UM0148
User Manual

Vending machine demo kit for RFID contactless memories

Introduction

The vending machine demo kit is designed to show how STMicroelectronic's short range RFID contactless memories can be used as e-purse keys for vending machines. The short range products suitable for e-purse applications are the SRIX512 and SRIX4K.

The SRIX512 and SRIX4K are contactless memories that are powered by a 13.56MHz transmitted carrier radio wave. They contain a 512-bit (SRIX512) or 4096-bit (SRIX4K) EEPROM, with memory mapping organized as blocks of 32 bits. They conform to the ISO 14443-B recommendation for the transfer of power and signals via radio transmission. The CRX14 USB Reader circuitry amplitude modulates (10% modulation) the data on the carrier using Amplitude Shift Keying (ASK). The SRIX512 / SRIX4K replies by load modulating the data on the carrier using Bit Phase Shift Keying (BPSK), which uses the 847kHz sub-carrier. The data transfer rate in each direction is 106 Kbits/second.

The Vending Machine Demo Kit consists of:

- One DemokitCRX14
- One CD-ROM
- Some SRIX512 and SRIX4K Samples
- Documentation

The software used to run the demo kit is available on the CD-ROM, but it can also be downloaded from *www.st.com* (file name: VendingMachine_UM0148.zip).

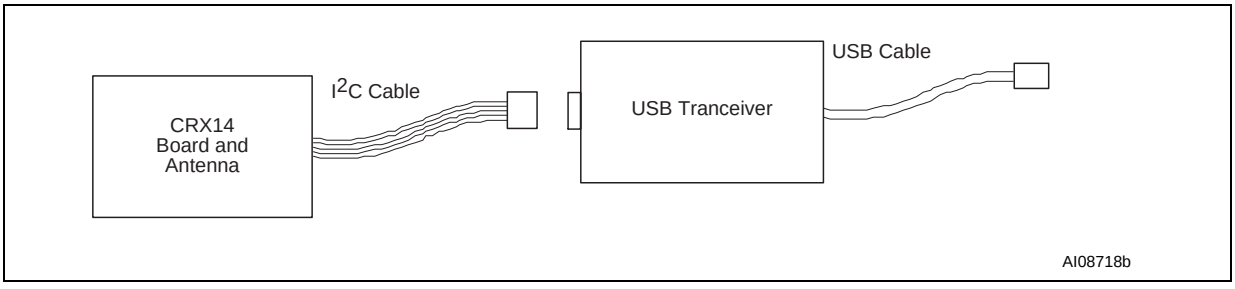
The Vending Machine Demo Kit is used to:

- Personalize tickets as a ticket issuer
- Demonstrate the selling process at any Point of Sale (POS)
- Reload the keys with new units
- Simulate and recover errors

Application features:

- RAM: 16 MB
- HDD free space: 6 MB
- USB version 1.1
- Compatible with Windows98 SE, Windows2000 and Windows XP platforms

Reader USB CRX14 Demokit V4.0 hardware



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1 Ticket mapping

The demo kit software proposes a ticket mapping for the vending machine demo. See *Appendix B: Memory mapping* for specific details. In e-purse applications, ticket mapping is where the specific data is written to the contactless memory (tag), which acts as the e-purse key.

1.1 Key personalization

In real applications, the first thing that must be done by the key manufacturer is the Key personalization (*Figure 1: Example of standard ticket manufacturing flow for SRIX4K*). During this phase, the empty tag inside the key is loaded with data for future use.

The following data is loaded into the tag during the Key personalization phase:

- Identification data, which is write protected after being written:
  - Serial number
  - Vending machine type identification number
  - Personal identification number
  - Date of issue and
  - Application certificate Fc1
- Customer specific data:
  - Unit counter value
  - Reload counter value
  - Unit counter certificate Fct2
  - Reload counter certificate Fct3
- Issuer information, which is stored in the OTP memory area

If the crypto backup (see *Section A.3*) feature is activated, the relevant security procedures are executed in the Key Personalization phase.

1.2 Using the e-purse key

Once the Key personalization phase has been successfully completed, the ticket is active and the user can buy goods. However before buying, several parameters of the key are checked:

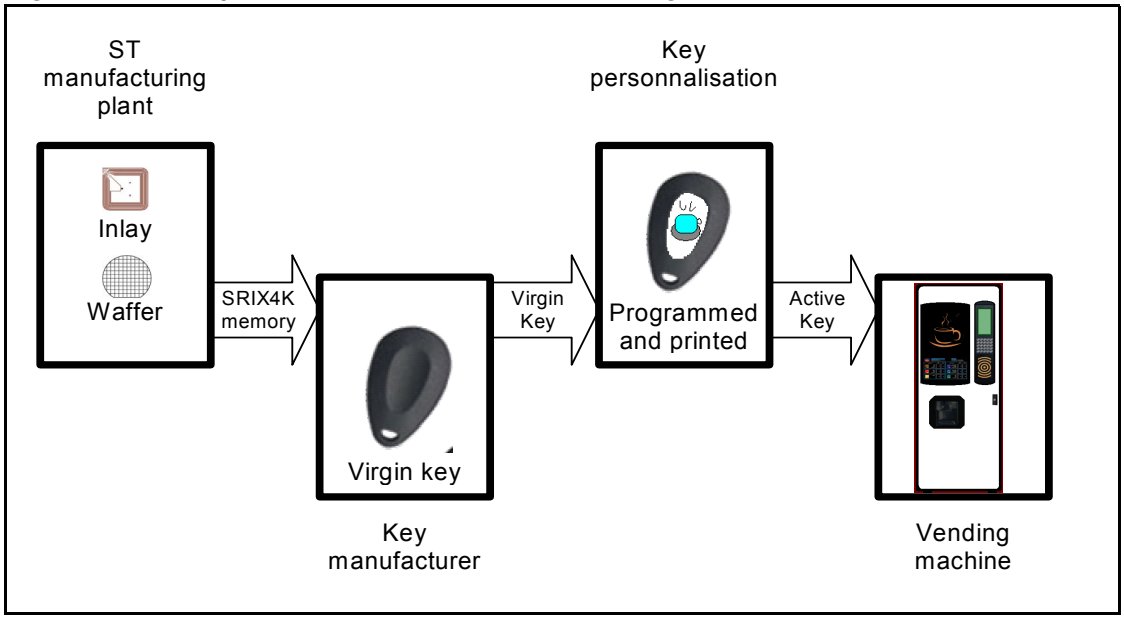
- Vending machine type identification number
- Personal identification number (in line with particular vending machine)
- Validity of all the accessible certificates and crypto backups

If the key contains enough units, then the user can buy goods and the units used are deducted from the Unit counter. Finally the linked certificates and backups are recalculated and loaded back into the key.

