Advanced Card Systems Limited

Card and Reader Technologies

Reference Manual

ACOS3

CONTENTS

1.0. INTRODUCTION

The purpose of this document is to describe in detail the features and functions of the ACS Smart Card Operating Systems Version 3 (ACOS3) developed by Advanced Card Systems Ltd.

1.1. Features

- Full 24 Kbytes of EEPROM memory for application data
- Compliance with ISO 7816 parts 1, 2, 3; supporting the T=0 direct protocol
- ISO7816-2 compliant 8-contact module.
- High-speed transmission possible (9.6 to 223.2 kbps) with modifiable ATR.
- DES / 3DES and MAC capabilities
- Five secret codes + issuer code
- PIN code that can be updated by card holder
- Key pair for mutual authentication
- Session key based on random numbers
- Transparent files and linear files with fixed record length (record length can be different for different files) are available.
- Secure messaging option ensures transmission of user data is secured against eavesdropping, replay attack and unauthorized modifications.
- Account data structure for highly secure payment applications as an optional feature
- Completely backward compatible with ACOS1 / ACOS2 cards.

1.2. Technical Specifications

The following are the physical properties of the ACOS3 card:

Electrical

- Operating at 5V DC+/-10% (Class A) and 3V DC +/-10% (Class B)
- Maximum supply current: <10 mA
- ESD protection: ≤ 4 KV

EEPROM

- Capacity: 24 Kbytes (24,576 bytes)
- EEPROM endurance: 100K erase/write cycles
- Data retention: 10 years

Environmental

- Operating temperature: -25 °C to 85 °C
- Storage temperature: -40 °C to 100 °C

1.3. History of Modification

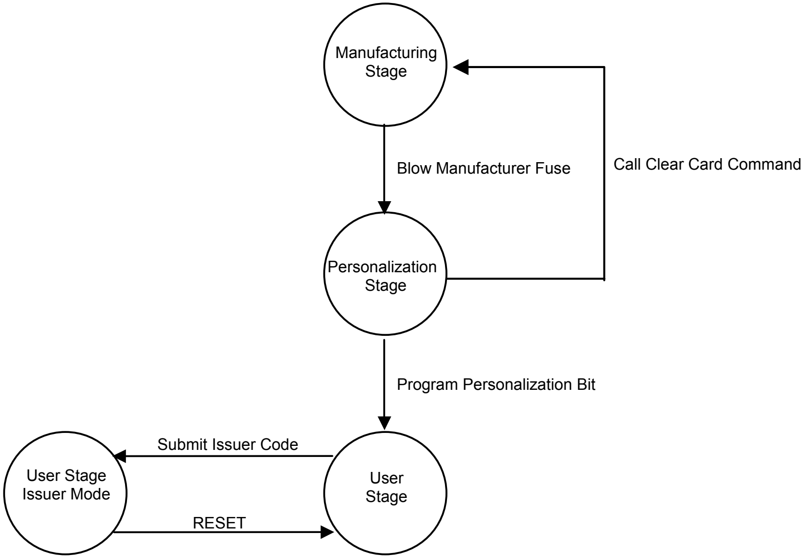
December 2005	ACOS3 revision 1.0
April 2007	ACOS3 revision 1.01 - Modification of the ATR for backward compatibility
August 2007	ACOS3 revision 1.03 - Extra ISO7816-3 guard time during transmission for enhanced reader compatibility - Enhancement added for 223.2 kbps communication support
October 2007	ACOS3 revision 1.06 - Added read/write record offset feature. - Added maximum code retry counters feature.
November 2007	ACOS3 revision 1.07 - Expanded user storage capacity to 24 Kbyte. - Added Transparent (Binary) file structure. - Added Secure Messaging for user data files.

2.0. CHIP LIFE CYCLE

During the whole life cycle of the chip-card, three phases and two different operating modes can be distinguished:

- Manufacturing Stage
- Personalization Stage
- User Stage
- User Stage - Issuer Mode

The card is at any moment in one of these four stages. The following diagram shows the possible transitions between the four stages:



The actual chip life cycle stage is determined by the card operating system immediately after a reset. The life cycle stage does not change during the operation of the card. Clear card command can be issued in the personalization stage and manufacture state to clear the card of all data. However, this command will not be able to be used after User Stage.

2.1. Manufacturing Stage

The Manufacturing Stage is effective from the moment of chip manufacturing until an associated fuse (i.e., a certain bit in the EEPROM), the so-called *Manufacturer Fuse*, has been programmed.

In the Manufacturing Stage, any write access to Internal Data Files, as well as the read access to the Security File is only possible after the presentation of the correct IC code. The initial IC code is programmed in the ACOS3 microcontroller during the chip manufacturing process.

The IC is presented to the card in plain, without encryption.

All card commands are available, although some of the commands, such as AUTHENTICATE will not produce reasonable results as long as the respective data, for example, the keys, have not been programmed in the card.

The following data items are written to the EEPROM memory in the Manufacturing Stage:

- The Manufacturer File, containing **2** records of **8** bytes each associated to the Manufacturing Stage. This file can only be written in the Manufacturing Stage. After programming the Manufacturer Fuse, the Manufacturer File is read-only. Data unique to each card and common card data can be programmed, such as, card manufacturer identification, card serial number, etc. The card does not interpret the data.
- The IC code for the Personalization Stage.
  The IC code must have been presented to the card before the card allows WRITE access to the data files in the *Personalization Stage*, which is applicable immediately after completion of the Manufacturing Stage.
- The Manufacturer Fuse, to irreversibly change the card life cycle from the Manufacturing Stage to the Personalization Stage. The Manufacturer Fuse is one bit in the 16 bytes Manufacturer File.

2.2. Personalization Stage

The Personalization Stage is effective from the moment of termination of the Manufacturing Stage until an associated bit in the EEPROM, the so-called *Personalization Bit,* has been programmed.

Once the Personalization Bit has been programmed and the Personalization Stage has thus been terminated, there is no possibility of resetting the card back into the personalization stage.

During card personalization, the card can be reset back to its virgin stage by calling the CLEAR CARD command. This command will physically erase the EEPROM memory and key data so reprogramming is possible.

In the Personalization Stage, any write access to Internal Data Files, as well as the read access to the Security File is only possible after the presentation of the correct IC code. The card manufacturer writes the IC code in the Manufacturing Stage.

The IC is presented to the card in plain, without encryption. The Authentication Process should not be executed prior to programming the correct keys in the Personalization Stage.

The following data items are written to the memory in the Personalization Stage:

- The Personalization File, containing 3 records of 4 bytes each associated to the Personalization Stage, including the Option Registers. This area can only be written in the Personalization Stage. After programming the Personalization Fuse, the Personalization File is read-only. Data unique to each card and common card data can be programmed in the Personalization File, such as, card issuer identification, card application code, etc. The first 10 bytes of the Personalization File are transmitted in the Historical Bytes in the Answer-to-Reset.
- Secret Codes and Keys
- The File Definition Blocks of the required User Data Files.
- The Account Data Structure (if enabled by the respective option bit)
- The Personalization Bit to change the card life cycle from the Personalization Stage to the User Stage.

2.3. User Stage

User Stage designates the 'normal' operating mode of the card. The User Stage is effective from the moment of termination of the Personalization Stage until the so-called Issuer Code has been submitted to the card. A submission of the Issuer Code changes the operation mode to the so-called Issuer Mode. This privileged mode allows access to certain memory areas, which are otherwise not accessible.

3.0. EEPROM MEMORY MANAGEMENT

The 24K Bytes EEPROM memory area provided by the card chip is fully usable for User Data Memory. There is an additional EEPROM area that stores Internal Data Memory.

- The Internal Data Memory is used for the storage of configuration data and it is used by the card operating system to manage card functionalities.
- The User Data Memory stores the data of the card under the control of the application.

3.1. Data Files

Access to both the Internal Data Memory area and the User Data Memory area is possible within the scopes of data files and data records. Data files in the Internal Data Memory are referred to as *Internal Data Files*. Data files in the User Data Memory are called *User Data Files*.

Data files are the smallest entity to which individual security attributes can be assigned to control the read and write access to the data stored in the EEPROM.

Data files are either of record type or transparent type.

A record data file contains N data records. The record number must be specified when a record (or data within a record) is read from or written to a file. A data file can contain up to 255 records. The record length can be different for different files but is always fixed within a file. Access to record files is done by issuing READ or WRITE RECORD.

A transparent data file contains a continuous block of EEPROM and it is accessed by providing a length and offset to be read or written within the block. It is also referred to as a binary file. The commands to access this file type is READ or WRITE BINARY.

Internal Data files are of RECORD type only. The file structures of the Internal Data Files (file size, file identifier, record length, security attributes) are defined by the operating system and cannot be changed. The file structure for the User Data Memory is determined in the card personalization. After programming the parameter N_OF_FILE in the Personalization Stage, the file structure is fixed.

Access to all files is possible only through the READ RECORD/BINARY and WRITE RECORD/BINARY commands. The operating system does not keep track of which records have actually been written through the WRITE RECORD/BINARY command. The data returned by the card in response to a READ RECORD/BINARY command are the actual data read from the EEPROM memory, regardless of whether that data have ever been written.

Each file is identified by two bytes File Identifier. The File Identifier is assigned to the file when the file is being defined during the Personalization Stage. The operating system does not perform any checking on the uniqueness of each File Identifier. If the same identifier has been assigned to more than one file, a malfunction of the card may occur.

A value of FF$_H$ of the first byte of the file identifier is used for Internal Data Files and cannot be used for User Data Files.

Before any READ or WRITE RECORD/BINARY access to a file, the file must be opened through the SELECT FILE command. Only one file is selected at any time. The READ and WRITE RECORD/BIANRY commands refer to the most recently selected file.

3.2. Data File Access Control

Two security attributes are assigned to each Data File: the Read Security Attribute and the Write Security Attribute. Security attributes define the security conditions that must be fulfilled to allow the respective operation:

- The Read Security Attribute controls the read access to the data in a file through the READ RECORD/BINARY command. If the security condition specified in the Read Security Attribute is not fulfilled, the card will reject a READ command to that file.
- The Write Security Attribute controls the write access to the data in a file through the WRITE RECORD/BINARY command. If the security condition specified in the Write Security Attribute is not fulfilled, the card will reject a WRITE command to that file.

The Read Security Attribute and the Write Security Attribute for each data file specify which Application Code, if any, must have been submitted correctly to the card to allow the respective operation, and whether the Issuer Code and/or the PIN code must have been submitted.

A logical OR function applies to the specified Application Codes, AC x, i.e., if more than one Application Code is specified in a security attribute, the security condition is fulfilled if any one of the specified Application Codes has been correctly submitted.

A logical AND function applies to the PIN and the IC code, i.e., if PIN and/or IC are specified in a security attribute, the PIN and/or IC code(s) must have been submitted in addition to the specified Application Codes(s).

Application Code AC0 can be specified in the Security Attribute, but cannot be submitted to the card. It is thus possible, for example, to completely write protect a file by specifying AC0 in the Write Security Attribute of that file.

For Internal Data Files, the security attributes are fixed in the card operating system.
For User Data Files, the security attributes of a file are stored in the associated File Definition Block.

The following table lists examples of security conditions that can be specified for User Data Files:

Security Attribute	Security Condition
-	No restriction; free access
AC x	Access only after correct submission of AC x
AC x, AC y, AC z	Access only after correct submission of AC x **or** AC y **or** AC z
IC	Access only after submission of IC
PIN	Access only after submission of PIN
PIN, IC	Access only after submission of PIN **and** IC
AC x, IC	Access only after submission of AC x **and** IC
AC x, PIN, IC	Access only after submission of AC x, **and** PIN **and** IC
AC x, AC y, PIN	Access only after correct submission of AC x **or** AC y, **and** PIN
AC0	No access

AC x	requires Application Code x
PIN	requires PIN code
IC	requires Issuer Code

A Security Attribute is defined in one byte as follows:

bit 7							bit 0
IC	PIN	AC5	AC4	AC3	AC2	AC1	AC0

Each bit of the byte represents a code. If the bit is set to '1', the corresponding code must have been submitted. If the bit is set to'0', the corresponding code is irrelevant for the access condition.

