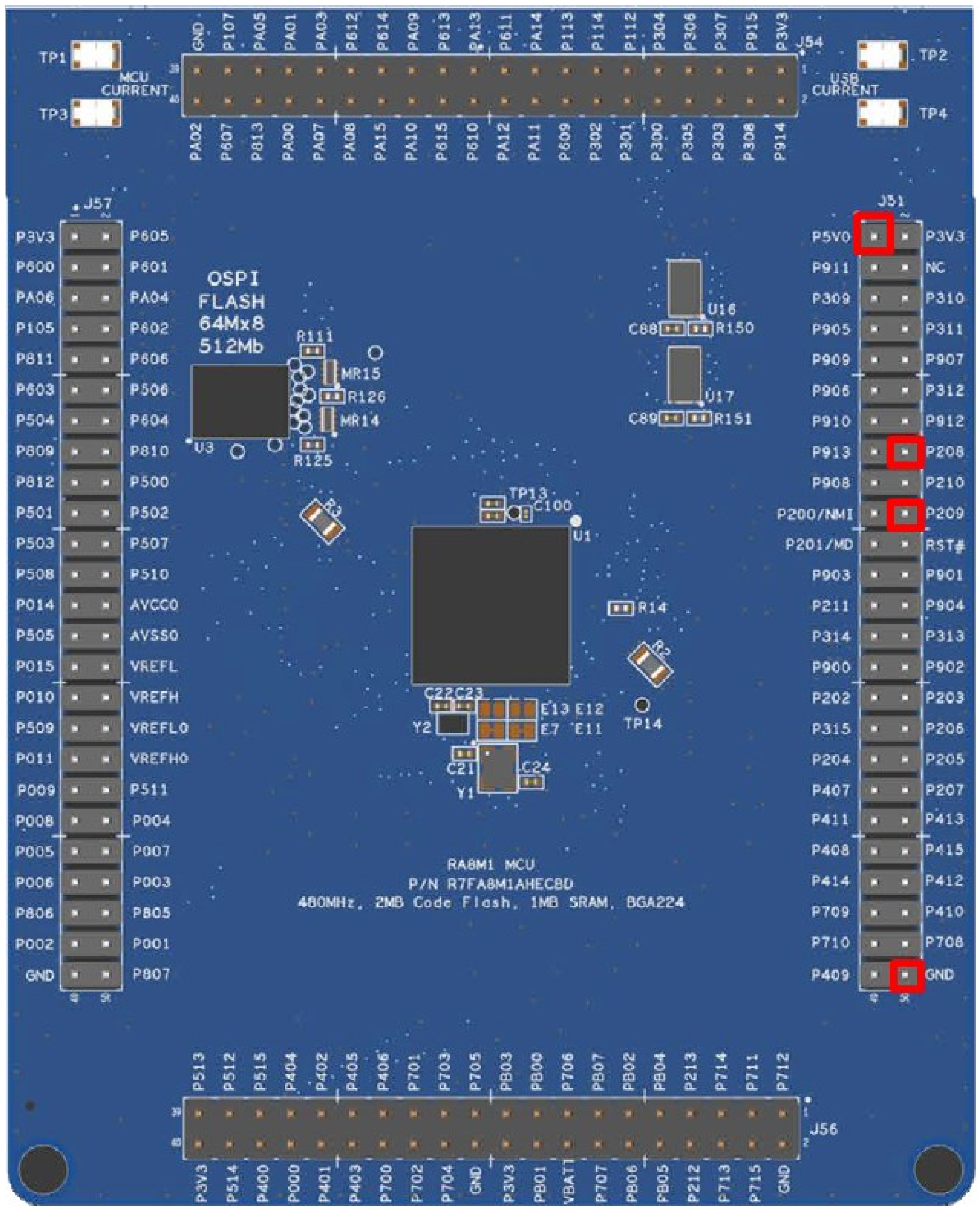


Figure 51. Hardware Setup using UART to USB Converter for EK-RA8M1

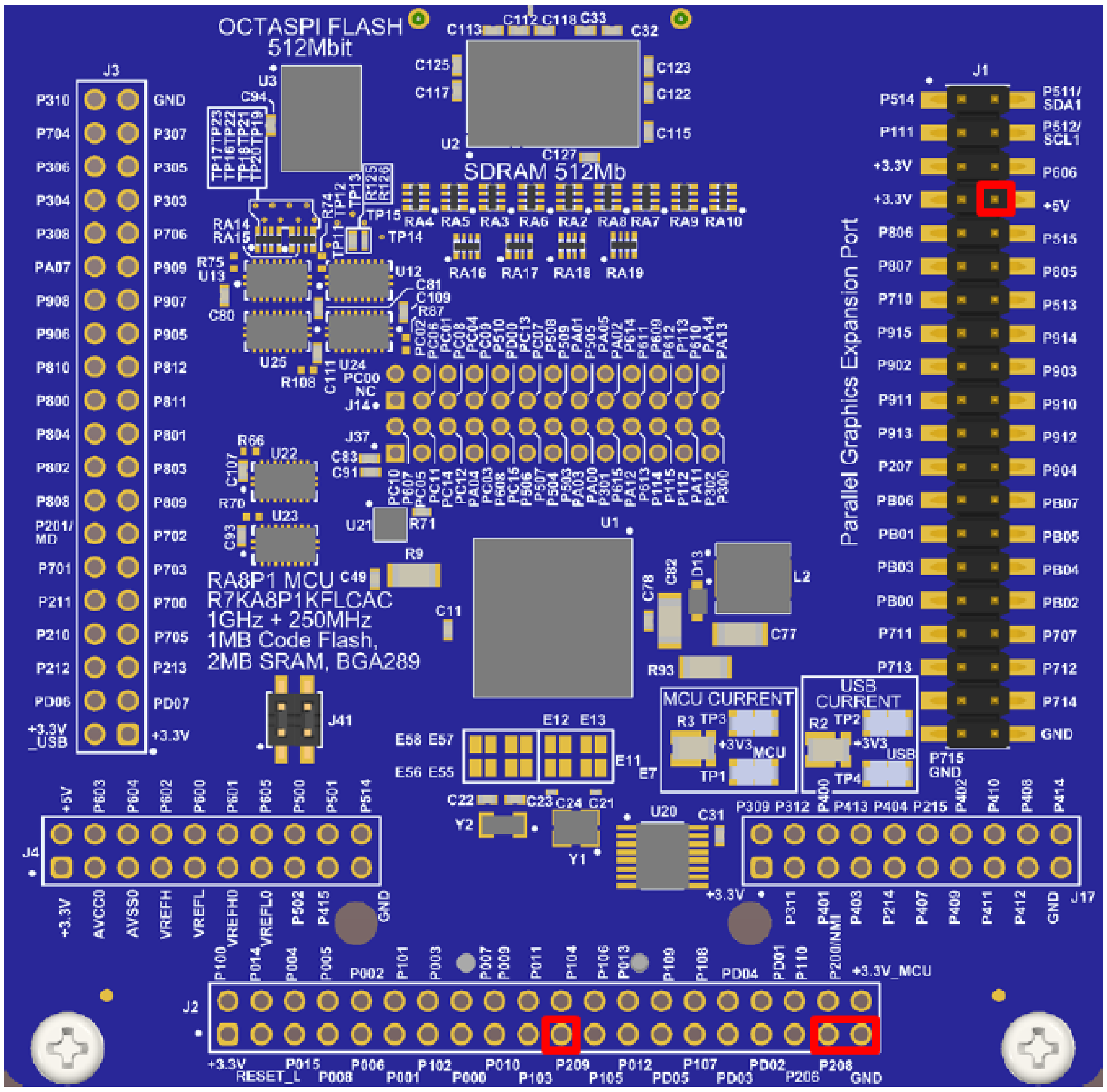
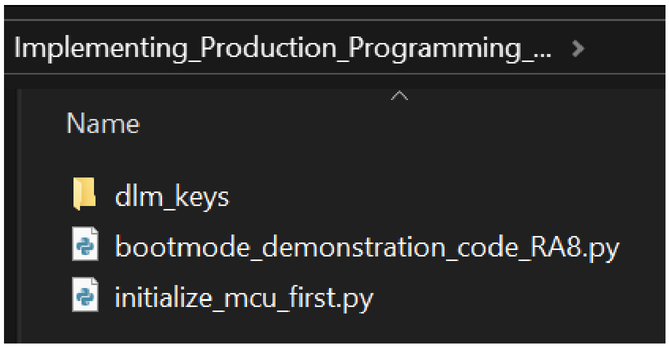