1.3 Reloading units

After use, the user may want to reload units into the key. If there are no errors detected in the tag, then the Reload unit counter is appropriately decreased and all the linked certificates and crypto backups (see *Section A.3*) are recalculated and loaded back into the tag's memory. If an error occurs, the errors must be corrected before any further reloading can take place.

Figure 1. Example of standard ticket manufacturing flow for SRIX4K



2 Installing the software

- Browse the CD and find the Vending Machine Demo folder
- After opening the folder, run the setup.exe program
- Read the text of the Welcome Screens, and then click on “Next” (*Figure 2*).
- Choose your destination location. The default folder is C:\Program Files\STM\VendingMachine (*Figure 3*)

Figure 2. Welcome screens

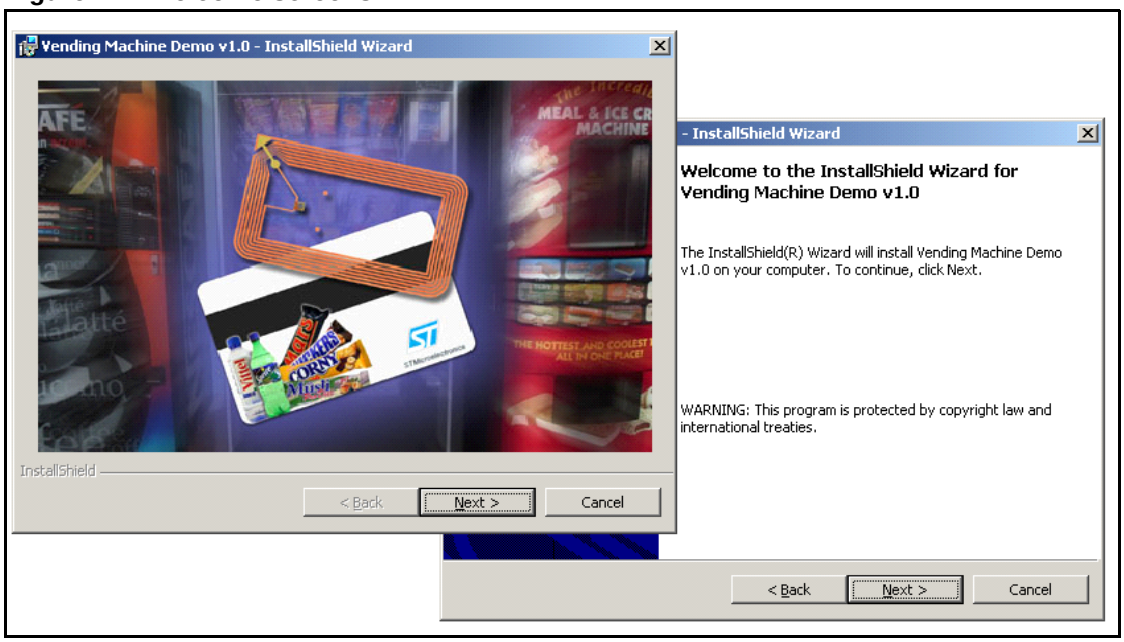
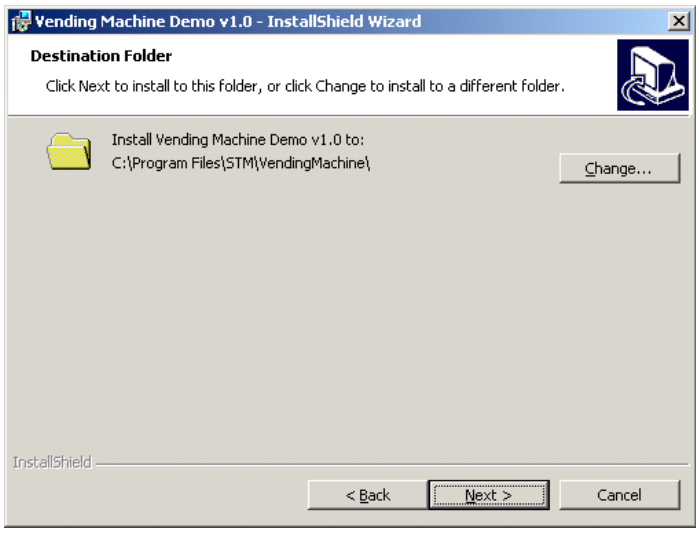


Figure 3. Choose destination location screen



3 Configuring the demo

Once installed, the demo software can be configured using the config.ini file, which is stored in the Res subdirectory of the program main directory (set during installation).

The *config.ini* file contains the following parameters:

- **WriteProtection** – the tag's memory write protection flag, active when set to "one"
- **MasterKey** – a demonstration parameter used internally for calculating certificates Fc2 and Fc3 (*Appendix A: Certificates*).
- **IssuerMachineReaderIndex, ReloadMachineReaderIndex, VendingMachineX/ ReaderIndex** – these are order indexes of specific virtual machines (issuer machine, reload/recover machine, specific vending machines). All indexes are set to zero by default, which means that it is configured for 1 reader.

  The indexes address the reader's tables, which are found during the initialization process.

  The initialization process searches incrementally for the CRX14 readers, via the I^2C bus, on all USB readers connected to the PC.