3.3. Internal Data Files

With exception of the Account Data Structure, which has associated a special set of commands, the memory areas of the Internal Data Memory are processed as data files.

The attributes of the Internal Data Files are defined in the card operating system and cannot be changed. However, the security attributes depend on the card life cycle stage.

The following Internal Data Files are defined:

		File Security Attributes			**Record Organization**
Memory Area	**Internal File ID**	**Manufacturing Stage**	**Personalization Stage**	**User Stage**	
MCU-ID File	FF 00_H	R: FREE W: NO ACCESS	R: FREE W: NO ACCESS	R: FREE W: NO ACCESS	2 x 8 bytes
Manufacturer File	FF 01_H	R: FREE W: IC	R: FREE W: NO ACCESS	R: FREE W: NO ACCESS	2 x 8 bytes
Personalization File	FF 02_H	R: FREE W: IC	R: FREE W: IC	R: FREE W: NO ACCESS	3 x 4 bytes
Security File	FF 03_H	R: IC W: IC	R: IC W: IC	R: NO ACCESS W: IC	12 x 8 bytes
User File Management File	FF 04_H	R: FREE W: IC	R: FREE W: IC	R: FREE W: IC	N_OF_FILE x 7 bytes
Account File	FF 05_H	R: FREE W: IC	R: FREE W: IC	R: IC W: IC	8 x 4 bytes
Account Security File	FF 06_H	R: FREE W: IC	R: FREE W: IC	R: NO ACCESS W: IC	4 x 8 bytes
ATR File	FF 07_H	R: FREE W: IC	R: FREE W: IC	R: FREE W: NO ACCESS	1 X 36 bytes
User File Data Area	File IDs: xx yy_H $xx \neq FF_H$	According to the file definitions			

3.3.1. MCU ID File

The MCU ID File contains two records of eight bytes each. The contents of this file are determined during the chip manufacturing process and cannot be altered.

The first record contains an 8 byte unique serial number of the chip. The second record contains ACOS3's version number – namely ACOS3 Revision XX.YY ZZ Kbyte EEPROM (41 43 4F 53 03 XX YY ZZ_H).

XX is the major version

YY is the minor version

ZZ is the user EEPROM capacity

This file is always free for READ access but not WRITE accessible.

3.3.2. Manufacturer File

The Manufacturer File comprises two records of eight bytes each that are written in the Manufacturing Stage of the card life cycle. After termination of the Manufacturing Stage, this file is read-only and free for READ access.

The termination of the Manufacturer Stage is indicated by writing a '1' into the MSB of byte 1 of the first record in the Manufacturer File (Manufacturer Fuse). After the next reset of the card, the Manufacturing Stage can never again be entered.

Manufacturer File, first record:

byte 1							byte 8
M/A/B							

M (bit7) = Manufacturer Fuse /
A (bit6) = INQ_ACC_MAC Flag /
B (bit5) = RECORD_NUMBERING Flag

Only the bits in M, A, B are interpreted by the operating system.

INQ_ACC_MAC flag affects the INQUIRY ACCOUNT command only. A one in this flag makes the composition of the MAC calculation including the credit and debit transaction reference. Please refer to the section of INQUIRY ACCOUNT for the details.

RECORD_NUMBERING flag affects the record numbering system of the whole card. This flag when one indicates that the records are numbered from 1 to N, a zero in this flag indicates that the records are numbered from 0 to N-1 (where N is the number of records in the file).

3.3.3. Personalization File

The Personalization File comprises 12 bytes, arranged as 3 records of 4 bytes each.

The Personalization File is written during the Personalization Stage of the card life cycle. After termination of the Personalization Stage, this file is read-only and free for READ access.

The termination of the Personalization Stage is indicated by writing a '1' into the MSB of byte 4 of the first record in the Personalization File (Personalization Bit). The change of stage will be effective immediately after the next reset of the card.

Personalization File:

Personalization Bit

	byte 1			byte 4
Record 1	Option Register	Security Option Register	N_OF_FILE	**P**
2				
3				

The first three bytes of the first record of the Personalization File are used to set certain parameters and to enable/disable optional features of the card operating system:

Byte 1 is called the *Option Register* and contains five option bits:

MSB							LSB
INQ_AUT	TRNS_AUT	REV_DEB	DEB_PIN	DEB_MAC	PIN_ALT	3DES	ACCOUNT

ACCOUNT This bit indicates whether the Account Data Structure is available in the card. If the bit is not set, indicating that the Account Data Structure is not present, the memory space required for storing the Account Data Structure and the associated security data is available for User Data Files and the Account processing commands cannot be executed.

3DES This bit indicates whether the encryption is DES or 3DES. If the bit is not set, single DES will only be performed. If the bit is set, triple DES is only supported.

PIN_ALT This bit determines whether the PIN code can be changed through the CHANGE PIN command. If the bit is set, the PIN code can be changed after it has successfully been submitted to the card.

DEB_MAC This bit indicates whether the DEBIT transaction must be authenticated by a MAC cryptographic checksum (see 'DEBIT'). If the bit is not set, the card does not evaluate the data transmitted as MAC checksum in the DEBIT command.

DEB_PIN This bit indicates whether the PIN code must be submitted for the DEBIT command. If the bit is set, the DEBIT command is only carried out after the PIN code has successfully been submitted to the card (see 'DEBIT').

REV_DEB This bit determines whether the card can execute the REVOKE DEBIT command. If the bit is not set, the card will reject the REVOKE DEBIT command. (see ‘REVOKE DEBIT’)

TRNS_AUT This bit determines whether the Account Transaction processing requires the previous completion of the mutual authentication process, and the use of the current Session Key in the computation of the MAC cryptographic checksums. If the bit is set, the mutual authentication must have been executed prior to any Account Transaction command and the MAC cryptographic checksum must be DES encrypted with the current session key before it is sent to the card.

INQ_AUT This bit determines whether the INQUIRE ACCOUNT command requires the previous completion of the mutual authentication process, and the use of the current Session Key in the computation of the MAC cryptographic checksum returned by the card in response to this command. If the bit is set, the mutual authentication must have been executed prior to the execution of the INQUIRE ACCOUNT command and the MAC cryptographic checksum is DES encrypted with the current session key before it is returned by the card.

NOTE: By enabling the options controlled by the bits TRNS_AUT and INQ_AUT, a *Unique Key per Transaction* scheme can be used with the Account transaction processing. This provides a very high security level.

Byte 2 is called the *Security Option Register* and contains seven option bits:

MSB LSB

IC_DES	PIN_DES	AC5_DES	AC4_DES	AC3_DES	AC2_DES	AC1_DES	-

These bits specify for the corresponding Secret Codes (IC, PIN, AC1...AC5), whether the codes are presented to the card in plain or encrypted. If a bit is set to ‘1’, the corresponding code submitted in the SUBMIT CODE command must be encrypted with the current session key before it is presented to the card. This means, the Mutual Authentication as described later in this document must have been completed.

If a bit is set to '0', the corresponding code is submitted in plain without encryption.

The bit PIN_DES also determines whether encryption is used with the CHANGE PIN command. If the bit is set, the new PIN code must be encrypted with the current session key before it is submitted in the CHANGE PIN command.

For security reasons it is highly recommended that in any application the IC must be submitted in encrypted form in the User Stage!

NOTE: The *Option Register* and the *Security Option Register* are evaluated by the ACOS3 operating system only after a card reset. After changing any option bit during the card personalization, a card reset must be performed in order for the change to take effect.

Byte 3 only has one significant bit:

N_OF_FILE This value specifies the number of data files allocated in the File Data Area. The card operating system expects that accordingly N_OF_FILE File Definition Blocks have been written as records in the User File Management File. The maximum number of files allowed in ACOS3 is 31.

Only the first 4 bytes of the Personalization File are interpreted by the card operating system.

The first 8 bytes (2 records) of the Personalization File are transmitted in the Historical Bytes in the Answer-To-Reset. The last record of 4 bytes can be personalized with user data not shown in the ATR.

3.3.4. Security File

The Security File stores the following information:

- The key pair used for card authentication.
- The five Application Codes used for the file access control.
- The Issuer Code IC.
- The PIN code.
- Error counters for limiting the number of unsuccessful code presentations and authentication.
- The seed for the random number generator.

The Security File can only be read during the Manufacturing Stage and the Personalization Stage of the card life cycle, after presentation of the correct IC.

*** **After termination of the Personalization Stage, there is NO possibility**
*** **to read the Security File**.

The Security File can be written in the Manufacturing Stage and in the Personalization Stage after presentation of the correct IC, and in the Issuer Mode of the User Stage.

The Security File comprises 14 records of 8 bytes length each and is organized as follows:

	byte 1															byte 8
Record 1	Issuer Code IC															
2	PIN															
3	Authentication Card Key K_C															
4	Authentication Terminal Key K_T															
5	Random Number Seed for RND_C															
6	Application Code AC1															
7	Application Code AC2															
8	Application Code AC3															
9	Application Code AC4															
10	Application Code AC5															
11	CNT AC1		CNT AC3	CNT AC2	CNT AC5	CNT AC4	CNT IC	CNT PIN		CNT K_T			CNT K_{rd}	CNT K_d		CNT K_{cr}
12	SCN AC1		SCN AC3	SCN AC2	SCN AC5	SCN AC4	SCN IC	SCN PIN		SCN K_T			SCN K_{rd}	SCN K_d		SCN K_{cr}
13	Right half of 3DES Authentication Card Key K_C															
14	Right half of 3DES Authentication Terminal Key K_T															

CNT xxx = Counter for the successive submission of wrong key / code xxx

SCN xxx = Starting CNT value. (See Section 4.3.6 for more information)

NOTE: Caution must be taken when writing record #11 and #12 during card personalization. Inadvertently writing a wrong value to this record may permanently lock the card and render it useless!

NOTE: Record numbers 12 is available in ACOS3 version 1.04 or above only.

NOTE: Record numbers 13 and 14 are available in ACOS1 version 3.0 or above only (It is available in ACOS3). The right half of the authentication keys is stored here. When single DES option is selected, these are not used but present.

3.3.5. User File Management File

The User File Management File consists of N_OF_FILE records of 6 bytes each and stores a File Definition Block for an allocated User Data File in each record.

The File Definition Blocks are written during the Personalization Stage of the card life cycle. After termination of the Personalization Stage, this file is free for read access and can be written after the Issuer Code has been submitted.

The sequence of File Definition Blocks in the User File Management Area is not relevant. When the SELECT FILE command is issued, the card operating system searches all File Definition Blocks for one whose File Identifier entry matches the value specified in the SELECT FILE command.

The Card Operating System does not provide any error checking on the File Definition Blocks nor does it check the consistency of the number of file definition blocks written with the parameter N_OF_FILE. Any inconsistency of these data can lead to a malfunction of the card.

3.3.6. User File Data Area

The User File Data Area stores the data written to the User Data Files. Security attributes are attached to User Data Files, which control the access to the data in the files.

User Data Files cannot be deleted. Once allocated, the memory space for a User Data File is reserved and cannot be released when the file is no longer used.

3.3.7. Account File

The Account File stores the Account Data Structure used for highly secure payment applications.

If the option bit ACCOUNT in the option registers is not set, this file is not processed by the card operating system and the memory space is available for User Data Files.

The Account File can be written during the Manufacturing and Personalization Stage of the card life cycle after presentation of the correct IC code. After Termination of the Personalization Stage, this file can be written after the Issuer Code has been submitted.

The Account File contents are explained in detail in section 4. *Account Transaction Processing*.

3.3.8. Account Security File

The Account Security File stores the four secret keys used for the calculation of the MAC cryptographic checksums used in connection with the Account processing commands.