Figure 52. Hardware Setup using UART to USB Converter for EK-RA8P1

Once the physical communication mechanism is connected, whether serial or USB, ensure the board is powered up and then press the Reset button to enter boot mode.

6.3 Running the First Demo Code

Unzip `production_programming_demo_cm85_dlm.zip` to reveal two Python files and the `\dlm_keys` folder which holds four DLM AL keys: two for RA8M1, two for RA8P1 which can be injected into the MCU.



Implementing_Production_Programming_...

Name

dlm_keys
bootmode_demonstration_code_RA8.py
initialize_mcu_first.py

Figure 53. Python Demo Code and Sample DLM Keys

The first of the demonstration examples, `initialize_mcu_first.py`, is intended to ensure that the MCU is correctly configured for production programming, running an Initialize command if required.

The full functionality of this code is described in Figure 54:

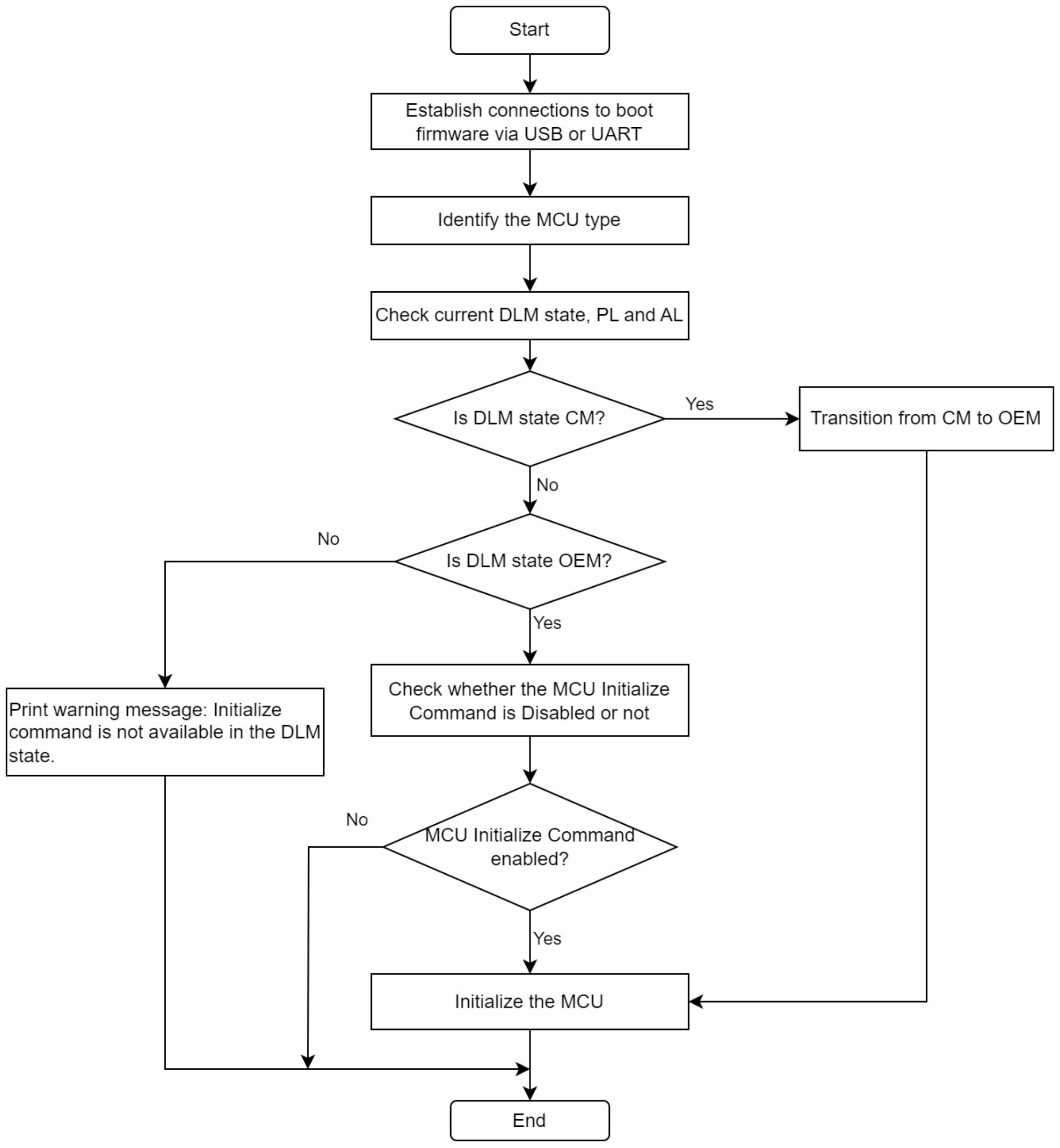
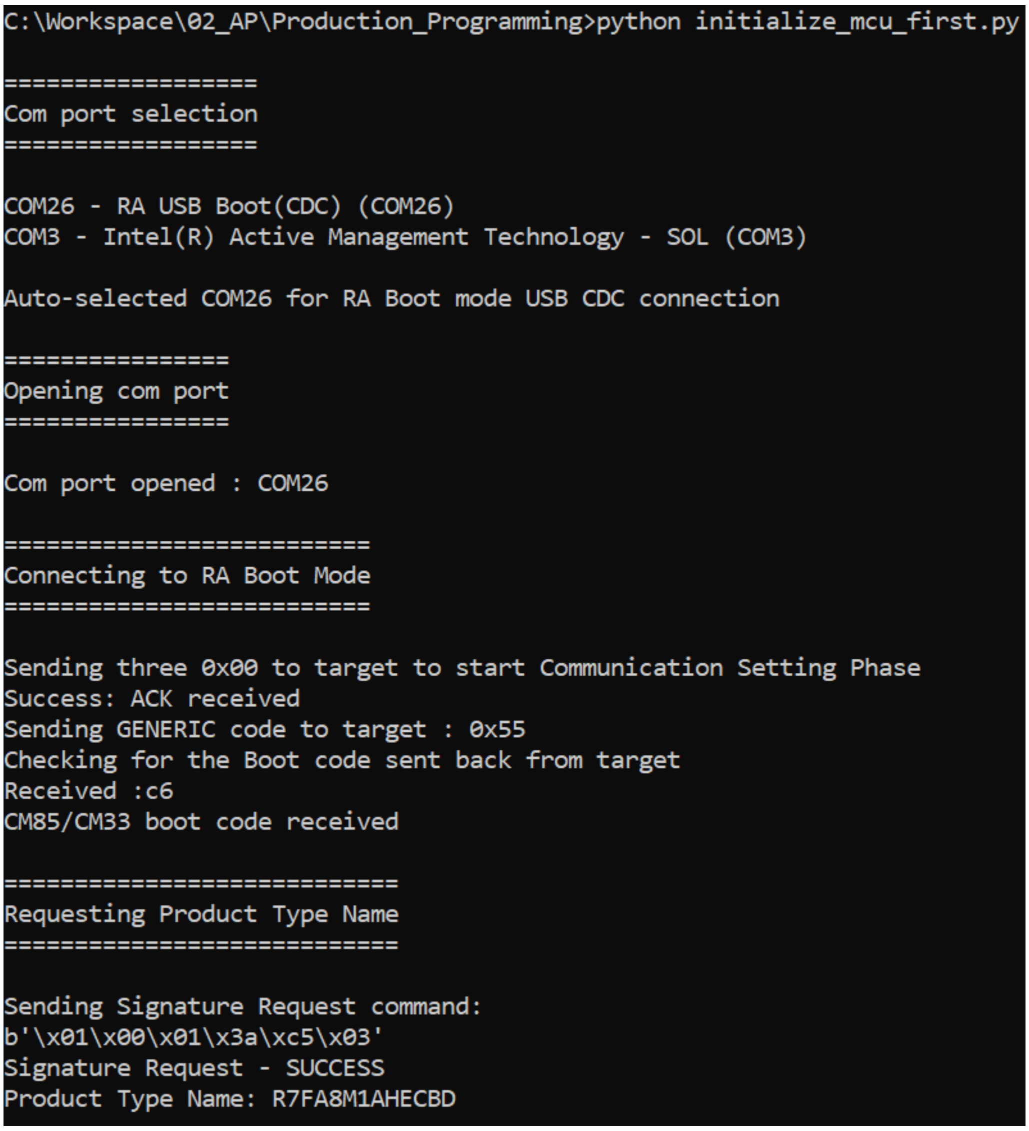