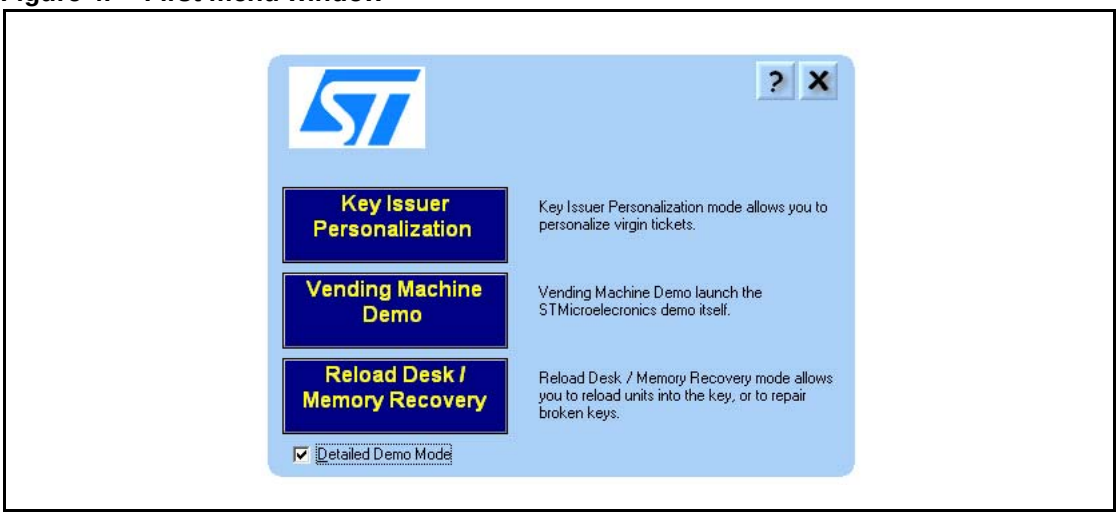
  When there is only one USB reader with several CRX14 readers connected via the I^2C bus, the CRX14 readers with lower I^2C address are the first to be added to the table and are put in the lower index position.

  In the case of multiple USB readers, the situation is more complex (it depends on how the operating system manages the USB devices) and it is necessary to plug the readers into the PC to find and set the correct indexes.
- **VendingMachineX/PersonalName** – usually the name of the vending machine location
- **VendingMachineX/PersonalID** – the ID number linked to the location
- **VendingMachineX/BackgroundJPEG** – the link to the background JPEG image for a pair of vending machines (left or right, recommended resolution of this image is 400 x 500 pixels.
- **VendingMachineX/OfferNameY** – the list of item's offered by the vending machine, it indicates the name of the products offered.
- **VendingMachineX/OfferPriceY** – the price list of the item's offered by the vending machine, it indicates the unit price of a particular product.
- **VendingMachineX/OfferBMPY** – the list of images which correspond to the item's offered by the vending machine, it indicates the link to the bitmap image (45 x 45 pixels), which represents the particular product.

4 Launching the demo

After successful installation, the demo program is launched from the Windows Start menu (*Start – Programs – Vending machine demo*). Immediately after execution the Splash screen appears. After the program is fully loaded into the memory, the first menu window (see *Figure 4*) appears, select the *Key Issuer Personalization mode*, the *Reload Desk / Memory Recovery mode* or the *Vending Machine Demo* to start the demo.

Figure 4. First menu window



5 Key personalization

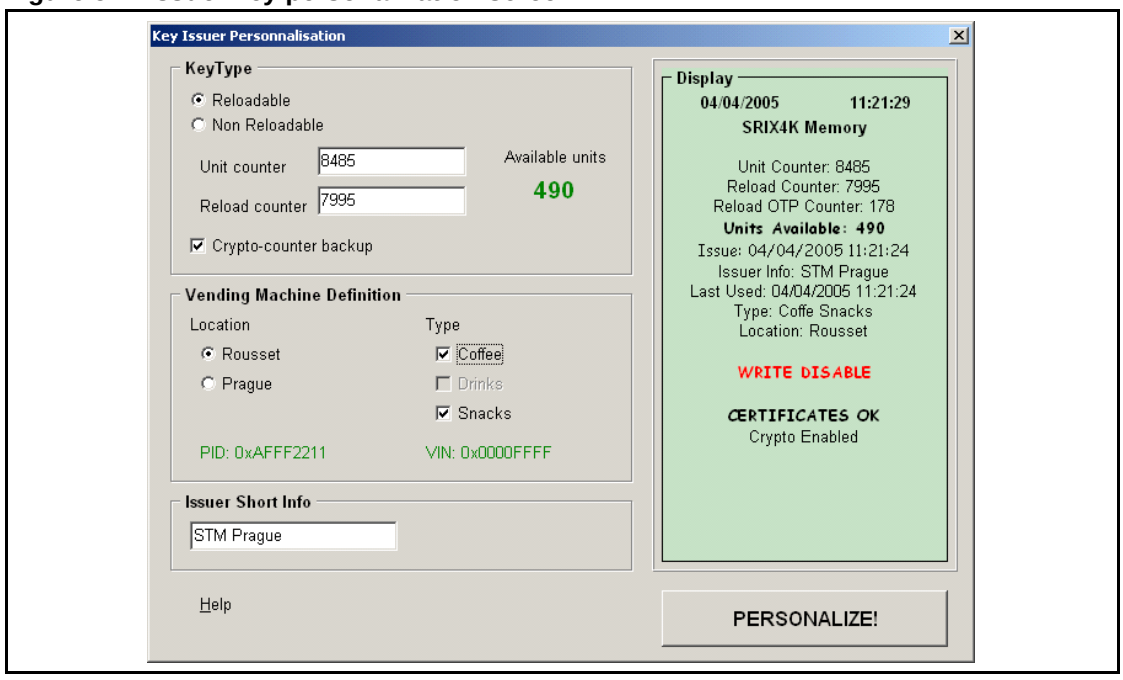
The key personalization is normally done in the production phase by the key manufacturer, and so final key users receive the contactless memories already personalized for their needs and specification. However, as the Contactless memory samples included in the kit are general samples used for a wide variety of applications, they must be personalized by the user before use.

To personalize an empty tag:

- choose a desired key type
- specify additional options
- put the tag into the reader's antenna field
- push the "Personalize!" button

Before personalization a "Write enable" statement is displayed. After successful personalization the appropriate tag's blocks could be write protected, depending on the program configuration. If a tag's block are write protected, then a "Write disabled" statement is displayed. It is not possible to personalize a write protected tag, and attempting to do so gives an error message.

Figure 5. Issuer key personalization screen



6 Using the vending machine

Figure 6 shows the main window of the program. All vending machines are offline at the beginning. Click on a machine to select it. The selected vending machine is immediately highlighted and its offer displayed on the virtual display. The user can choose a product by pressing the corresponding button or by clicking on the virtual display. Once the requested product is selected, the user places the memory key in the reader's antenna field, to execute the transaction and receive the product.

Several types of errors can occur during the transaction. These errors are listed in *Appendix D*.

If the user places the key in the reader's antenna field when no product is selected, the status of the ticket is shown on the virtual display.