The Account Security File can only be read during the Manufacturing Stage and the Personalization Stage of the card life cycle.

*** **After termination of the Personalization Stage, there is NO possibility**
*** **to read the Account Security File**.

The Account Security File can be written in the Manufacturing Stage and in the Personalization Stage after presentation of the correct IC code, and in the Issuer Mode.

If the option bit ACCOUNT in the option registers is not set, this file is not processed by the card operating system and the memory space is available for storage User Data Files.

The Account Security File contents are explained in detail in section *4. Account Transaction Processing.*

3.3.9. ATR File

The application developer can change the card's Answer-To-Reset string by setting the customized ATR into this file. The file contains 1 36-byte record. The 1st byte of this record allows the speed of the card to be customized. The second and subsequent bytes allow changes to the historical bytes of the ATR to change. If these fields are found to be invalid, the card OS will then use the default values in the ATR.

Please see Section 5.0 for more information.

3.4. User Data Files

User Data Files are allocated in the Personalization Stage of the card life cycle. There are two types of User Data Files, Record and Binary files. Record files are specified by number of records and a fixed record length. Binary files are specified by a file size and accessed via offsetting into the file.

The data stored in a User Data File can be read through the READ RECORD / BINARY command and updated through the WRITE RECORD / BINARY command when the security conditions associated to the data file are fulfilled.

User Data Files are defined by writing the corresponding File Definition Blocks in the records of the User File Management File during the Personalization Stage. It is not possible to change the number of records of a file once any of the User Data Files has been used. User will be able to access these data as long as it's within the capacity of the card.

A User Data Record File can contain up to 255 records of maximum of 255 bytes record length each. A User Data Binary File can have a specified size up to the length of the card.

Care must be taken by the card issuer to assure that the memory space allocated for all User Data Files does not exceed the available memory space! ACOS3 does not check the available memory space at the time of allocation. Writing and reading beyond the capacity of the card will result in an error condition.

3.4.1. User File Definition Block

Each User Data File is described in an associated File Definition Block which contains the file identifier, record length/number (or file length) and security attributes and flags. Each File Definition Block comprises 7 bytes:

byte 1	byte 2	byte 3	byte 4	byte 5 / 6	byte 7
Record Length	Number of Records	Read Security Attribute	Write Security Attribute	File Identifier	File Access Flags

OR

byte 1	byte 2	byte 3	byte 4	byte 5 / 6	byte 7
File Length (High Byte)	File Length (Low Byte)	Read Security Attribute	Write Security Attribute	File Identifier	File Access Flags

The two types of User Data File correspond to the Record and Binary file types respectively and it is distinguished by the File Access Flag field described below.

The File Definition Blocks of all files are stored in the User File Management File. They can be read through READ RECORD commands after selection the User File Management File with the SELECT FILE command.

The number of records in the User File Management File is given by the value of the parameter N_OF_FILE in the option register.

The File Access Flag contains the following fields:

b7	b6	b5	b4	b3	b2	b1	b0	Meaning
0								Record File type – byte 1 and 2 of User File Definition Block specifies Record Length and Record Number respectively
1								Binary File type – byte 1 and 2 of User File Definition Block specifies File Length
	1							Read requires Secure Messaging
		1						Write requires Secure Messaging
			0	0	0	0	0	Reserved for future use

On default, File Access Flags will be 00$_H$ which will correspond to record file type and no secure messaging required. This will be backward compatible to previous versions of ACOS1/2/3.

3.4.2. User File Allocation

For the allocation of User Data Files in a new card, follow the steps as listed below. It is assumed that the IC has been presented to the card prior to this operation such that the Internal Data Files can be written.

1. Use the SELECT FILE command with file ID = FF 02$_H$ to select the Personalization File.
2. Write the number of User Data Files required to the option register N_OF_FILE, which is the third byte of the first record of the Personalization File, to allocate the required space (number of records) in the User File Management File.
3. Use the SELECT FILE command with file ID = FF 04$_H$ to select the User File Management File.
4. Write the N_OF_FILE file definition blocks to the User File Management File with the WRITE RECORD command. Write the seven bytes of each File Definition Block at once.
5. Now the User Data Files can be selected and read and written.

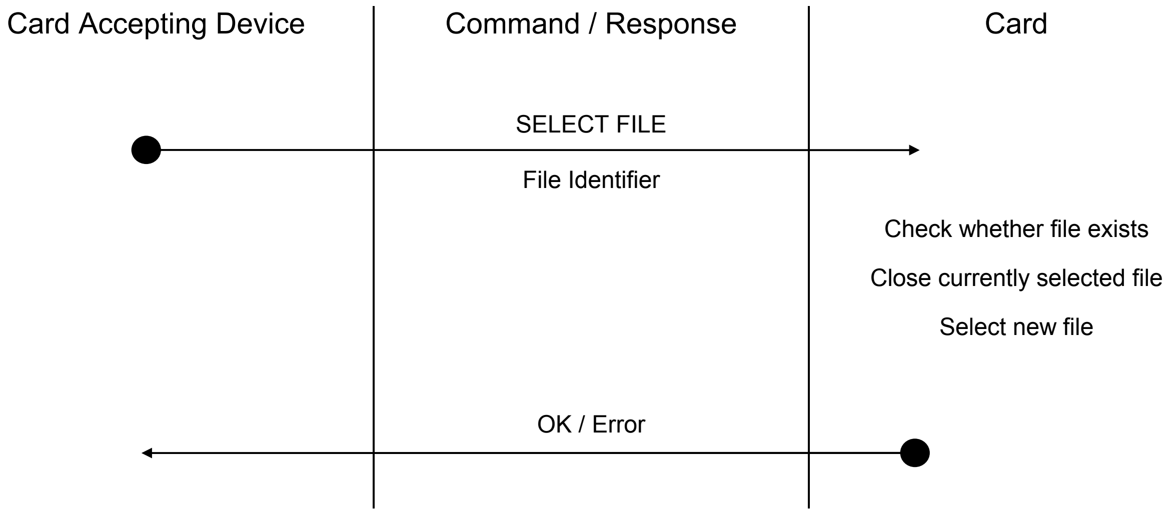
3.5. Data File Access

The process of data file access is identical for Internal Data Files and for User Data Files.

3.5.1. SELECT FILE

The SELECT FILE command can be executed any time. The specified file - if existent - will be selected and the previously selected file - if any - will be closed. If the specified file does not exist, the card returns an error code and does not change the status of a currently selected file. The security conditions specified for the newly selected file are not checked in the SELECT FILE processing and the Mutual Authentication need not be completed prior to the execution of the SELECT FILE command. After a card reset, no file is selected.

The SELECT FILE command is carried out as follows:



File Identifier Two bytes file identifier of the file to be selected

3.5.2. READ RECORD / BINARY

The READ RECORD / BINARY command can be executed once a file has been selected through the SELECT FILE command.

The security conditions associated to the currently selected file are checked prior to the execution of the command by the card. If the security conditions are not fulfilled (i.e., the specified secret codes have not been submitted to the card), the command is rejected by the card.

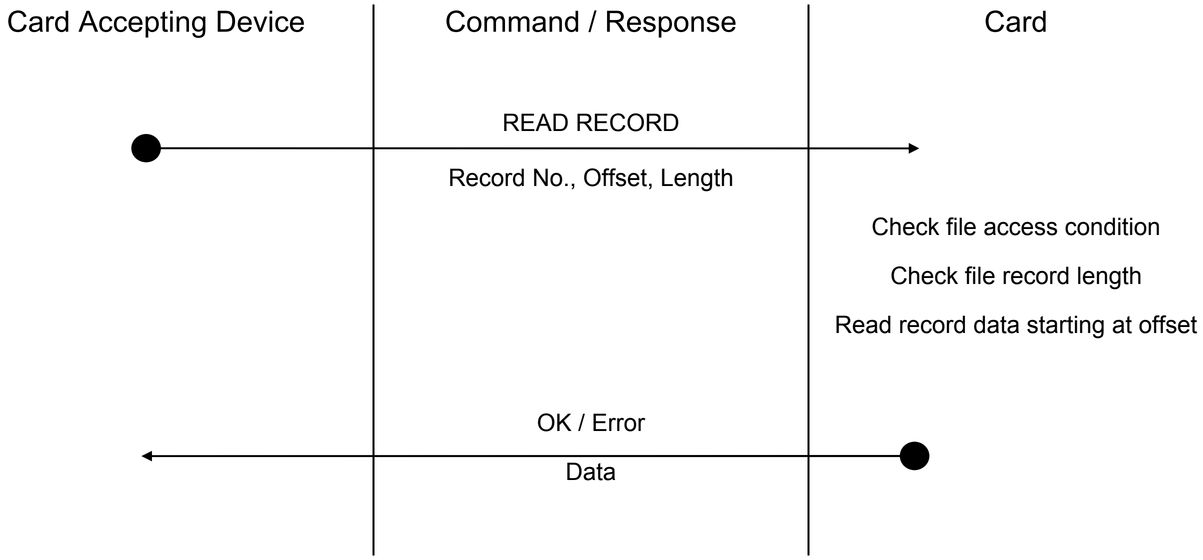
For READ RECORD, data from only one record can be read in each READ RECORD operation. The number of bytes and offset to be read is specified in the command.

For READ BINARY, the number of bytes and offset to be read is specified in the command.

The maximum number of bytes to be read is equal to the record length.

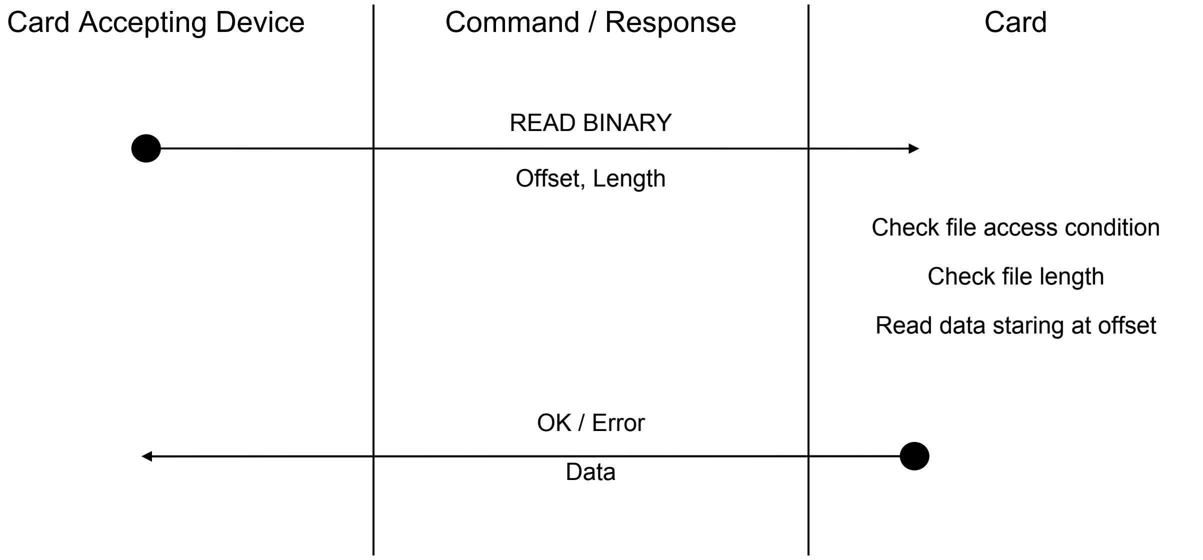
If the number of bytes read (= N) is smaller than the record length, the first N bytes of the record are returned by the card.

The READ RECORD command is carried out as follows:



Record No.	One byte logical record number
Offset	The byte to start reading from within the record
Length	Number of data bytes to be read from the record, max. 255
Data	Record data, *Length* bytes

The READ BINARY command is carried out as follows:



Length	Number of data bytes to be read
Offset	The byte to start reading from within the file

Data	Record data, *Length* bytes

3.5.3. WRITE RECORD

The WRITE RECORD command can be executed once a file has been selected through the SELECT FILE command.