Start
Establish connections to boot firmware via USB or UART
Identify the MCU type
Check current DLM state, PL and AL
Is DLM state CM?
Yes
Transition from CM to OEM
No
Is DLM state OEM?
No
Yes
Print warning message: Initialize command is not available in the DLM state.
Check whether the MCU Initialize Command is Disabled or not
MCU Initialize Command enabled?
No
Yes
Initialize the MCU
End

Figure 54. Operational Flow of the First Demo Code

To execute the example, open a command line prompt and navigate to the folder where the Python example code is stored. Then enter:

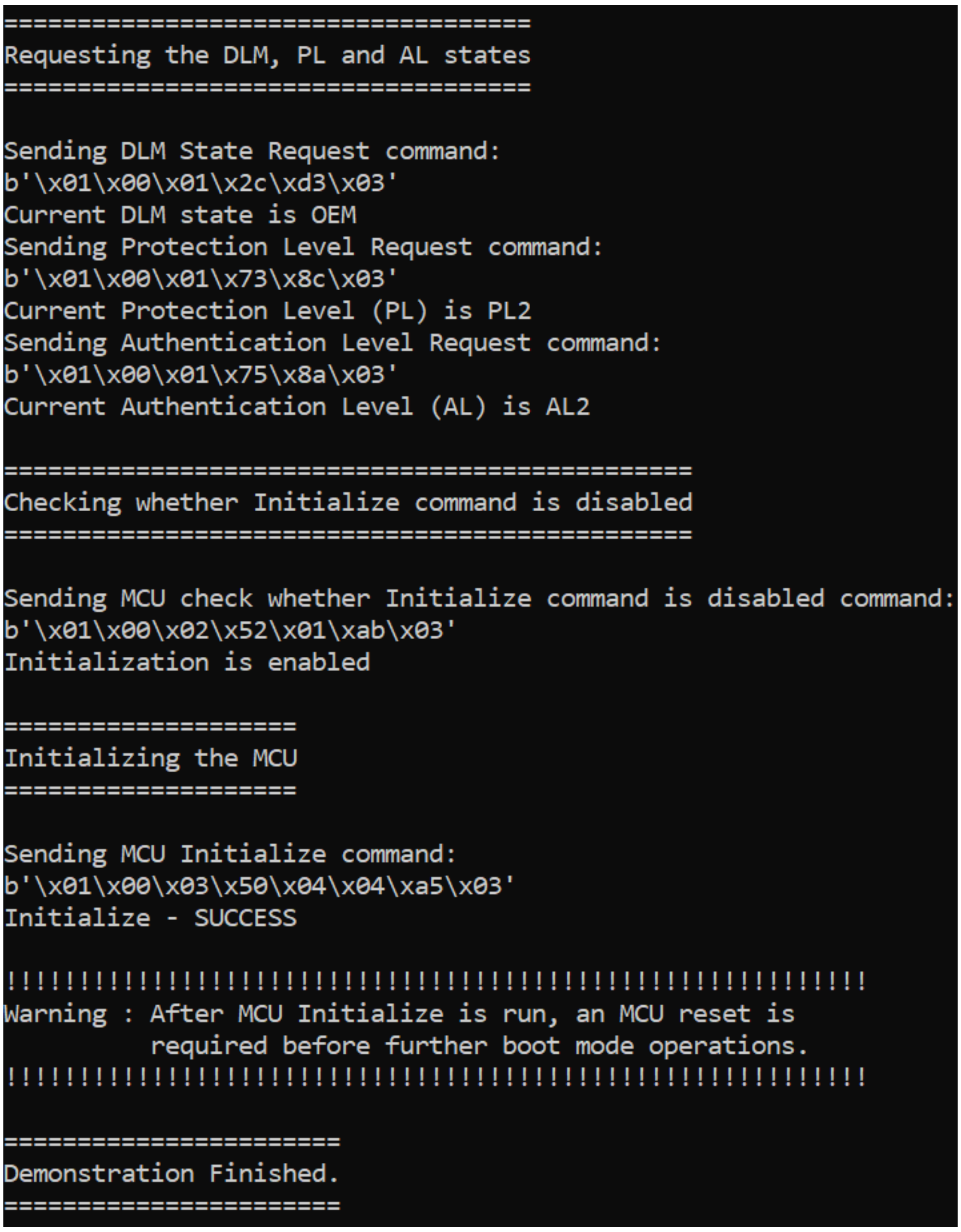
```
python initialize_mcu_first.py
```

Figure 55 and Figure 56 shows sample output from running the demonstration with a USB connection to the board.



```
C:\Workspace\02_AP\Production_Programming>python initialize_mcu_first.py

==================
Com port selection
==================

COM26 - RA USB Boot(CDC) (COM26)
COM3 - Intel(R) Active Management Technology - SOL (COM3)

Auto-selected COM26 for RA Boot mode USB CDC connection

================
Opening com port
================

Com port opened : COM26

==========================
Connecting to RA Boot Mode
==========================

Sending three 0x00 to target to start Communication Setting Phase
Success: ACK received
Sending GENERIC code to target : 0x55
Checking for the Boot code sent back from target
Received :c6
CM85/CM33 boot code received

============================
Requesting Product Type Name
============================

Sending Signature Request command:
b'\x01\x00\x01\x3a\xc5\x03'
Signature Request - SUCCESS
Product Type Name: R7FA8M1AHECBD
```