In the detailed mode, which is shown on the screen in *Figure 7* there are also buttons to generate error states (*Unit Counter Error, Unit Counter Cert Error, Reload Counter Cert Error*).

Figure 6. Vending machine demo main screen

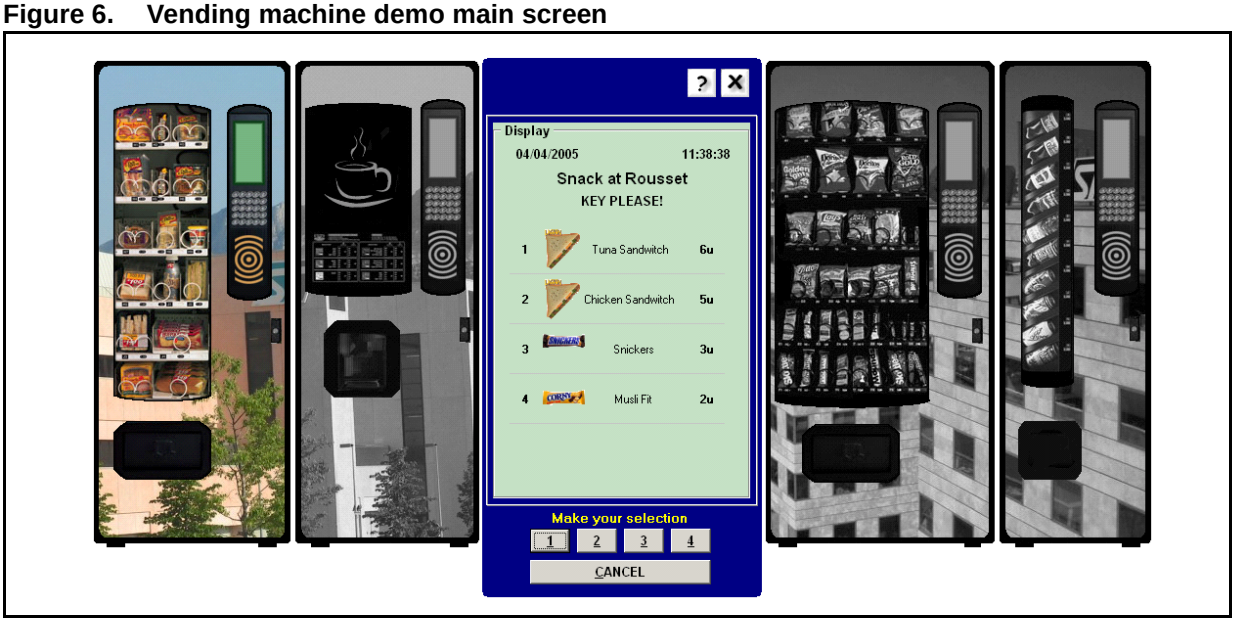


Figure 7. Detailed mode screen

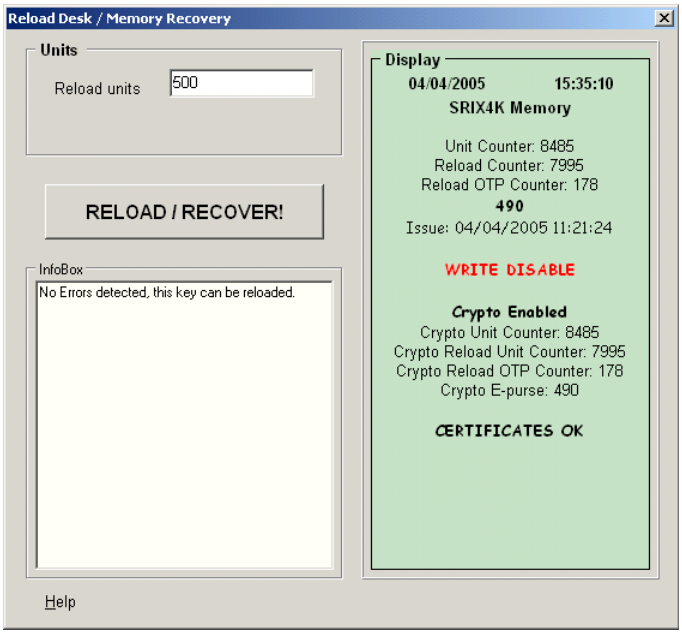
7 Reload desk / memory recovery

The *Reload desk/ memory recover* is used when an error has occurred or there are no more units available in the key.

When the key is placed in the reader's antenna field, the status of the ticket is shown on the virtual display. If no error is detected, select the number of units to reload and start the procedure by clicking on *Reload/Recover*.

When errors are detected, the Reload function is disabled and the errors have to be corrected before doing another Reload. The InfoBox provides short descriptions of the errors and the proposed recovery actions. See *Appendix D* for a list of all the possible error states.

Figure 8. Reload desk / memory recovery screen



8 Detailed mode

Selecting the *Detailed Demo Mode* checkbox on the first demo screen shows the memory map of the key (see *Figure 9*).

If the *Record Memory Access* checkbox is unselected, the content of the last detected tag is shown. If the reader fails to read the memory content, the memory map provides information about the fail and the block number of the last successfully read block.

If the *Record Memory Access* checkbox is selected, the screen is not updated when a new tag is inserted into the reader's antenna field. Instead all previous memory accesses, undertaken during the Key issuer personalization procedure, item buying procedure and reload / recovery actions, can be seen using the *Prev* and *Next* buttons (see *Figure 10*). The InfoBox provides a short description.