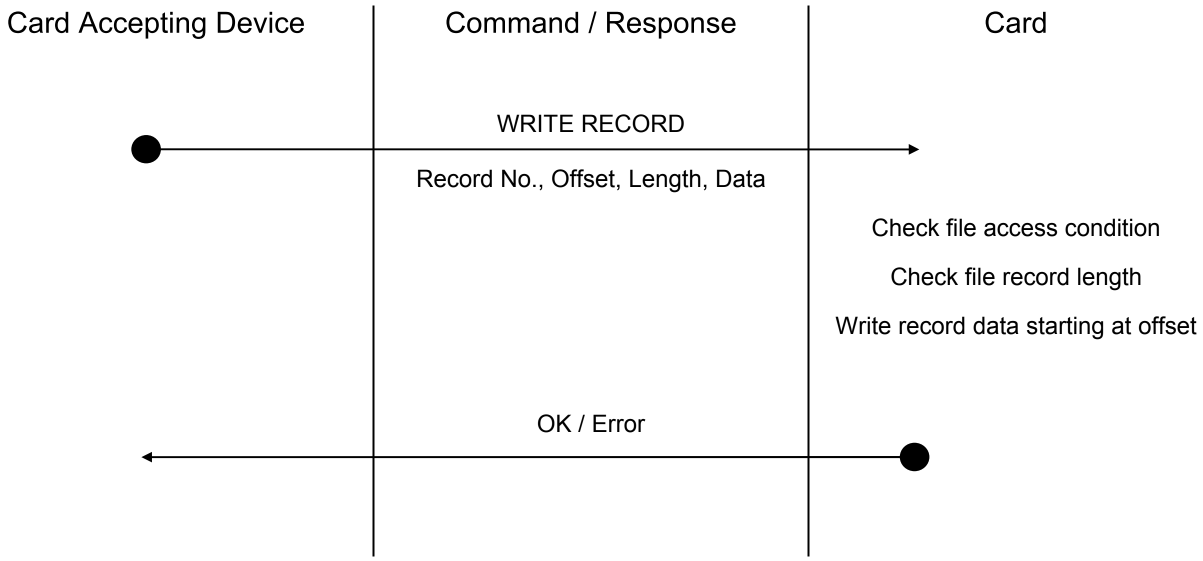
The security conditions associated to the currently selected file are checked prior to the execution of the command by the card. If the security conditions are not fulfilled (i.e., the specified secret codes have not been submitted to the card), the command is rejected by the card.

For WRITE RECORD, data can be written to only one record in each WRITE RECORD operation. The number of bytes and offset to be written in the record is specified in the command.

For WRITE BINARY, the number of bytes and offset to be written is specified in the command.

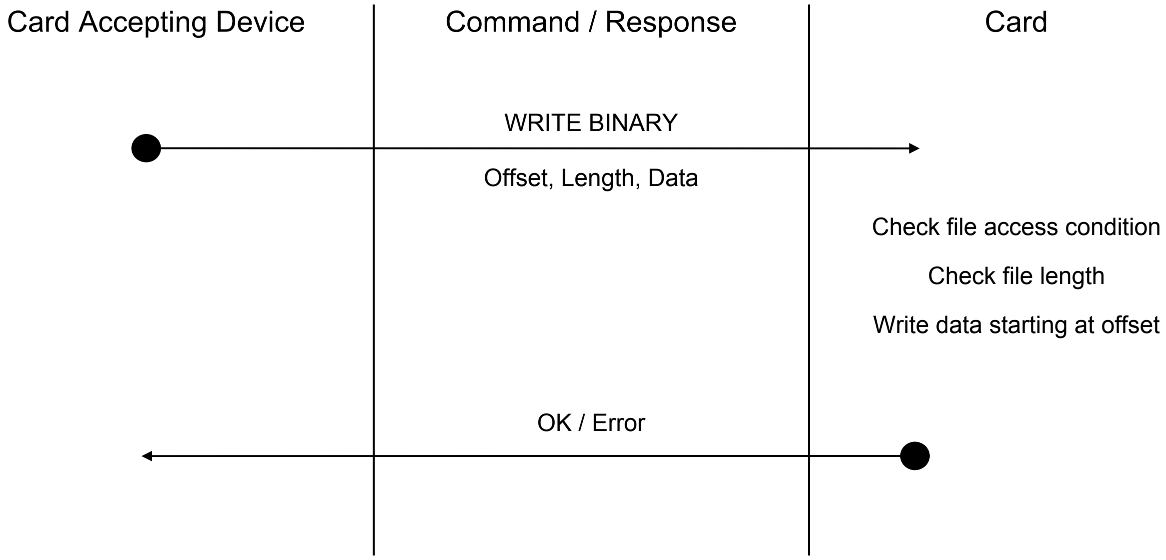
The maximum number of bytes to be written is equal to the record or file length.

The WRITE RECORD command is carried out as follows:


Card Accepting Device
Command / Response
Card
WRITE RECORD
Record No., Offset, Length, Data
Check file access condition
Check file record length
Write record data starting at offset
OK / Error

Record No.	One byte logical record number
Offset	Offset in the record to begin writing.
Length	Length of data to write
Data	Data bytes of Length bytes to be written to the record

The WRITE BINARY command is carried out as follows:



Offset Offset in the file to begin writing.

Length Length of data to write

Data Data bytes of Length bytes to be written to the file

3.6. Account Data Structure

The Account Data Structure - *Account*, for short - is dedicated for the use in applications in which a numeric value representing some ‘amount’ must be securely processed. The Account is stored in the Account File.

In the User Stage of the card life cycle, the data in the Account cannot be manipulated by WRITE instructions like the data in User Data Files. A set of dedicated instructions is available for the processing of the Account, i.e. for adding value to and subtracting value from the balance in the Account and for reading the current balance.

Different access conditions can be specified for adding to, subtracting from and reading the Account.

Critical Account operations, for example, CREDIT, are carried out under strict security control conditions, as explained below in 'Account Transaction Processing'.

The Account Data Structure in the Account File has the following form:

	byte 1			byte 4
Record 1	TRANSTYP 0	BALANCE 0		
2	ATC 0		CHKSUM 0	00
3	TRANSTYP 1	BALANCE 1		
4	ATC 1		CHKSUM 1	00
5	MAXBAL			00
6	AID			
7	TTREF_C			
8	TTREF_D			

TRANSTYP Together with the balance values is stored the type of transaction that resulted in that balance value. This information is updated when the balance value is updated. The following transaction types are distinguished: CREDIT, DEBIT, and REVOKE DEBIT.

BALANCE Balance value is three bytes long, can store a value of up to 16.8 Million (2^24-1). Only positive integer values are possible for the Balance.

ATC The Account Transaction Counter ATC is incremented before each transaction to give a unique electronic signature for each transaction. Together with the Account ID AID, the ATC builds the Account Transaction reference ATREF, which is used in the calculation of MAC cryptographic checksums to certify the execution of Account related commands by the card. When ATC reaches its maximum value (FF FF_H), the operating system does not allow any further transaction.

CHKSUM The checksum is the least significant byte of the algebraic sum of the bytes of TRANSTYP, BALANCE and ATC, plus one.

MAXBAL The Maximum Balance value is checked by the operating system when a CREDIT transaction is performed. If the sum of current balance plus the amount to be credited exceeded the Maximum Balance value, the card will reject the CREDIT command.

AID The Account Identification is a four bytes value that is combined with the Account Transaction Counter (ATC) to give the six bytes ATREF:

byte 1	byte 4	byte 5	byte 6
AID		ATC	

The AID is written once in the Personalization Stage of the card life cycle. It is never modified.

TTREF-C The Terminal Transaction Reference - Credit is provided by the Card Accepting Device when a CREDIT transaction is executed. It is only stored but not interpreted by the card. The Card Accepting Devices can evaluate this information, for example, to reject a card that has been credited by an unauthorized terminal.

TTREF-D The Terminal Transaction Reference - Debit is provided by the Card Accepting Device when a DEBIT or REVOKE DEBIT transaction is executed.
The TTREF-D is stored in the Account when a DEBIT transaction is executed. The REVOKE DEBIT command will only be executed if the TTREF-D submitted with the command is identical with the stored TTREF-D. This identity proves that the same terminal that issued the preceding DEBIT command issued the REVOKE DEBIT command.

TRANSTYP, BALANCE and ATC are stored two times to prevent a loss of this important information when a power-fail or a card reset occurs during a transaction. The larger of the two ATC values in the account indicates the data set used in the most recent transaction.

The checksum is used to verify the integrity of the data in the Account. The checksum is calculated when the account data are updated in a transaction. The checksum is verified by the card operating system before any transaction is executed.

NOTE: If the checksum is found incorrect, the card allows the execution of transactions only in the Issuer Mode, i.e., after the submission of the Issuer Code IC.

3.6.1. Account Processing Keys

The encryption keys used in the computation of MAC cryptographic checksums with the Account processing are stored as records in the Account Security File as follows:

Key storage for Single DES

Byte 1 Byte 8

Record 1	K_D
2	K_{CR}
3	K_{CF}
4	K_{RD}

K_D The DEBIT key, used in the computation of the MAC for the DEBIT command

K_{CR} The CREDIT key, used in the computation of the MAC for the CREDIT command

K_{CF} The CERTIFY key, used in the computation of the MAC with the INQUIRE ACCOUNT command

K_{RD} The REVOKE DEBIT key, used in the computation of the MAC for the REVOKE DEBIT command

NOTE: keys are 8-byte long

Key storage for Triple DES

byte 1 byte 8

Record 1	Right half of K_D
2	Right half of K_{CR}
3	Right half of K_{CF}
4	Right half of K_{RD}
5	Left half of K_D
6	Left half of K_{CR}
7	Left half of K_{CF}
8	Left half of K_{RD}

K_D The DEBIT key, used in the computation of the MAC for the DEBIT command

K_{CR} The CREDIT key, used in the computation of the MAC for the CREDIT command

K_{CF} The CERTIFY key, used in the computation of the MAC with the INQUIRE ACCOUNT command

K_{RD} The REVOKE DEBIT key, used in the computation of the MAC for the REVOKE DEBIT command

Note: keys are 16-byte long

4.0. SECURITY ARCHITECTURE

The following security mechanisms are provided by the ACOS3 card operating system:

- DES/3DES and MAC calculation
- Mutual Authentication and Session Key based on Random Numbers
- Secret Codes
- Secure Messaging for data files
- Secure Account Transaction Processing

DES refers to the DEA algorithm for data encryption and decryption as specified in the standard ANSI X3.93. MAC refers to the algorithm for the generation of cryptographic checksums (DEA in Cipher Block Chaining mode) as specified in the standard ANSI X3.93.

Mutual Authentication is a process in which both the card and the Card Accepting Device verify that the respective counterpart is genuine. The Session Key is a result of the successful execution of the Mutual Authentication. It is used for data encryption and decryption during a 'session'. A session is defined as the time between the successful execution of a Mutual Authentication procedure and a reset of the card or the execution of another START SESSION command.

Secret Codes and the PIN code are used to selectively enable access to data stored in the card and to features and functions provided by the card, for example, the READ and WRITE commands.

The Account Transaction Processing provides mechanism for the secure and auditable manipulation of data in the Account Data Structure, in particular, the balance value.

4.1. DES and MAC Calculation

All keys used in DES / 3DES and MAC calculation are 8 / 16 bytes long depending on Single / Triple DES selection in *Option Register*. The least significant bit of each byte of the key is not used in the calculation and is not interpreted by the card operating system.