Figure 55. Demonstration with USB Connection – Part 1



```
====================================
Requesting the DLM, PL and AL states
====================================

Sending DLM State Request command:
b'\x01\x00\x01\x2c\xd3\x03'
Current DLM state is OEM
Sending Protection Level Request command:
b'\x01\x00\x01\x73\x8c\x03'
Current Protection Level (PL) is PL2
Sending Authentication Level Request command:
b'\x01\x00\x01\x75\x8a\x03'
Current Authentication Level (AL) is AL2

===============================================
Checking whether Initialize command is disabled
===============================================

Sending MCU check whether Initialize command is disabled command:
b'\x01\x00\x02\x52\x01\xab\x03'
Initialization is enabled

====================
Initializing the MCU
====================

Sending MCU Initialize command:
b'\x01\x00\x03\x50\x04\x04\xa5\x03'
Initialize - SUCCESS

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Warning : After MCU Initialize is run, an MCU reset is
          required before further boot mode operations.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

=======================
Demonstration Finished.
=======================
```

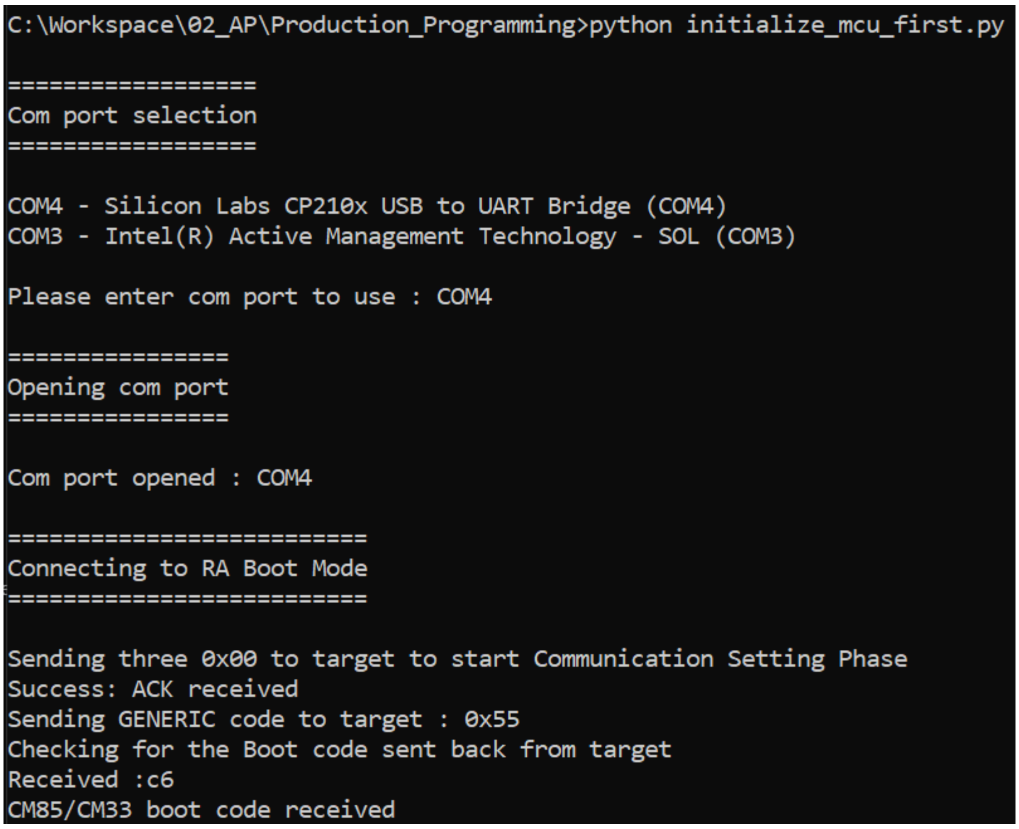
Figure 56. Demonstration with USB Connection – Part 2

Some Renesas evaluation boards might be distributed in the CM state. In this case, the demonstration code will transition the DLM state from CM to OEM, then the Initialize command will be executed. In this case, there is no need to check whether the Initialize command is disabled or not as the Initialize command cannot be issued in the CM state and transitioning from CM to OEM is a one-way process.

After the demonstration example finishes running, follow the warning in the output to reset the board before running the second demonstration example.

Note that with the USB connection, the code has automatically identified the RA boot mode USB CDC interface and automatically connected to it.

With a serial connection, it is necessary to enter the COM port to use manually. This is shown in partial output in Figure 56.



```
C:\Workspace\02_AP\Production_Programming>python initialize_mcu_first.py

==================
Com port selection
==================

COM4 - Silicon Labs CP210x USB to UART Bridge (COM4)
COM3 - Intel(R) Active Management Technology - SOL (COM3)

Please enter com port to use : COM4

================
Opening com port
================

Com port opened : COM4

==========================
Connecting to RA Boot Mode
==========================

Sending three 0x00 to target to start Communication Setting Phase
Success: ACK received
Sending GENERIC code to target : 0x55
Checking for the Boot code sent back from target
Received :c6
CM85/CM33 boot code received
```

Figure 57.   Demonstration with Serial Connection

6.4   Running the Second Demonstration Code

The second of the demonstration examples, `bootmode_demonstration_code_RA8.py`, is intended to show the main steps likely to be required for a real production programming sequence (except for programming an application image into flash).

The full functionality of this code is described in Figure 58.