Figure 9. Memory map standard screen

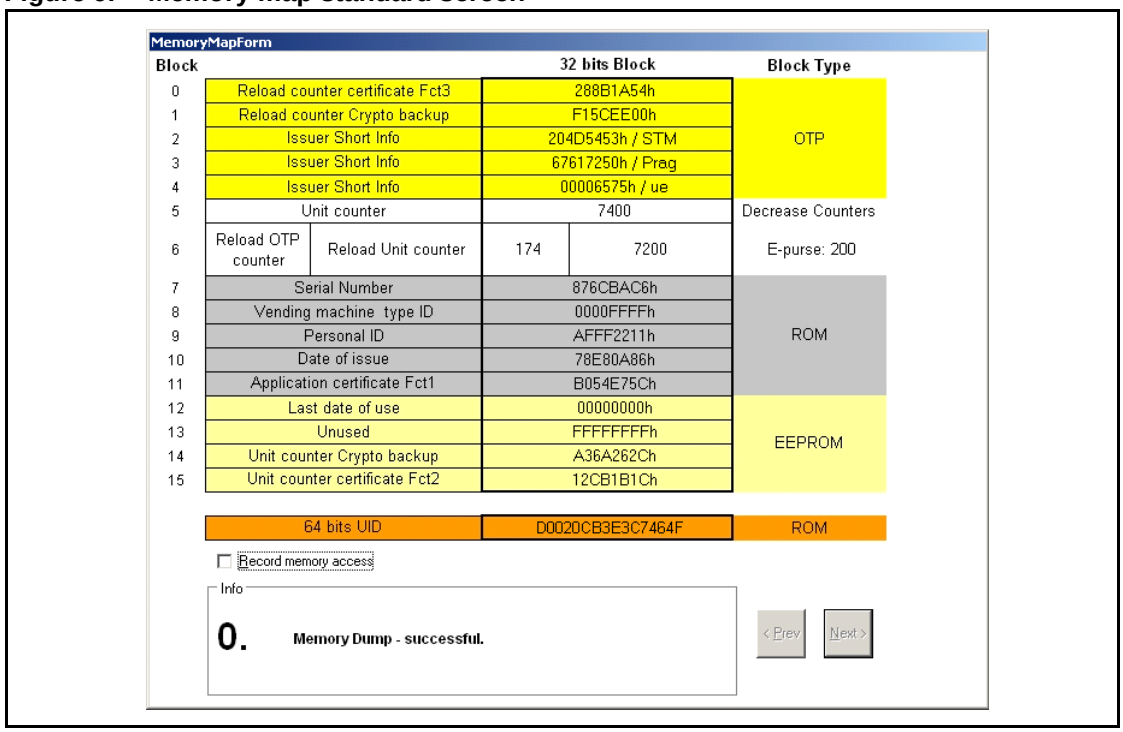
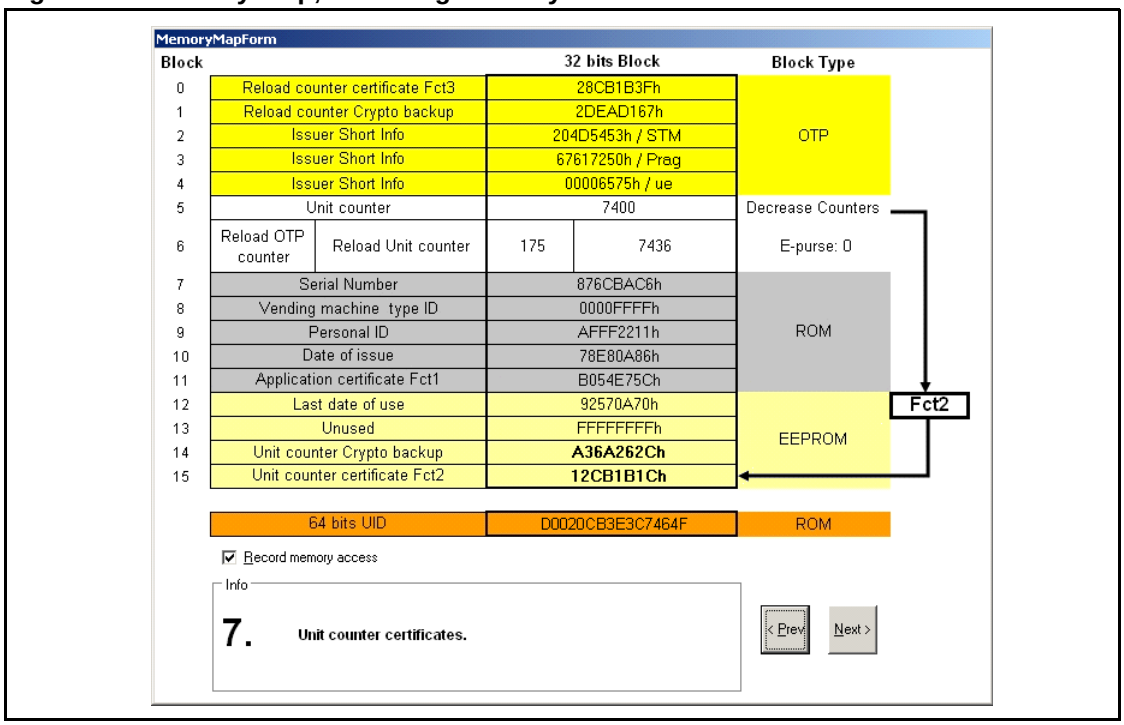


Figure 10. Memory map, recording memory accesses screen



Appendix A Certificates

Several variables are used to calculate certificates:

- **UID** - the Unique Identifier of the tag, its value is controlled by the manufacturer (ST) and securely stored in the silicon (read only).
- **Serial Number** – a unique number that is controlled by the application owner.
- **MK** - the Master Key dedicated to the application, which is controlled by the application owner and can be used to differentiate between the various applications of particular customer.
- **Vending machine type identification number** – this parameter stores the flags of the type of vending machines that use the key
- **Personal identification number** – a unique number used to help the provider differentiate between the various locations of the vending machines.

A.1 Application certificate Fct1

The Fct1 certificate is used to authenticate the personalized data. *Figure 11* shows and example.

In this example, the key is personalized for a snack machine (Vending machine type identification = 40 00 55 AA) in ST Rousset (personal identification number = AF FF 11 11). The SRIX4K UID number is D0 02 18 00 11 22 33 44 with serial number 12 34 56 78.

The Fct1 certificate is always fully managed by the customer's application and so provides a high level of security.

Figure 11. Application certificate example

UID	D0 02 18 00 + 11 22 33 44
Serial Number	+ 12 34 56 78
Vending machine type identification number	+ 40 00 55 AA
Personal identification number	+ AF FF 11 11
Date of issue	+ 01 01 20 05
Application certificate	**Fct1 = E4 59 28 7C**

A.2 Counter certificates Fct2, Fct3

Certificates Fct2 and Fct3 are used to authenticate the counter values. See *Figure 12* for an example.

As for the Fct1 certificate, the Fct2 and Fct3 certificates are always fully managed by the customer's application and so provide a high level of security.