4.2. Mutual Authentication and Session Key Generation

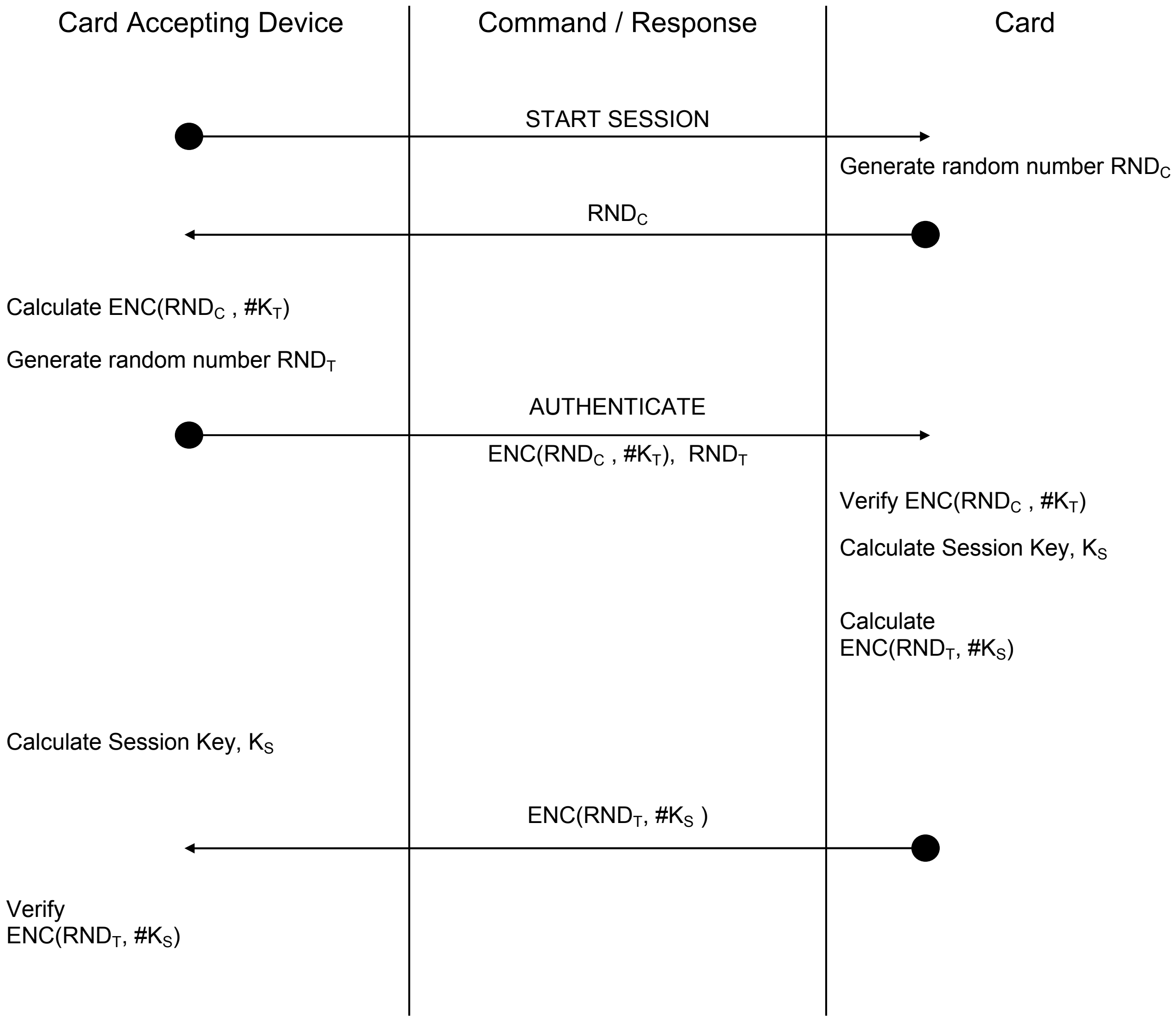
The Mutual Authentication is based on the exchange and mutual verification of secret keys between the Card and the Card Accepting Device. The key exchange is performed in a secure way by use of random numbers and DES data encryption.

ACOS3 maintains a dedicated pair of data encryption/decryption keys for the Mutual Authentication, K_T, called *Terminal Key*, and $K_{C,}$ called *Card Key*.

ACOS3 also provides a generator for the random numbers used in the Mutual Authentication process, RND_C, called *Card Random Number*.

The session key is the final result of the Mutual Authentication process and it is based on the random numbers of both card and terminal.

The Mutual Authentication process is carried out as follows:


Card Accepting Device
Command / Response
Card
START SESSION
Generate random number RND_C
RND_C
Calculate ENC(RND_C , #K_T)
Generate random number RND_T
AUTHENTICATE
ENC(RND_C , #K_T), RND_T
Verify ENC(RND_C , #K_T)
Calculate Session Key, K_S
Calculate
ENC(RND_T, #K_S)
Calculate Session Key, K_S
ENC(RND_T, #K_S)
Verify
ENC(RND_T, #K_S)

NOTE: ENC shall be DES or 3DES depending on *Option*

Calculation of Session Key K_S also depends on the encryption selected.

If single DES option has been selected

K_S = DES (DES (RND_C, $\#K_C$) ⊕ RND_T, $\#K_T$)

If Triple DES option has been selected,

Left half of K_S = 3DES (3DES (RND_C, $\#K_C$), $\#K_T$) **&** Right half of K_S = 3DES (RND $_T$, #(reverse K_T)),

where #(reverse K_T) is obtained by exchanging the Left and Right half of K_T

RND $_C$	Eight bytes random number generated by the Card
RND $_T$	Eight bytes random number generated by the Card Accepting Device
K_C	Card Key
K_T	Terminal Key
K_S	Session Key

The successful completion of the Mutual Authentication is recorded in the card. The resulting Session Key K_S is used for all data encryption and decryption during the same session.

The Mutual Authentication between Card and Card Accepting Device must be completed in the specified order. If any other card command is sent to the card interrupting the Mutual Authentication procedure as specified above, the card will abort the Mutual Authentication process and erase any intermediate data resulting from the preceding Mutual Authentication commands. The terminal must restart the complete Mutual Authentication procedure from the START SESSION command.

If after a successfully completed Mutual Authentication procedure the card receives the START SESSION command, it erases the previous session key and the complete Mutual Authentication procedure must be repeated to define a new session key. The current security status of the card will be maintained, i.e., Secret Codes that have successfully been submitted to the card need not be submitted again.

The card maintains an error counter CNT K_T to count and limit the number of consecutive unsuccessful executions of the AUTHENTICATE command:

- The error counter is incremented by one each time the AUTHENTICATE operation fails, i.e., a wrong K_T is presented to the card.
- The error counter is reset to SCN K_T when the AUTHENTICATE operation is successful.
- If the error counter reaches a value of 8 (eight), the card will not execute the command AUTHENTICATE any longer. In this case, all related security mechanisms (e.g., the submission of Secret Codes) are blocked. **This condition is irreversible and can render the card unusable.**

The error counter is stored in the Security File. The value of the counter is returned in the card response if a wrong K_T is used in the AUTHENTICATE command.

The Card Random Number RND_C is derived in a complex non-predictable mathematical process from the Random Number Seed stored in the Security File. The Random Number Seed is internally updated by the Operating System after each START TRANSACTION command.

4.3. Secret Codes

Secret codes stored in the card are used to restrict the access to data stored in user data files and to certain commands provided by the card. Secret codes must be presented to the card in order to be able to read data from or write data to user data files and to execute certain privileged card commands.

ACOS3 provides the following secret codes:

- Five Application Codes (AC)
- One Issuer Code (IC)
- One PIN Code (PIN)

4.3.1. Application Codes

Five Application Codes (AC1…AC5) are available to control the access to the data stored in data files. Each Application Code is eight bytes long.

An option bit in the Security Option Register in the Personalization File specifies for each code whether the code must be submitted to the card in plain or encrypted with the current session key.

4.3.2. Issuer Code

The Issuer Code is provided to control access to data files and to privileged card functions; it is eight bytes long.

An option bit in the Security Option Register in the Personalization file specifies for the IC whether it must be submitted to the card in plain or encrypted with the current session key.

4.3.3. PIN code

The PIN Code is provided to control access to data files.

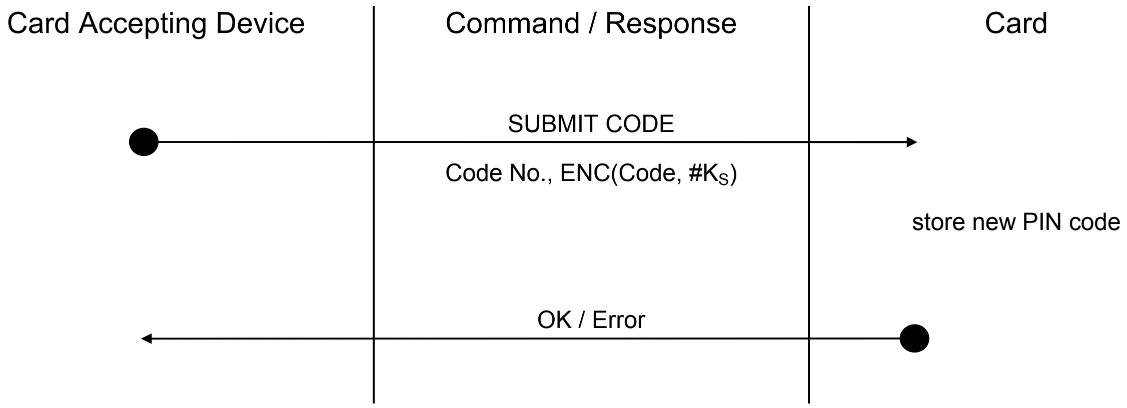
The PIN is eight bytes long. The PIN is presented to the card with the SUBMIT CODE command. Depending on the corresponding option bit PIN_DES in the Security Option Register, the PIN is DES encrypted with the current session key before the presentation to the card, or it is presented in plain.

The PIN code can be changed with the CHANGE PIN command if setting the PIN_ALT option bit in the option register has enabled this option. Depending on the option bit PIN_DES, the new code is DES encrypted with the current session key before it is written to the card, or it is written in plain.

4.3.4. Secret Code Submission and Error Counters

Depending on the setting of the corresponding bit in the Security Option Register, a code is submitted to the card in plain or DES-encrypted with the current session key.

If the option bit xx_DES for the code XX is set, the code is presented as follows:



NOTE: ENC shall be DES or 3DES depending on selected *Option*

Code No. Reference to the particular code that is submitted with the command:

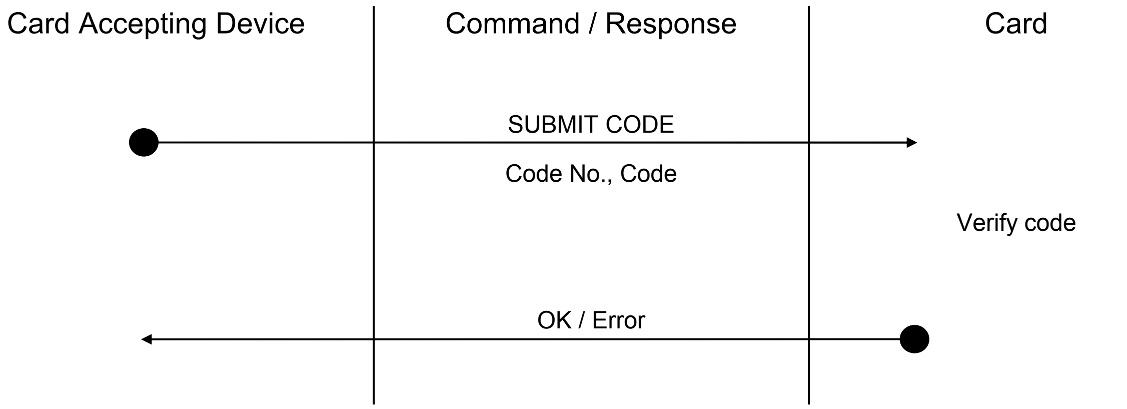
1 ... 5	=	Application Codes AC1...AC5
6	=	PIN
7	=	Issuer Code IC

Other values for *Code No*. are not allowed and will be rejected by the card.