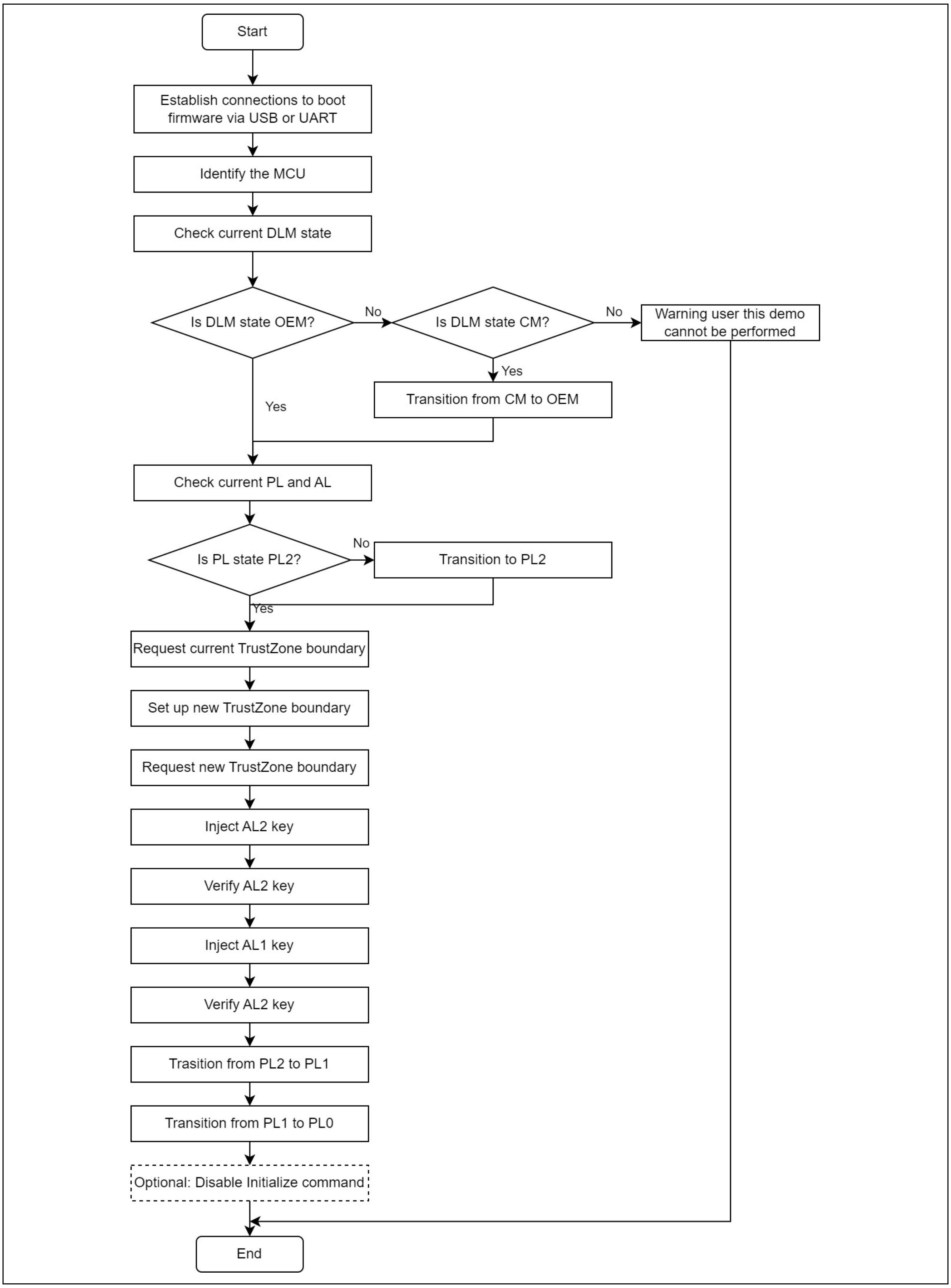

Start
Establish connections to boot firmware via USB or UART
Identify the MCU
Check current DLM state
Is DLM state OEM?
No
Is DLM state CM?
No
Warning user this demo cannot be performed
Yes
Transition from CM to OEM
Yes
Check current PL and AL
Is PL state PL2?
No
Transition to PL2
Yes
Request current TrustZone boundary
Set up new TrustZone boundary
Request new TrustZone boundary
Inject AL2 key
Verify AL2 key
Inject AL1 key
Verify AL2 key
Trasition from PL2 to PL1
Transition from PL1 to PL0
Optional: Disable Initialize command
End

Figure 58. Operational Flow of the Second Demonstration Code

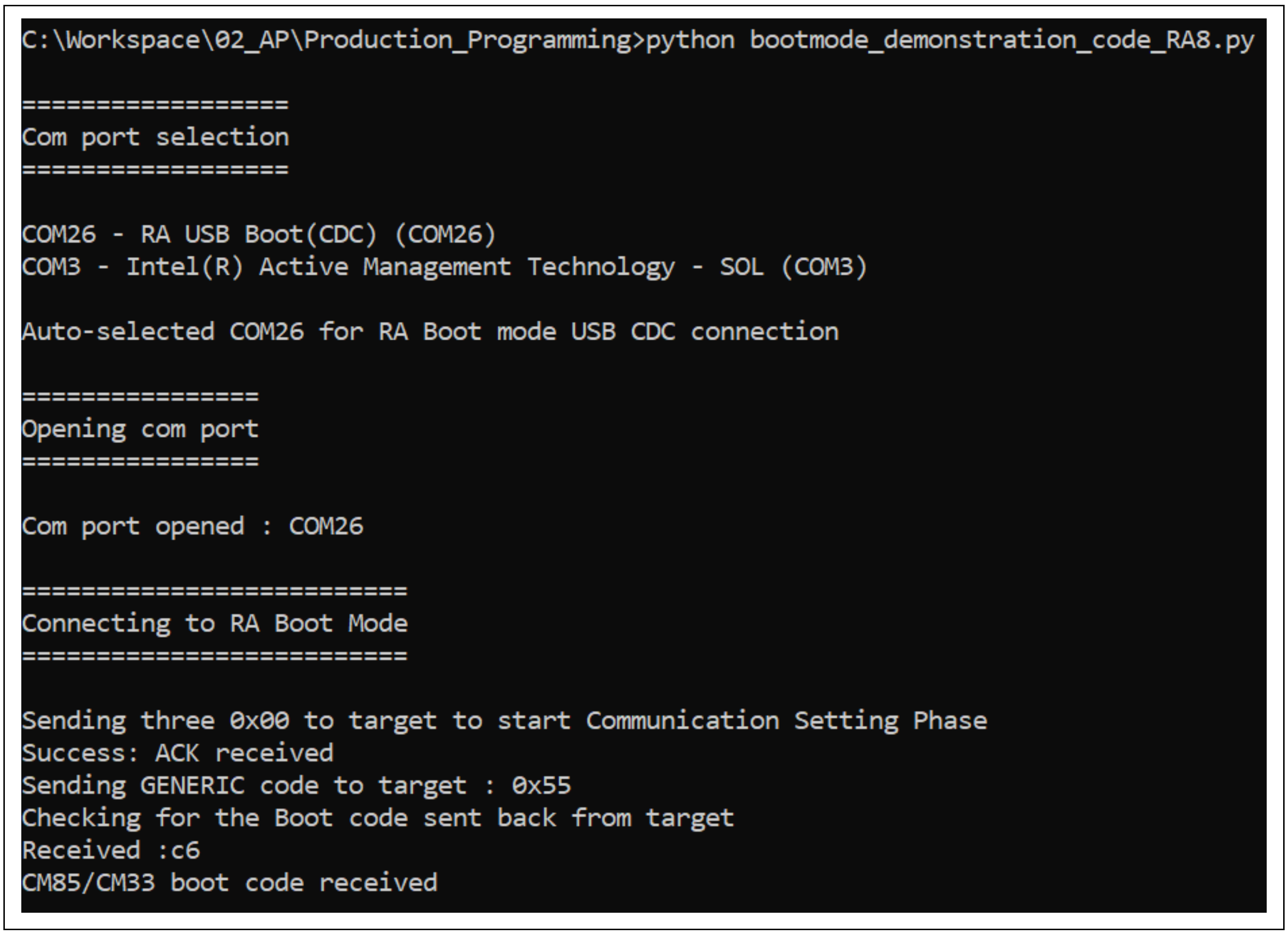
To execute the example, ensure that you have reset the board, then enter the following command in the previously opened command prompt:

```
python bootmode_demonstration_code_RA8.py
```

Below is sample output from running the demonstration with a USB connection to the board.