Figure 12. Unit and Reload counter certificate example

UID	D0 02 18 00 + 11 22 33 44
MK	+ 12 CA FE 34
Unit Counter (10 000 = 2710h)	+ 00 00 27 10
Unit Counter certificate	**Fct2 = F3 EF 70 88**
OTP Counter (200 | 9500 = 1900251Ch)	19 00 25 1C
Reload Counter certificate	**Fct3 = 0C EF 6E 94**

A.3 Crypto backup

The Crypto Backup feature allows a user to encrypt and decrypt selected blocks using a system similar to DES (Data Encryption Standard). The version of DES used in the Crypto backup operates on 32-bit data blocks using a 24-bit key. It iterates over 8 keys and transforms the data stream through 4 S-boxes. All permutations and transformations of the DES algorithm are reproduced.

All the steps of the full DES are used, but with less iteration and smaller blocks.

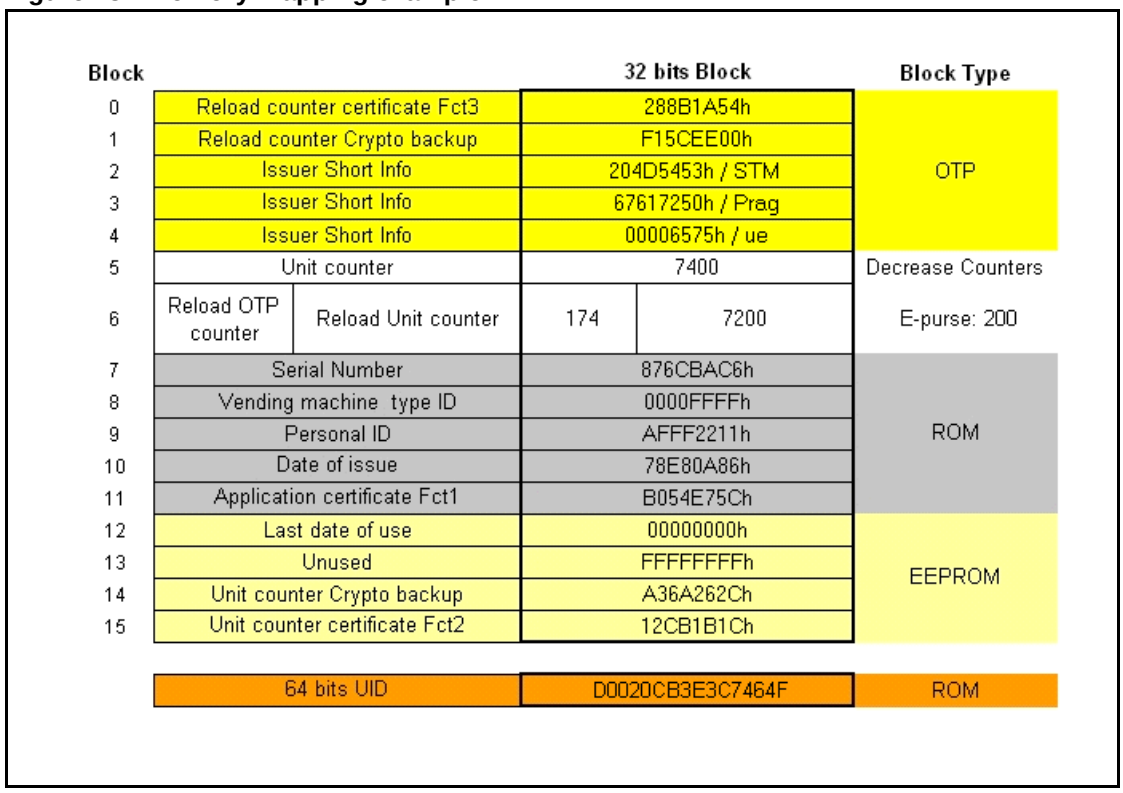
- a 24-bit key is used instead of a 56-bit key
- the data is divided into 32-bit blocks instead of 64-bit blocks
- there are only 8 iterations through the F-module instead of 16
- there are only 4 S-boxes instead of 8
- the steps to encrypt and decrypt are virtually the same, except that decrypting uses the keys in reverse order, and the roles of the left and right hand sides of the data block are reversed.

A.3.1 F-module

The F-module combines 16 bits of data with a 24-bit key and performs substitutions with the DES S-boxes. The 16-bits of data are expanded to 24 bits with the E[] table, then XOR'ed with the key. The result is divided into four 6-bit groups, which are fed through the S-boxes as described in the DES standard (the outer two bits select the S-box row, and the inner four bits select the S-box column).

Appendix B Memory mapping

Figure 13. Memory mapping example



Block		32 bits Block	Block Type
0	Reload counter certificate Fct3	288B1A54h	OTP
1	Reload counter Crypto backup	F15CEE00h	
2	Issuer Short Info	204D5453h / STM	
3	Issuer Short Info	67617250h / Prag	
4	Issuer Short Info	00006575h / ue	
5	Unit counter	7400	Decrease Counters
6	Reload OTP counter / Reload Unit counter	174 / 7200	E-purse: 200
7	Serial Number	876CBAC6h	ROM
8	Vending machine type ID	0000FFFFh	
9	Personal ID	AFFF2211h	
10	Date of issue	78E80A86h	
11	Application certificate Fct1	B054E75Ch	
12	Last date of use	00000000h	EEPROM
13	Unused	FFFFFFFFh	
14	Unit counter Crypto backup	A36A262Ch	
15	Unit counter certificate Fct2	12CB1B1Ch	
	64 bits UID	D0020CB3E3C7464F	ROM

Appendix C Memory accesses

Figure 14, *Figure 15* and *Figure 16* show the step by step procedures of selected memory operations. The numbers in the brackets indicate the memory block numbers for a particular memory operations.