Code The eight bytes secret code to be submitted

K_S The current session key

If the option bit xx_DES is not set, the DES encryption of the code is not necessary and the code is submitted in plain:



Code No. Reference to the particular code that is submitted with the command:

1 ... 5	=	Application Codes AC1...AC5
6	=	PIN
7	=	Issuer Code IC

Other values for *Code Number* are not allowed and will be rejected by the card.

Code The eight bytes secret code to be submitted

The card maintains an error counter CNT xx for each secret code to count and limit the number of consecutive unsuccessful executions of the SUBMIT CODE command:

- The error counter for a particular code is incremented by one each time the SUBMIT CODE operation for that code fails, i.e., a wrong secret code is submitted to the card.
- The error counter for a particular secret code is reset to SCN xx when the SUBMIT CODE operation for that code has successfully been executed.
- If the error counter reaches a value of eight (8), the card will reject the command SUBMIT CODE for that code.

The error counters CNT xx and starting counters SCN xx are stored in the Security File. The counter value for a particular code is returned in the response by the card to an unsuccessful SUBMIT CODE operation. To see how to change the error counter and starting CNT, please refer to Section 4.3.6.

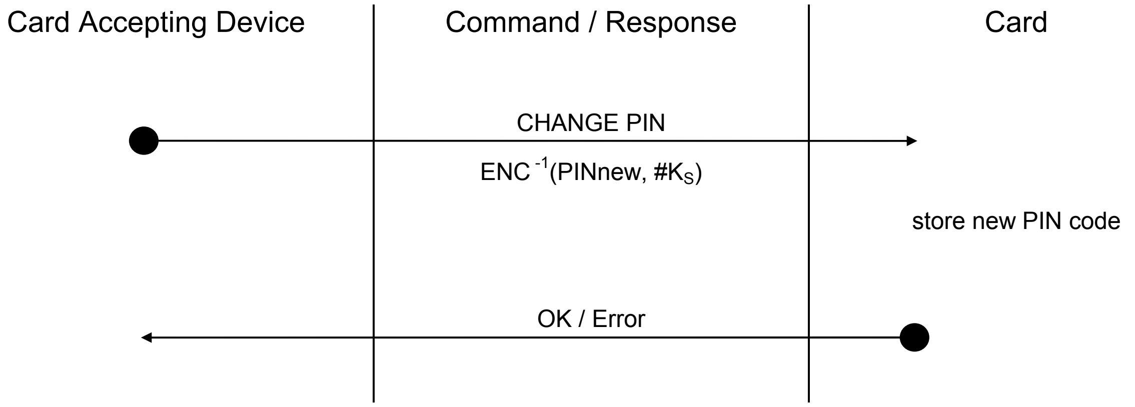
4.3.5. Change PIN Code

The PIN code can be changed in the User stage with the command CHANGE PIN if the option bit PIN_ALT is set.

To program a new PIN code in the card, the current PIN code must have been submitted first.

For security reasons, the CHANGE PIN command can only be executed immediately after a Mutual Authentication process. No other command must have been executed between the Mutual Authentication and the CHANGE PIN command. Otherwise, the command is rejected.

If the option bit PIN_DES is set, the changing of the PIN code is carried out as follows:

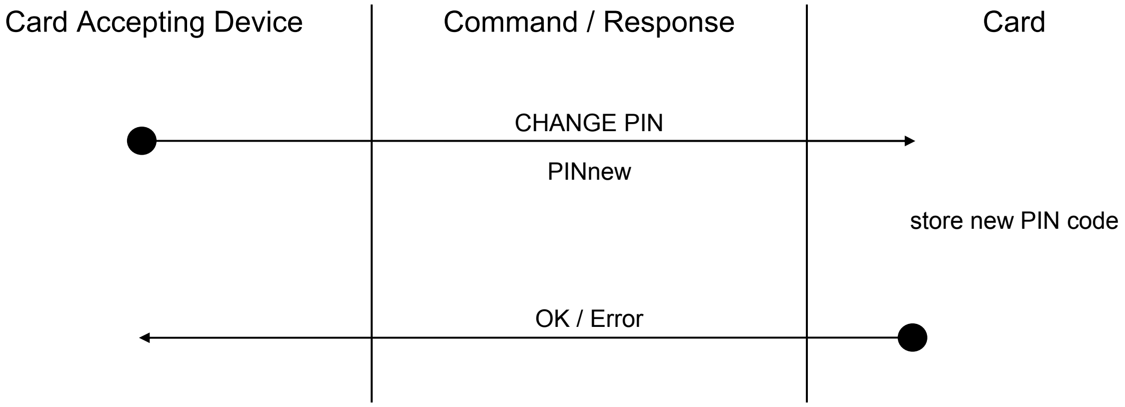


NOTE: ENC shall be DES or 3DES depending on selected *Option*

PINnew The new PIN code

K_S The current session key

If the option bit PIN_DES is not set, the DES^{-1} encryption of the new PIN is not necessary and the changing of the PIN code is carried out as follows:



4.3.6. Change Key and Code Retries

The terminal key KT and all codes have default maximum number of retries of 8. This can be customized by modifying the Starting CNT Value (SCN xxx) and the current Error Counter (CNT xxx). For example, to change the maximum number of retries for PIN to 3, the nibble corresponding to PIN in record #11 and record #12 can be written with 5.

IMPORTANT: Care must be taken when writing to record #11 and record 12. If any CNT or SCN are written with the nibble 8 or above, that code would be locked. If CNT_{IC} is greater than or equals to 8, the card would become permanently locked.

4.4. Secure Messaging

ACOS3 Version 1.05 and above supports secure messaging (SM) for data files. Secure messaging ensures data transmitted between the card and terminal/server is secured and not susceptible to eavesdropping, replay attack and unauthorized modifications. User data file can specify (In FF04$_H$) that secure messaging is required for Read / White Record / Binary commands. Almost all the other command can also use secure messaging initiated by the terminal. The commands that do not accept secure messaging are START SESSION, MUTUAL AUTHENTICATION and GET RESONSE.

The SM employed in ACOS3 both encrypts and signs the data transmitting into and out of the card. The card will interprets the terminal command is in SM mode if the CLA of the command has the secure messaging bits set.

Sections 4.4.1 to 4.4.7 discuss the constructs used in secure messaging. Section 4.4.8 details the exact constructs of secure messaging commands and response. Section 4.4.9 lists the secure messaging return codes.

4.4.1. Notations

To describe the two SM modes adequately, there are some notations to be introduced in this section. The following are the possible ISO7816 part 3 communications protocol command and response pairs.

Commands:

a. Without command data:

	CLA	INS	P1	P2	P3
Bytes	1	1	1	1	1

b. With command data

	CLA	INS	P1	P2	P3 = n	Data in
Bytes	1	1	1	1	1	n

Responses:

a. Without response data

	Sw1Sw2
Bytes	2

b. With response data

	Response	Sw1Sw2
Bytes	n	2

The class (CLA) byte stated above does not have the SM bits set.
The modified CLA* for SM in Section 4.4.8 has the SM bits b3 and b2 set to 1. That is, the original CLA XOR 0C$_H$.
P3 is the normal length of the command data.
P3* will be the length of the command data under SM.

4.4.2. Secure Messaging Key

The key used in secure messaging is the Session Key computed in Section 4.2. The SM Key is either DES or 3DES depending on the size of the Session Key generated.

4.4.3. Sequence Number

The sequence number (seq#) *n* is used as the initial vector in the CBC calculation. The start of the sequence number is the increment of the random number of the LAST TWO bytes of the Start Session command padded with 6 NULL bytes. The response data is the increment of the command sequence number. The sequence number is used to prevent man-in-the-middle attack.

If a command is sent from the terminal to the card SM'ed with a sequence number *n*, and secure messaging is successful, the card will reply with a MAC computed with *n* + 1. The next secure messaging command to send will use the sequence number *n* + 2. When the sequence number reaches 00 00 00 00 00 00 FF FF_H, the next number would be 00 00 00 00 00 00 00 00_H.

4.4.4. Authentication and Integrity

The COS and terminal will use the SM key and DES / 3DES in CBC mode to compute the MAC. The notation is as follows:

SIGN_CBC (data to sign, Initial Vector = seq#)

Only the first 4 bytes of the resultant MAC are used for the command and response data. When a SM command is sent to the card, the card will first verify the MAC_{cmd} with the command and command data. Only if the MAC_{cmd} is verified, will the COS execute the command. This will ensure that the data is genuinely from the terminal.

If the MAC_{cmd} verification failed (status word = 6988_H), the sequence number *n* would have been incremented. The next command should use *n* + 1. In the case that the sequence number is out of synchronization between the terminal and card, a new session key can be reestablished.

4.4.5. Confidentiality

The COS and terminal will use the SM key and DES / 3DES in CBC mode to compute the encryption. The notation is as follows:

ENC_CBC (plaintext to encrypt, Initial Vector = seq#)

After verifying the MAC_{cmd} the COS will decrypt the command data encrypted by the terminal. This command data will be written to the card based on the write binary or record command.

4.4.6. Padding

DES and 3DES algorithms take input block sizes of 8. Therefore appropriate padding is necessary. If the data to sign or encrypt is not in a multiple of 8, a 80_H byte is appended followed by 0 to 6 00_H to make the data to sign to be a multiple of 8 bytes. If data to sign or encrypt is a multiple of 8, then no padding is applied.

4.4.7. Secure Messaging Data Object

Secure Messaging Data Objects (SMDOs) are necessary to describe the data elements fully when transferring in SM mode. The following SMDOs are supported in ACOS3 Secure Messaging:

TAG	LENGTH	DESCRIPTION
87_H	Var.	Padding-content indicator byte followed by cryptogram
89_H	4	Command header (CLA* INS P1 P2)
$8E_H$	4	Cryptographic checksum
97_H	1	Original P3 in an ISO-out command
99_H	2	Processing status word (Sw1 Sw2) of the command.

The exact usage of these SMDOs is stated in the next section with the possible command and response data pair for SM.

4.4.8. Secure Messaging Semantics

Card commands are basically input and output commands– called ISO-IN and ISO-OUT. Some commands have both input and outputs and it needs to call GET RESPONSE to retrieve the outputs. This is called an ISO-IN-OUT command. In order to send out a secure messaging command, the normal APDU of Section 4.4.1 will be modified with SMDOs. The following two sections show how those modifications are to be done.

4.4.8.1. ISO-IN

In commands such as Write Record and Binary, the commands are extended with SMDOs as follows:

	CLA*	INS	P1	P2	P3*	87_H	L_{87}	Pi	Encrypted Data	$8E_H$	04_H	MAC_{cmd}
Bytes	1	1	1	1	1	1	1	1	n*	1	1	4

CLA* = CLA OR $0C_H$ = $8C_H$
P3* = 3 + n* + 2 + 4
L_{87} = n* + 1 (Length of Tag 87_H)
Pi = Padding indicator: 00 – No padding is used in encrypted data
$01\text{-}07_H$ – Number of padding bytes used in encrypted data
n* = P3 + length (padding) = P3 + Pi
Encrypted Data = ENC_CBC (<Command Data> padding, ++Seq#))
MAC_{cmd} = SIGN_CBC (<89_H 04_H CLA* INS P1 P2> <87_H L_{87} Pi Encrypted Data> padding, Seq#)

Since the maximum of P3* must be less than 255, with the MAC, padding and the SMDO, the original P3 must be less than or equal to 240 bytes. Note that in the MAC calculation, the sequence number is not pre-incremented. This is because the encryption and the MAC will use the same sequence number with the encryption to be performed first.

If the command accepts secure messaging, the key has been established and the MAC_{cmd} is correct, the response will be $610C_H$. Note that $610C_H$ may not actually mean that the command is successful. It merely means that the Secure Messaging is successful. A subsequent call to GET RESPONSE will yield the actual Status Words stating success or error. The GET RESPONSE must have P3 = $0C_H$ exactly. Otherwise $6C0C_H$ will be replied without SM.