Establishing the Connection (USB)

6.4.1 Establishing the Connection (USB)

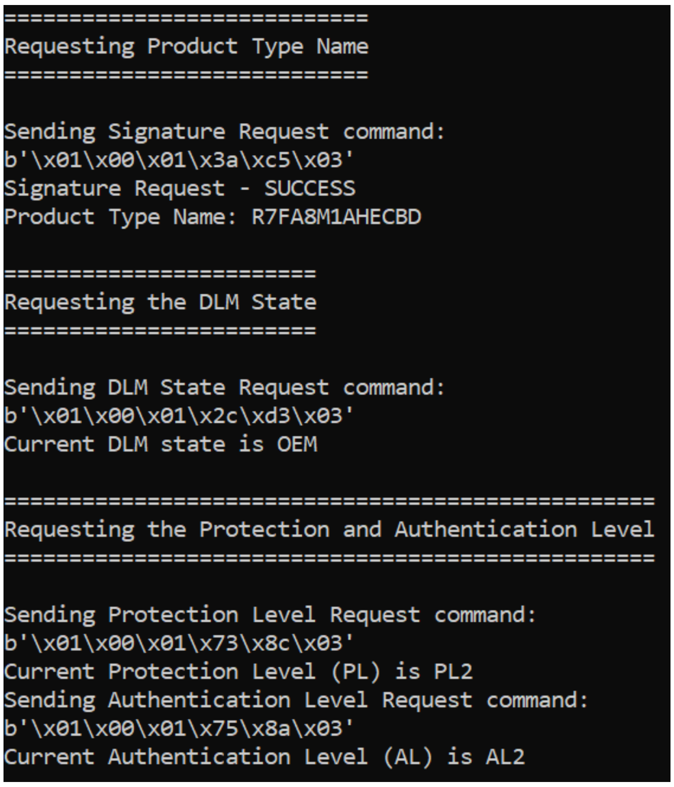


```
C:\Workspace\02_AP\Production_Programming>python bootmode_demonstration_code_RA8.py

==================
Com port selection
==================

COM26 - RA USB Boot(CDC) (COM26)
COM3 - Intel(R) Active Management Technology - SOL (COM3)

Auto-selected COM26 for RA Boot mode USB CDC connection

================
Opening com port
================

Com port opened : COM26

==========================
Connecting to RA Boot Mode
==========================

Sending three 0x00 to target to start Communication Setting Phase
Success: ACK received
Sending GENERIC code to target : 0x55
Checking for the Boot code sent back from target
Received :c6
CM85/CM33 boot code received
```

Figure 59. Establishing the Connection USB

If a serial connection is used, it will be necessary to enter the COM port manually, as shown in Figure 57.

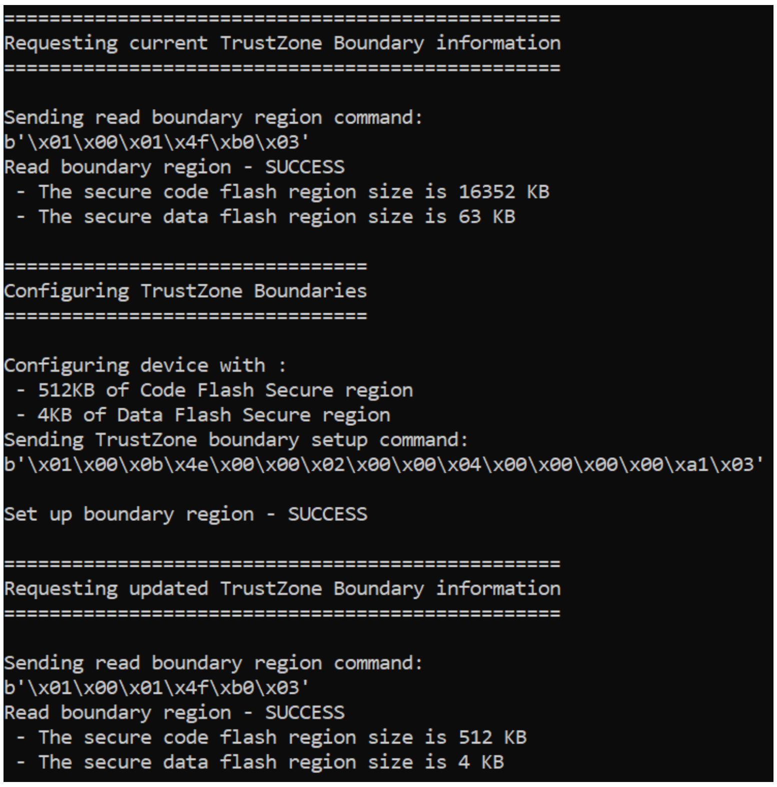
6.4.2 Checking Product Type Name, Current DLM State, Protection Level and Authentication Level



```
============================
Requesting Product Type Name
============================

Sending Signature Request command:
b'\x01\x00\x01\x3a\xc5\x03'
Signature Request - SUCCESS
Product Type Name: R7FA8M1AHECBD

========================
Requesting the DLM State
========================

Sending DLM State Request command:
b'\x01\x00\x01\x2c\xd3\x03'
Current DLM state is OEM

==================================================
Requesting the Protection and Authentication Level
==================================================

Sending Protection Level Request command:
b'\x01\x00\x01\x73\x8c\x03'
Current Protection Level (PL) is PL2
Sending Authentication Level Request command:
b'\x01\x00\x01\x75\x8a\x03'
Current Authentication Level (AL) is AL2
```

Figure 60. Checking Product Type Name, Current DLM State, PL and AL

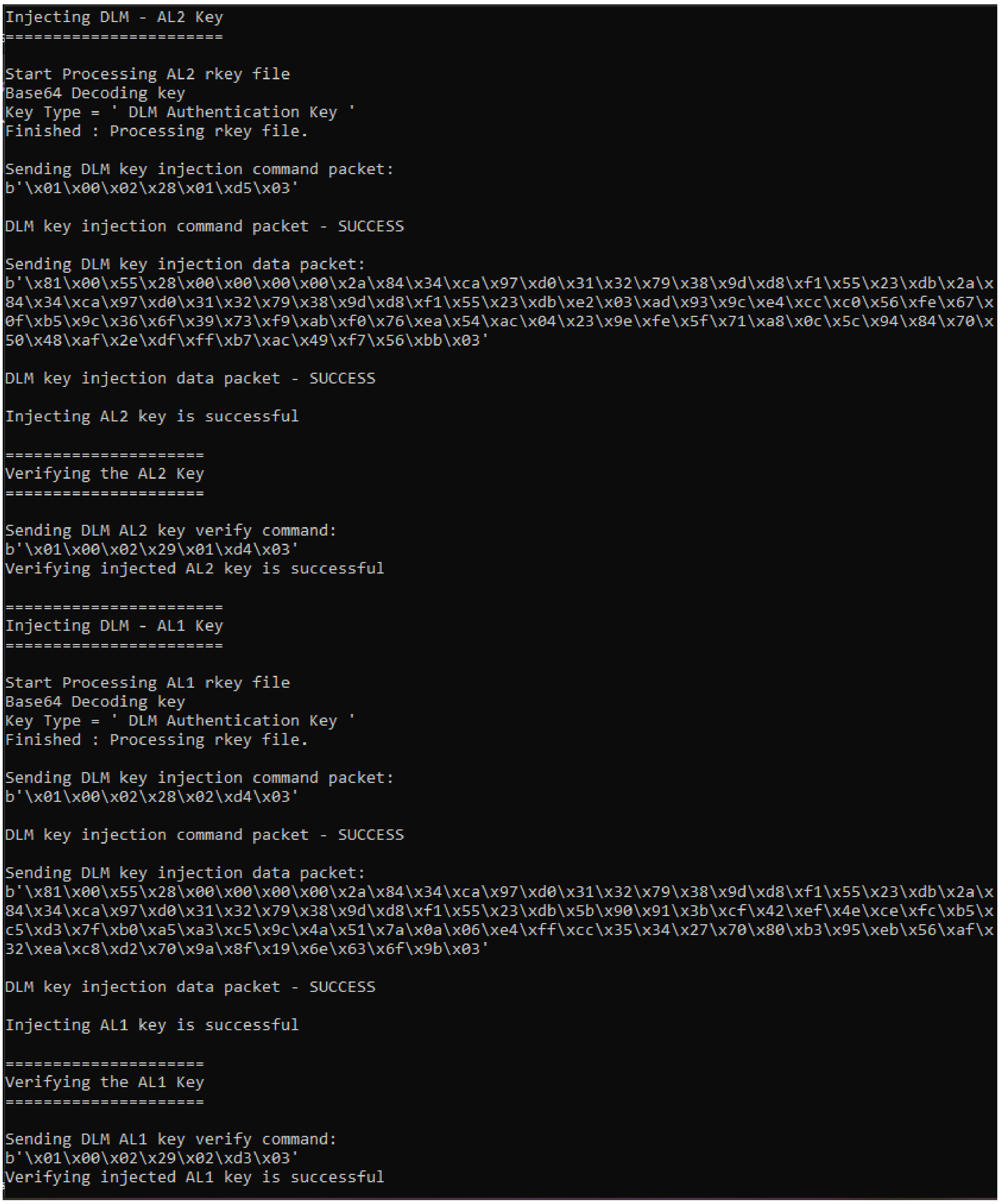
6.4.3 Configuring TrustZone Partition Boundaries



```
================================================
Requesting current TrustZone Boundary information
================================================

Sending read boundary region command:
b'\x01\x00\x01\x4f\xb0\x03'
Read boundary region - SUCCESS
 - The secure code flash region size is 16352 KB
 - The secure data flash region size is 63 KB

================================
Configuring TrustZone Boundaries
================================

Configuring device with :
 - 512KB of Code Flash Secure region
 - 4KB of Data Flash Secure region
Sending TrustZone boundary setup command:
b'\x01\x00\x0b\x4e\x00\x00\x02\x00\x00\x04\x00\x00\x00\x00\xa1\x03'

Set up boundary region - SUCCESS

================================================
Requesting updated TrustZone Boundary information
================================================

Sending read boundary region command:
b'\x01\x00\x01\x4f\xb0\x03'
Read boundary region - SUCCESS
 - The secure code flash region size is 512 KB
 - The secure data flash region size is 4 KB
```