Figure 14. Issuer sequence flowchart

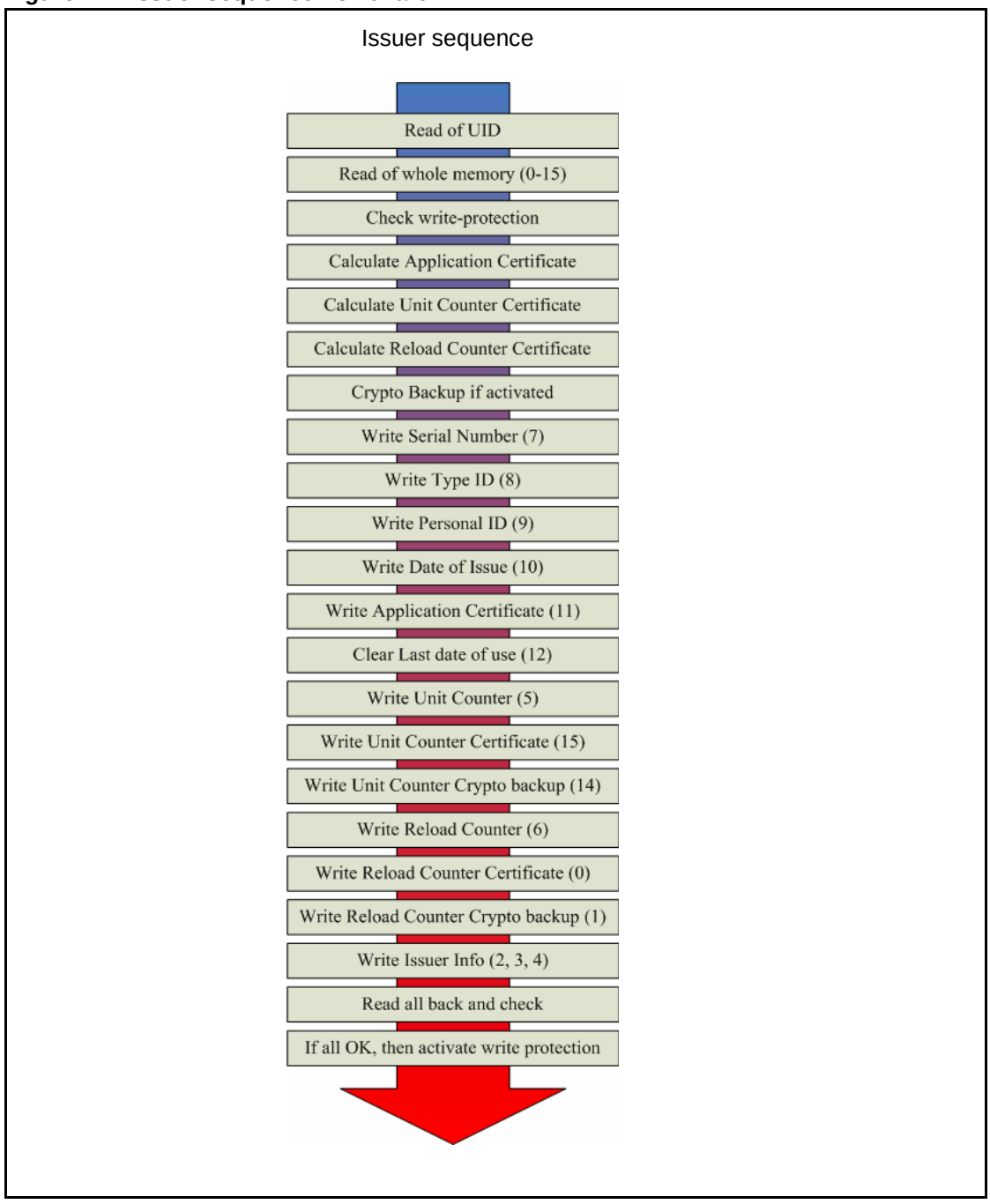


Figure 15. Buying Items flowchart

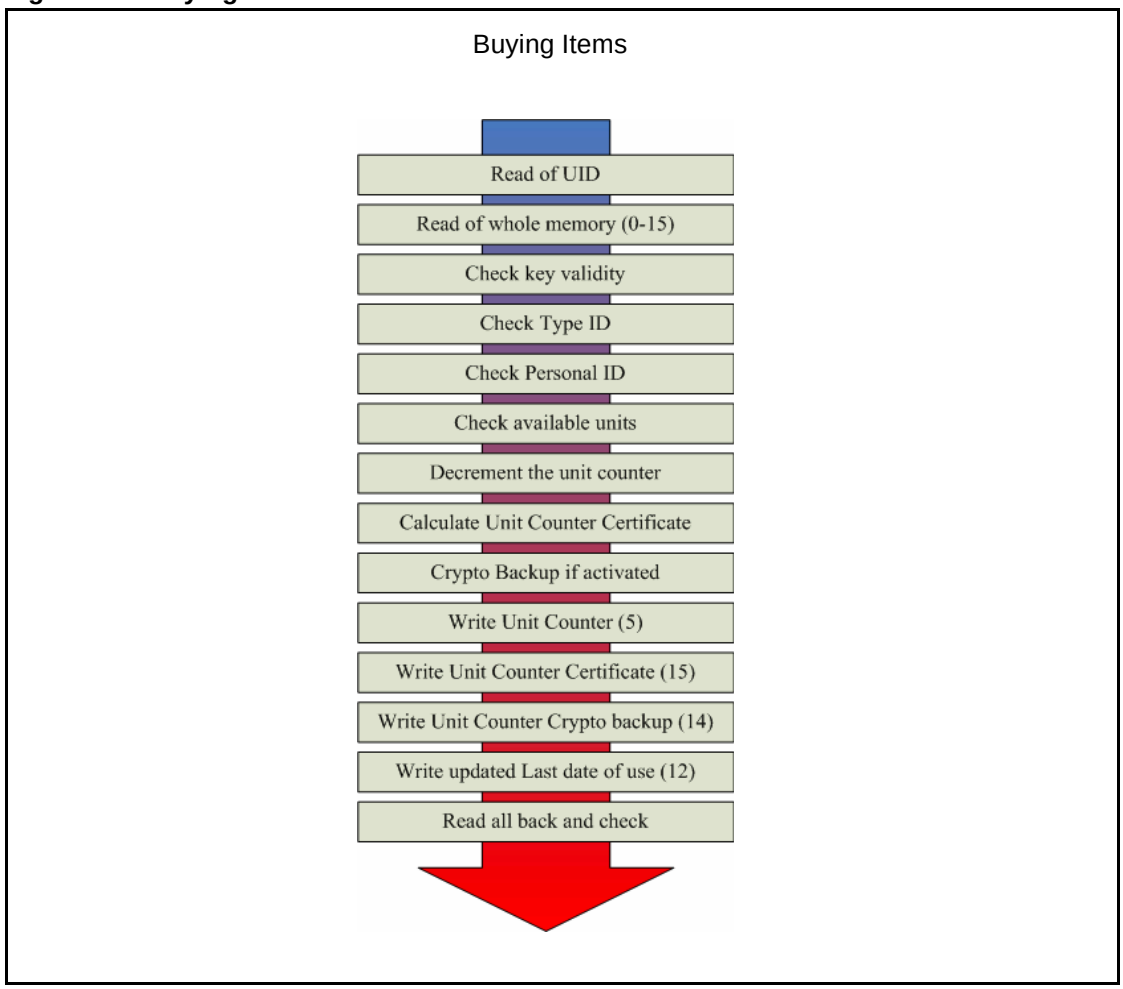
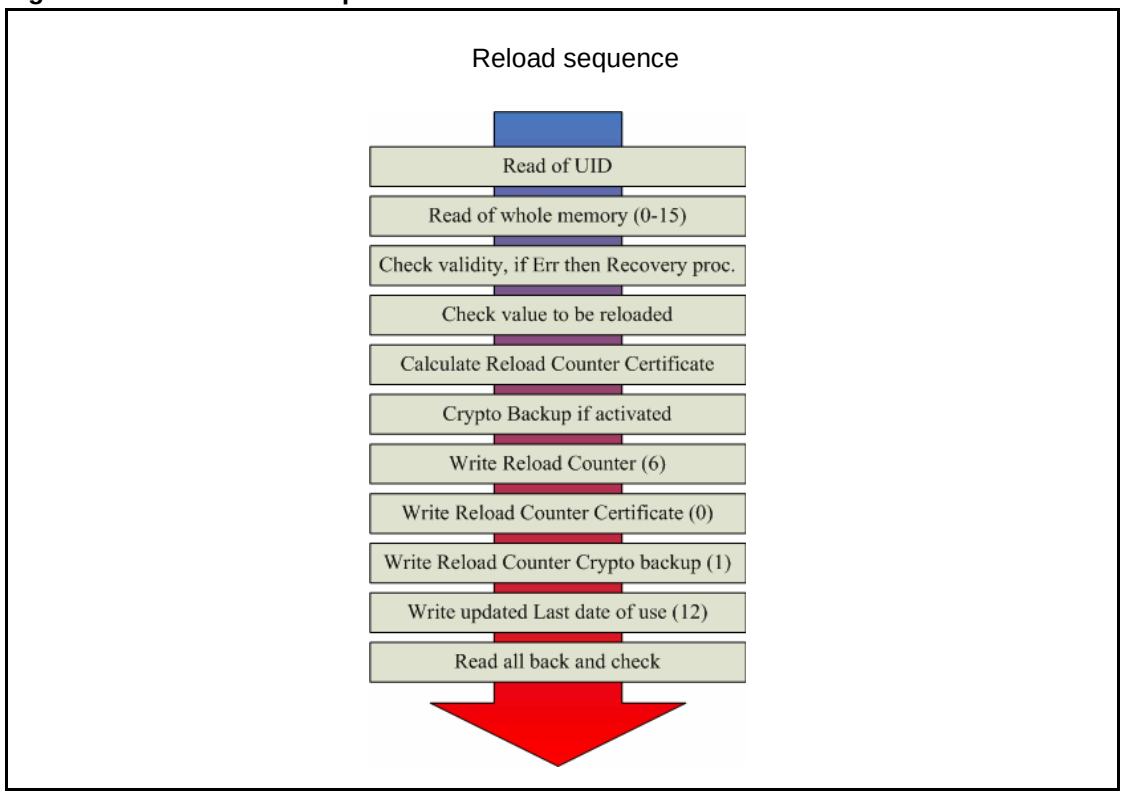


Figure 16. Unit Reload sequence flowchart



Appendix D Emulated errors

D.1 Application certificate error

An Application certificate error occurs when the Application certificate value in the tag differs from the values calculated in Fct1. The value of the Application certificate is located in block 11.

The application certificate error can be recovered by a new Application certificate recalculation only if the write protection was not yet activated on the affected key. Visit the Reload/Recovery desk.

D.2 Unit counter error

A Unit counter error occurs when the Unit Counter value is smaller then the Reload Counter value. The value of the Unit counter is located in block 5.

The solution is to align the Reload Counter to the same value as the unit counter, which sets the e-purse value to “0”, after which the key must be reloaded. All involved certificates are then recalculated. Visit the Reload/Recovery desk.

D.3 Unit counter certificate error

A Unit counter certificate error occurs when the Unit counter certificate is corrupted. The value of the Unit counter certificate is located in block 15.

The solution is to recalculate the Unit counter certificate. In this case the value of the E-purse is lower, and the certificate is recalculated. Visit the Reload/Recovery desk.

D.4 Reload counter certificate error

A Reload counter certificate error occurs when the Reload counter certificate is corrupted. The value of the Reload counter certificate is located in block 0. The solution is to recalculate all the involved certificates.