The response to GET REPSONSE is as follows:

	99_H	02_H	Sw1Sw2	$8E_H$	04_H	MAC_{rsp}	9000_H
Bytes	1	1	2	1	1	4	2

MAC_{rsp} = SIGN_CBC (<89 04 CLA* INS P1 P2> <99 02 Sw1 Sw2> padding, ++Seq#)

The field Sw1Sw2 is the actual status word returned for the command. The last status word 9000_H states that the GET RESPONSE is successful.

4.4.8.2. ISO-OUT

The ISO-out commands effectively become an ISO-in command when the SM field is set.

	CLA*	INS	P1	P2	P3*	97_H	01_H	P3	$8E_H$	04_H	MAC_{cmd}
Bytes	1	1	1	1	1	1	1	1	1	1	4

CLA* = CLA OR $0C_H$ = $8C_H$
P3* = 9
MAC_{cmd} = SIGN_CBC (<89_H 04_H CLA* INS P1 P2> <97_H 01_H P3> padding, ++Seq#)

If the command accepts secure messaging, the key has been established and the MAC_{cmd} is correct, the response will be $61xx_H$. Same as ISO-in, the status word of $61xx_H$ only means that SM on the command is successful. The actual success of the overall command will depend on the SW1SW2 data object when a subsequent GET RESPONSE is called with P3 = xx, where xx can be $15\text{-}FD_H$.

Note the get response must be called with P3 = xx exactly, else $6Cxx_H$ will be returned. This is to prevent man in the middle attack. The original data out *n* must be less than or equal to 240 bytes. Else, error status 6700_H will be returned.

The response is as follows:

	87_H	L_{87}	Pi	Encrypted data	99_H	02_H	Sw1Sw2	$8E_H$	04_H	MAC_{rsp}	9000_H
Bytes	1	1	1	n*	1	1	2	1	1	4	2

L_{87} = n* + 1 (Length of Tag 87_H)
Pi = Padding indicator: 00_H – No padding is used in encrypted data
$01\text{-}07_H$ – Number of padding bytes used in encrypted data
Encrypted Data = ENC_CBC (<Response Data> padding, ++Seq#))
n* = P3 + length (padding) = P3 + Pi
MAC_{rsp} = SIGN_CBC (<89_H 04_H CLA* INS P1 P2> <87_H L_{87} Pi Encrypted Data> <99_H 02_H Sw1 Sw2> padding, Seq #)

Note that in the MAC calculation, the sequence number is not pre-incremented. This is because the encryption and the MAC will use the same sequence number with the encryption to be performed first.

4.4.8.3. ISO-IN-OUT

In commands such as INQUIRE ACCOUNT and DEBIT, the commands are extended with SMDOs as follows:

	CLA*	INS	P1	P2	P3*	87_H	L_{87}	Pi	Encrypted Data	$8E_H$	04_H	MAC_{cmd}
Bytes	1	1	1	1	1	1	1	1	n*	1	1	4

CLA* = CLA OR $0C_H$ = $8C_H$
P3* = 3 + n* + 2 + 4
L_{87} = n* + 1 (Length of Tag 87_H)
Pi = Padding indicator: 00 – No padding is used in encrypted data
$01\text{-}07_H$ – Number of padding bytes used in encrypted data
n* = P3 + length (padding) = P3 + Pi
Encrypted Data = ENC_CBC (<Command Data> padding, ++Seq#))
MAC_{cmd} = SIGN_CBC (<89_H 04_H CLA* INS P1 P2> <87_H L_{87} Pi Encrypted Data> padding, Seq#)

Since the maximum of P3* must be less than 255, with the MAC, padding and the SMDO, the original P3 must be less than or equal to 240 bytes. Note that in the MAC calculation, the sequence number is not pre-incremented. This is because the encryption and the MAC will use the same sequence number with the encryption to be performed first.

If the command accepts secure messaging, the key has been established and the MAC_{cmd} is correct, the response will be $61xx_H$. Same as ISO-in, the status word of $61xx_H$ only means that SM on the command is successful. The actual success of the overall command will depend on the SW1SW2 data object when a subsequent GET RESPONSE is called with P3 = xx, where xx can be $15\text{-}FD_H$.

Note the get response must be called with P3 = xx exactly, else $6Cxx_H$ will be returned. This is to prevent man in the middle attack. The original data out *n* must be less than or equal to 240 bytes. Else, error status 6700_H will be returned.

The response is as follows:

	87_H	L_{87}	Pi	Encrypted data	99_H	02_H	Sw1Sw2	$8E_H$	04_H	MAC_{rsp}	9000_H
Bytes	1	1	1	n*	1	1	2	1	1	4	2

L_{87} = n* + 1 (Length of Tag 87_H)
Pi = Padding indicator: 00_H – No padding is used in encrypted data
$01\text{-}07_H$ – Number of padding bytes used in encrypted data
Encrypted Data = ENC_CBC (<Response Data> padding, ++Seq#))
n* = P3 + length (padding) = P3 + Pi
MAC_{rsp} = SIGN_CBC (<89_H 04_H CLA* INS P1 P2> <87_H L_{87} Pi Encrypted Data> <99_H 02_H Sw1 Sw2> padding, Seq #)

Note that in the MAC calculation, the sequence number is not pre-incremented. This is because the encryption and the MAC will use the same sequence number with the encryption to be performed first.

4.4.9. SM specific return codes

The following table lists the the specific SM return codes:

SW1	SW2	Meaning
61	xx	SM successful, call Get Response to retrieve xx bytes.
67	00	The original P3 is greater than 240 bytes. SMDO overflow.
68	82	Secure messaging not allowed.
69	82	Condition of use not satisfied – Secure Messaging required but not present.
69	85	The Session Key has not been established.
69	87	Expected secure messaging data objects missing.
69	88	The MAC_{cmd} does not match the data.
6C	xx	Get Repsonse with xx byte as P3 is expected. Please re-issue Get Response with P3=xx.

4.5. Account Transaction Processing

Associated to the Account are four keys:

- The Credit Key K_{CR}
- The Debit Key K_D
- The Certify Key K_{CF}
- The Revoke Debit Key K_{RD}

The keys are stored in the Account Security File.

The keys are used in the calculation and verification of MAC cryptographic checksums on commands and data exchanged between the card and the Card Accepting Device in the Account processing.

All keys are 8 bytes long. The least significant bit of each byte of the keys is not used in the calculation and not interpreted by the card operating system.

Debit Key, Credit Key and Revoke Debit Key have each associated an error counter CNT K_{xx} to count and limit the number of consecutive unsuccessful executions of the transaction commands:

- The error counter for a key is incremented by one each time a command using the key fails due to a wrong key used by the Card Accepting Device.
- The error counter is reset to CNT K_{xx} when a command using the key is successful.
- If the error counter of a command reaches a value of eight (8), the card will reject any further commands using that key.

The error counters CNT K_{xx} for the transaction processing keys are stored in the normal Security File. Anti-tearing protection is done on the update to prevent a loss of this important information during update.

Four different transaction types can be executed on the Account Data Structure under security conditions:

- INQUIRE ACCOUNT
- DEBIT
- REVOKE DEBIT
- CREDIT

The Account Data Structure can be read as a record oriented file in the Manufacturing Stage, in the Personalization Stage and in the User Stage after presentation of the Issuer Code IC. In the normal User Stage, a WRITE access to the Account is possible only through the special Account processing commands. WRITE RECORD access is possible after presentation of the Issuer Code IC.

As an additional security feature for very security critical applications, the option bits TRNS_AUT and INQ_AUT in the Options Register allow to link the Account Processing to the Mutual Authentication.

If the option bit TRNS_AUT is set, the CREDIT, DEBIT and REVOKE DEBIT commands are executed by the card only after a successful completion of the Mutual Authentication. Furthermore, the MAC cryptographic checksum used to prove the authenticity and integrity of the respective command is encrypted with the current Session Key before it is transmitted to the card.

If the option bit INQ_AUT is set, the INQUIRE ACCOUNT command can be executed only after a successful completion of the Mutual Authentication and the MAC cryptographic checksum returned by the card to prove the integrity and authenticity of the account data is encrypted with the current Session Key.

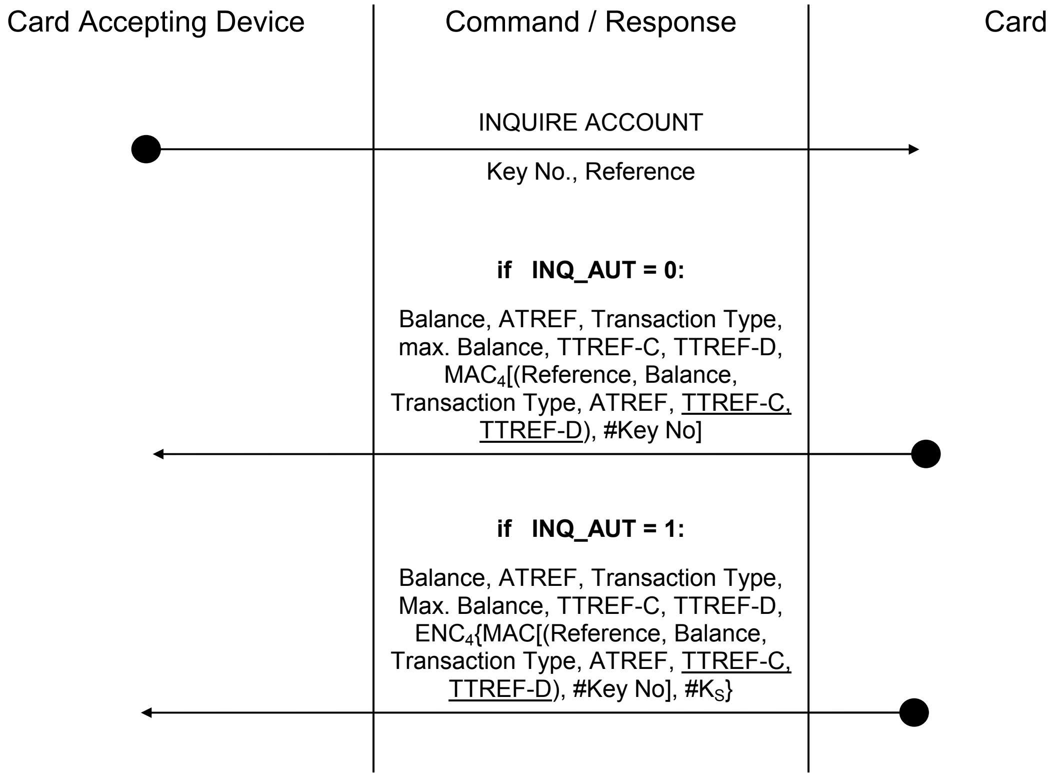
4.5.1. INQUIRE ACCOUNT

In the INQUIRE ACCOUNT transaction, the card returns the current balance value together with other relevant account information and a MAC cryptographic checksum on the relevant data. This signature can be regarded as a certificate issued by the card on the current balance and on the immediately preceding transaction. The key to be used in the generation of the MAC cryptographic checksum can be specified.

To prevent a replay of the response from a previous INQUIRE ACCOUNT command, the card-accepting device can pass a reference value to the card to be included in the MAC calculation.

If the option bit INQ_AUT is set, the Mutual Authentication process must have been completed prior to the execution of the INQUIRE ACCOUNT command.

The INQUIRE ACCOUNT transaction is carried out as follows:



INQUIRE ACCOUNT

Key No., Reference

if INQ_AUT = 0:

Balance, ATREF, Transaction Type, max. Balance, TTREF-C, TTREF-D, MAC_4[(Reference, Balance, Transaction Type, ATREF, TTREF-C, TTREF-D), #Key No]

if INQ_AUT = 1:

Balance, ATREF, Transaction Type, Max. Balance, TTREF-C, TTREF-D, ENC_4{MAC[(Reference, Balance, Transaction Type, ATREF, TTREF-C, TTREF-D), #Key No], #K_S}

Note : Underlined fields are included only when the INQ_ACC_MAC flag in the Manufacturer File is equal to one.