Figure 61. Configuring TrustZone Partition Boundaries

6.4.4 Injecting DLM AL Keys

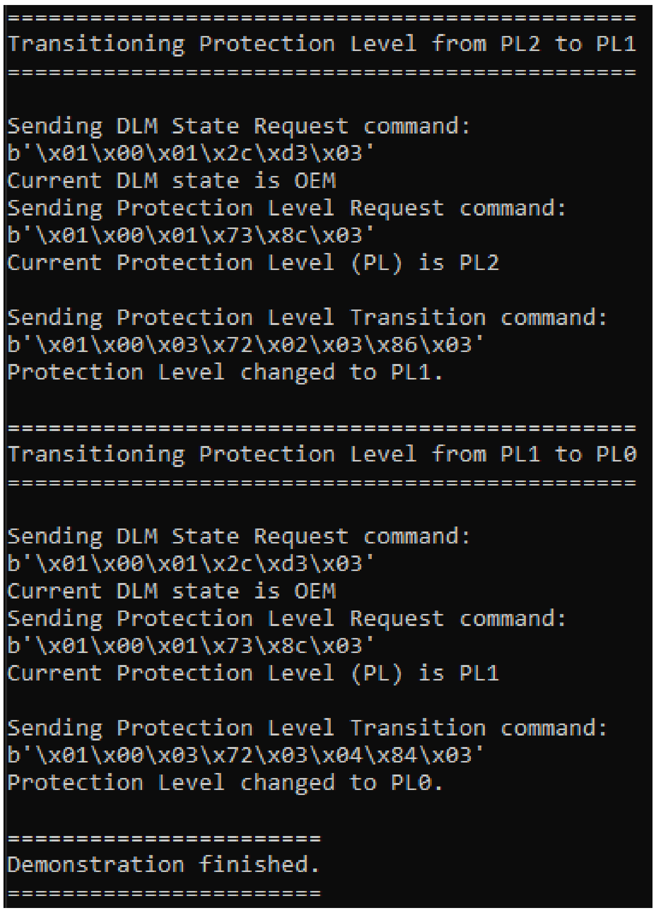


```
Injecting DLM - AL2 Key
=======================

Start Processing AL2 rkey file
Base64 Decoding key
Key Type = ' DLM Authentication Key '
Finished : Processing rkey file.

Sending DLM key injection command packet:
b'\x01\x00\x02\x28\x01\xd5\x03'

DLM key injection command packet - SUCCESS

Sending DLM key injection data packet:
b'\x81\x00\x55\x28\x00\x00\x00\x00\x2a\x84\x34\xca\x97\xd0\x31\x32\x79\x38\x9d\xd8\xf1\x55\x23\xdb\x2a\x
84\x34\xca\x97\xd0\x31\x32\x79\x38\x9d\xd8\xf1\x55\x23\xdb\xe2\x03\xad\x93\x9c\xe4\xcc\xc0\x56\xfe\x67\x
0f\xb5\x9c\x36\x6f\x39\x73\xf9\xab\xf0\x76\xea\x54\xac\x04\x23\x9e\xfe\x5f\x71\xa8\x0c\x5c\x94\x84\x70\x
50\x48\xaf\x2e\xdf\xff\xb7\xac\x49\xf7\x56\xbb\x03'

DLM key injection data packet - SUCCESS

Injecting AL2 key is successful

=====================
Verifying the AL2 Key
=====================

Sending DLM AL2 key verify command:
b'\x01\x00\x02\x29\x01\xd4\x03'
Verifying injected AL2 key is successful

=======================
Injecting DLM - AL1 Key
=======================

Start Processing AL1 rkey file
Base64 Decoding key
Key Type = ' DLM Authentication Key '
Finished : Processing rkey file.

Sending DLM key injection command packet:
b'\x01\x00\x02\x28\x02\xd4\x03'

DLM key injection command packet - SUCCESS

Sending DLM key injection data packet:
b'\x81\x00\x55\x28\x00\x00\x00\x00\x2a\x84\x34\xca\x97\xd0\x31\x32\x79\x38\x9d\xd8\xf1\x55\x23\xdb\x2a\x
84\x34\xca\x97\xd0\x31\x32\x79\x38\x9d\xd8\xf1\x55\x23\xdb\x5b\x90\x91\x3b\xcf\x42\xef\x4e\xce\xfc\xb5\x
c5\xd3\x7f\xb0\xa5\xa3\xc5\x9c\x4a\x51\x7a\x0a\x06\xe4\xff\xcc\x35\x34\x27\x70\x80\xb3\x95\xeb\x56\xaf\x
32\xea\xc8\xd2\x70\x9a\x8f\x19\x6e\x63\x6f\x9b\x03'

DLM key injection data packet - SUCCESS

Injecting AL1 key is successful

=====================
Verifying the AL1 Key
=====================

Sending DLM AL1 key verify command:
b'\x01\x00\x02\x29\x02\xd3\x03'
Verifying injected AL1 key is successful
```

Figure 62. Injecting DLM AL Keys

If the Python code is modified to change the value of `DEBUG_OUTPUT_ENABLE` from 0 to 1, then additional details will be displayed as the content of the .rkey file is processed.