A sophisticated recovery procedure, which takes into account all possible inputs (Reload Counter value and Reload OTP counter value) and the Reload counter certificate and Reload counter crypto backup outputs, can be build in to real applications. Visit the Reload/Recovery desk.

D.5 Unit counter crypto error

A Unit counter crypto errors occurs when the Unit counter crypto backup is corrupted. The value of the Unit counter crypto is located in block 14.

The solution is to recalculate the Unit counter crypto backup. In this case the value of the E-purse is lower, and the crypto backup is recalculated. Visit the Reload/Recovery desk.

D.6 Reload counter crypto error

A Reload counter crypto error occurs when the Reload Counter Crypto Backup is corrupted. The value of the Reload counter crypto is located in block 1.

The solution is to recalculate all the involved certificates.

A sophisticated recovery procedure, which takes into account all possible inputs (Reload Counter value and Reload OTP counter value) and the Reload counter certificate and Reload counter crypto backup outputs, can be build in to real applications. Visit the Reload/Recovery desk.

D.7 Wrong Type ID

The Wrong Type ID warning message indicates that the user is trying to use the key with the wrong type of vending machine. The value of the Type ID is located in block 8. Visit the Reload/ Recovery desk.

D.8 Wrong Personal ID

The Wrong personal ID warning message indicates that the user is trying to use the key at the wrong location. The value of the personal ID is located in block 9. Visit the Reload/Recovery desk.

D.9 Want of Units

A Want of Units warning message indicates that there are not enough units available on the key to buy the requested item. The solution is to visit the Reload/Recovery desk and reload more units onto the key.

Revision history

Date	Revision	Changes
01-Jul-2005	1	Initial release.

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