6.4.5 Configuring Final Protection Level State



```
============================================
Transitioning Protection Level from PL2 to PL1
============================================

Sending DLM State Request command:
b'\x01\x00\x01\x2c\xd3\x03'
Current DLM state is OEM
Sending Protection Level Request command:
b'\x01\x00\x01\x73\x8c\x03'
Current Protection Level (PL) is PL2

Sending Protection Level Transition command:
b'\x01\x00\x03\x72\x02\x03\x86\x03'
Protection Level changed to PL1.

============================================
Transitioning Protection Level from PL1 to PL0
============================================

Sending DLM State Request command:
b'\x01\x00\x01\x2c\xd3\x03'
Current DLM state is OEM
Sending Protection Level Request command:
b'\x01\x00\x01\x73\x8c\x03'
Current Protection Level (PL) is PL1

Sending Protection Level Transition command:
b'\x01\x00\x03\x72\x03\x04\x84\x03'
Protection Level changed to PL0.

=======================
Demonstration finished.
=======================
```

Figure 63. Configuring Protection Level State

6.5 Testing Authenticated DLM Transitions

Authenticated DLM transitions are not generally required to be supported in production programming tools, as such transitions are generally only required during product development, or for in-field debug.

This means that the example code simply uses the DLM key verify command to check that keys have been injected correctly.

However, if required, it is possible to test that the injected keys do indeed allow authenticated DLM/PL transitions by referring Authenticated Transition using RFP section from Application Note R11AN0785 to perform the authenticated transitions using the Renesas Flash Programmer:

- This step is typically not needed in a production programming environment. Perform PL0 to PL1 or PL2 transition following case 1 or case 3.
  The plaintext raw AL2 key value for the example `AL2.rkey` and `AL2_RA8P1.rkey` files is "000102030405060708090A0B0C0D0E0F". This value needs to be used when transitioning from the PL0 state to the PL1 or PL2 state.
- Perform PL1 to PL2 transition following case 2.
  The plaintext raw AL1 key value for the example `AL1.rkey` and `AL1_RA8P1.rkey` files is "010102030405060708090A0B0C0D0E0F". This value needs to be used when transitioning from the PL1 state to the PL2 state.

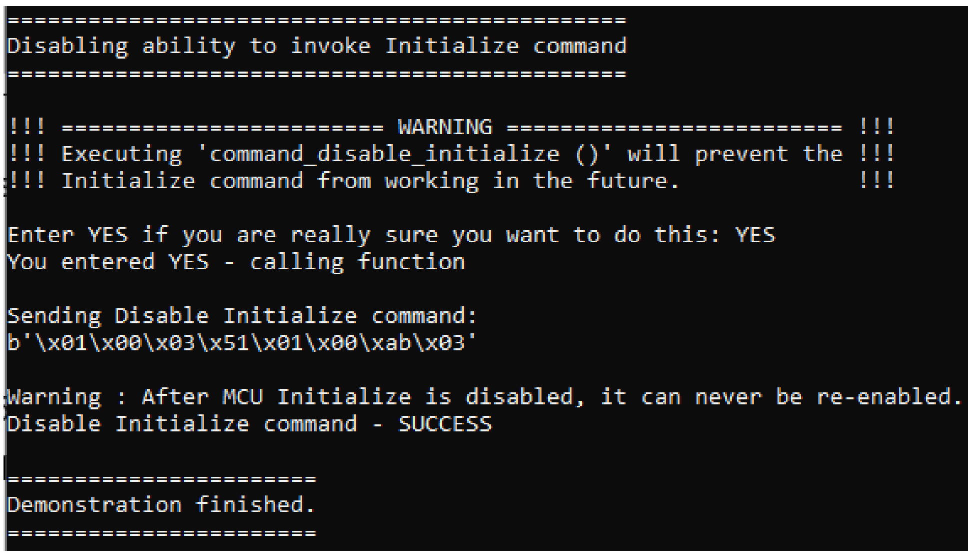
Note: Unlike using the "Initialize" command, the Code Flash, Data Flash, and TrustZone partition boundary settings are preserved in this process.

6.6 Disabling the Initialize Command

The `bootmode_demonstration_code_RA8.py` example contains a function called `command_disable_initialize()`, which will cause the 'Initialize' boot mode command to be disabled. Executing `command_disable_initialize()` prevents the DLM state from being reset to the OEM state using the 'Initialize' command in the future.

This action may be required during a real production programming run, but not while doing testing. Therefore, the calling of this function is disabled by default. To enable the call, change the value of `INVOKE_DISABLE_INITIALIZE_COMMAND` from 0 to 1.

Once changing the value of `INVOKE_DISABLE_INITIALIZE_COMMAND` from 0 to 1, as an extra level of protection, it will still be necessary to enter `YES` when prompted for the call to `command_disable_initialize()` to be made. When `INVOKE_DISABLE_INITIALIZE_COMMAND` is set to 1, the demonstration code will display the following prompt before ending:



```
==============================================
Disabling ability to invoke Initialize command
==============================================

!!! ======================== WARNING ========================= !!!
!!! Executing 'command_disable_initialize ()' will prevent the !!!
!!! Initialize command from working in the future.             !!!

Enter YES if you are really sure you want to do this: YES
You entered YES - calling function

Sending Disable Initialize command:
b'\x01\x00\x03\x51\x01\x00\xab\x03'

Warning : After MCU Initialize is disabled, it can never be re-enabled.
Disable Initialize command - SUCCESS

=======================
Demonstration finished.
=======================
```

Figure 64. Disable the Initialize Command

The next time that `initialize_mcu_first.py` is run, the system will report that the Initialize command is disabled. In this case, the only way to partially recover the board is to use the injected AL keys to move the PL state back to PL2 as explained in section 6.5.

7. References

- Renesas RA Family Device Lifecycle Management for RA8 MCUs (R11AN0785)
- Renesas RA Family Renesas Boot Firmware for RA8M1 MCU Group (R01AN7140)
- Renesas RA Family Renesas Boot Firmware for RA8D1 MCU Group (R01AN7290)
- Renesas RA Family Renesas Boot Firmware for RA8T1 MCU Group (R01AN7291)
- Renesas RA Family Renesas Boot Firmware for RA8E1 MCU Group (R01AN7535)
- Renesas RA Family Renesas Boot Firmware for RA8E2 MCU Group (R01AN7547)
- Renesas RA Family Renesas Boot Firmware for RA8P1 MCU Group (R01AN7823)
- Renesas RA Family RA8M1 User's Manual: Hardware (R01UH0994)
- Renesas RA Family RA8D1 User's Manual: Hardware (R01UH0995)
- Renesas RA Family RA8T1 User's Manual: Hardware (R01UH1016)
- Renesas RA Family RA8E1 User's Manual: Hardware (R01UH1129)
- Renesas RA Family RA8E2 User's Manual: Hardware (R01UH1130)
- Renesas RA Family RA8P1 User's Manual: Hardware (R01UH1064)
- Renesas RA Family RA8 Quick Design Guide (R01AN7087)
- Security Key Management Tool User's Manual (R20UT5349)

8. Website and Support

Visit the following URLs to learn about the RA family of microcontrollers, download tools and documentation, and get support.

RA Product Information	renesas.com/ra
Flexible Software Package (FSP)	renesas.com/ra/fsp
RA Product Support Forum	renesas.com/ra/forum
Renesas Support	renesas.com/support

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun.30.25	—	First release of this document.

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.