NOTE: ENC shall be DES or 3DES depending on selected *Option*

Reference Four (4) bytes reference value supplied by the card-accepting device to be included in the calculation of the MAC cryptographic checksum

Key No. Reference to the Account key to be used in the calculation of the MAC cryptographic checksum:

0	=	Debit Key K_{D1}
1	=	Credit Key K_{CR}
2	=	Certify Key K_{CF}
3	=	Revoke Debit Key K_{RD}

Other values are not permitted and will be rejected by the card.

Balance Current balance value

ATREF Account Transaction Reference of last transaction

Transaction Type One byte specifying the type of the last transaction performed on the Account:

1 = DEBIT
2 = REVOKE DEBIT
3 = CREDIT

Max. Balance The maximum allowed balance value in the card

TTREF-C Terminal Transaction Reference of the last CREDIT transaction

TTREF-D Terminal Transaction Reference of the last DEBIT transaction

MAC_4 The first 4 bytes of MAC cryptographic checksum using the key specified by *Key No.*

ENC_4 The first 4 bytes of the MAC cryptographic checksum using the key specified by *Key No.,* encrypted with the current Session Key $K_{S.}$

If INQ_ACC_MAC flag in Manufacturer file is zero, the first two blocks (16 bytes) will be used to calculate the MAC cryptographic checksum. If INQ_ACC_MAC flag is one, all three blocks (24 bytes) will be used to calculate the MAC cryptographic checksum.

1st block	2nd block
3rd block	

byte 1		byte 8	byte 1	byte 8
Reference	Transaction Type	Balance	ATREF	00 00
TTREF-C	TTREF-D			

NOTE: ACS writes The INQ_ACC_MAC flag before the devices are being shipped. It is not changeable by the card issuer.

4.5.2. DEBIT

In a DEBIT transaction, the balance in the Account is decreased by the specified amount. The maximum amount that can be debited to the Account is the current balance value. Negative balance values are not allowed.

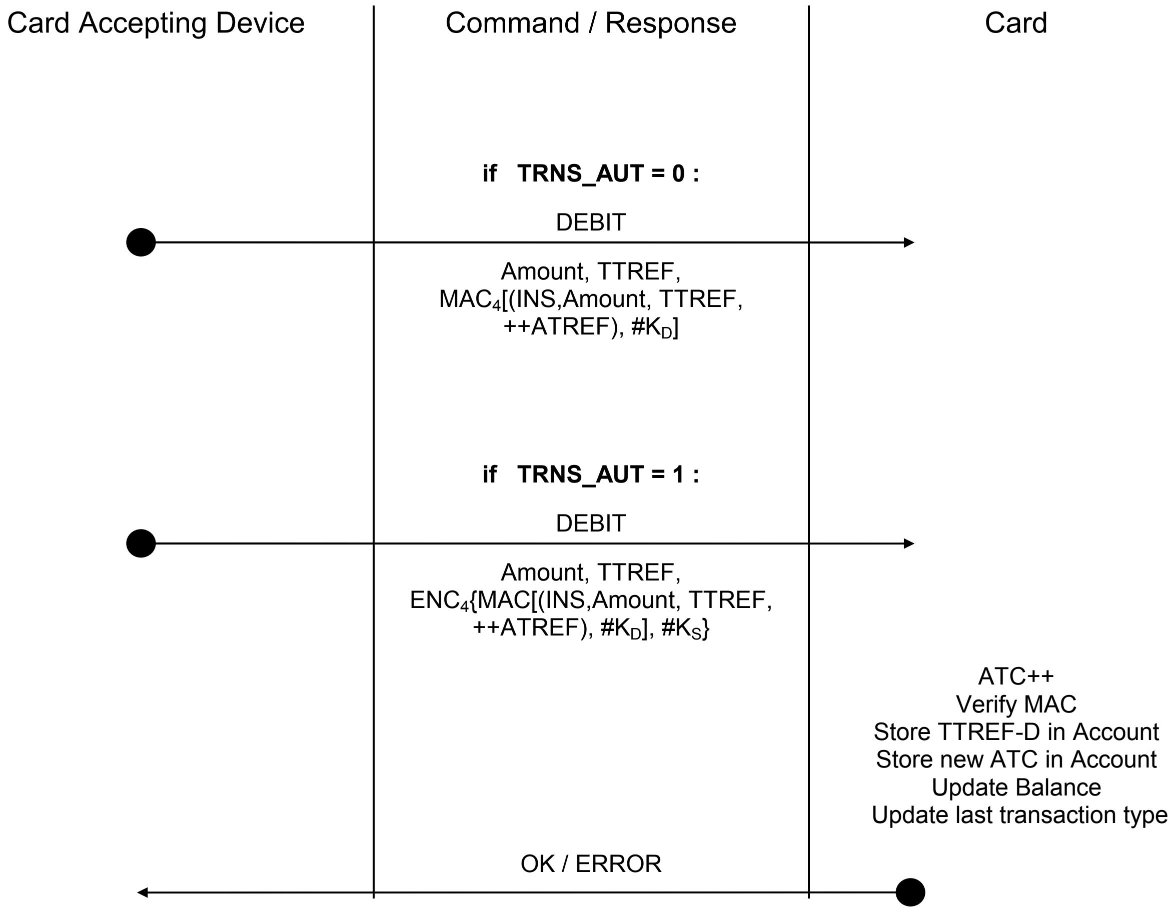
Different security conditions can be specified for the DEBIT transaction to allow for different security requirements. The security conditions for the DEBIT transaction are specified in the DEB_MAC and DEB_PIN option bits in the options register.

Proper setting of these option bits can specify four different security conditions:

DEB_MAC	DEB_PIN	Security Condition
0	0	no security checking; the DEBIT transaction can always be executed
0	1	the PIN code must have been submitted to the card prior to the execution of the DEBIT transaction
1	0	the MAC cryptographic checksum is required with the DEBIT transaction
1	1	the MAC cryptographic checksum with the DEBIT transaction is required **and** the PIN code must have been submitted to the card

If the option bit TRNS_AUT is set, the Mutual Authentication process must have been completed prior to the execution of the DEBIT command.

The DEBIT transaction is carried out as follows:



If OK and P1 = 1, Debit Certificate (DC)

If TRNS_AUT=0:

DC = MAC (Transaction Type, New Balance, Amount Debited, ATC, TTREFd)

If TRNS_AUT=1

DC = ENC$_4$(MAC (Transaction Type, New Balance, Amount Debited, ATC, TTREFd), #K$_s$)

NOTE: ENC shall be DES or 3DES depending on selected *Option*

TTREF	Terminal Transaction Reference for this DEBIT transaction
++ATREF	Account Transaction Reference for this transaction;
INS	ACOS3 instruction code for DEBIT command
Amount	Amount to be debited to the Account
K_D	Debit Key
MAC$_4$	The first 4 bytes of a MAC cryptographic checksum using K_D as the key.
ENC$_4$	The first 4 bytes of (MAC cryptographic checksum using K_D, encrypted with the current Session Key $K_{S.}$)

Note: The transaction counter in the card is <u>incremented</u> <u>before</u> the transaction is being executed!

The sixteen bytes data string on which the MAC cryptographic checksum is calculated is composed as follows:

1st block			2nd block	
byte 1		byte 8	byte 1	byte 8
E6$_{HEX}$	Amount	TTREF-D	ATREF	00 00

If the option bit DEB_MAC is not set, the 4 bytes of MAC cryptographic checksum must be transmitted in the command to the card but they are not evaluated by the operating system. The card will accept any value transmitted.

Debit Certificate

To make sure that the DEBIT command is indeed executed, the terminal may request for a DEBIT CERTIFICATE from the card. The DEBIT Certificate is a MAC cryptographic checksum computed by the DEBIT KEY and the following data block:

1st block				2nd block	
byte 1			byte 8 byte 1		byte 8
01	New Balance	Amount Debited	ATC	TTREFD	00 00 00

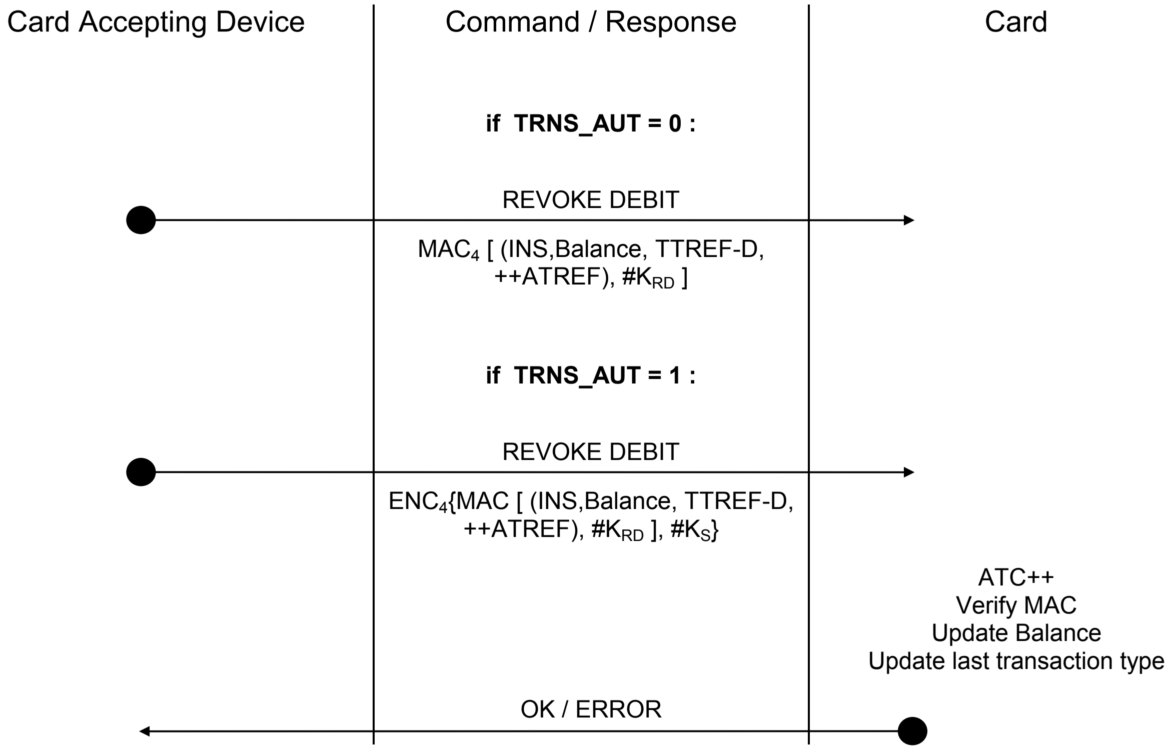
4.5.3. REVOKE DEBIT

A REVOKE DEBIT is only possible after a DEBIT transaction and applies always to the immediately preceding DEBIT transaction. The REVOKE DEBIT transaction can be executed to annul a DEBIT transaction, for example, if the amount debited was found wrong later on. As a result of the transaction, the balance value that was valid before the last DEBIT transaction is restored.

The REVOKE DEBIT transaction is enabled and disabled by the option bit REV_DEB in the option register.

If the option bit TRNS_AUT is set, the Mutual Authentication process must have been completed prior to the execution of the REVOKE DEBIT command.

The REVOKE DEBIT transaction is carried out as follows:



NOTE: ENC shall be DES or 3DES depending on selected *Option*

INS	ACOS3 instruction code for REVOKE DEBIT command
Balance	Balance value to be restored (= balance before the preceding DEBIT transaction)
TTREF-D	Terminal Transaction Reference used in the preceding DEBIT transaction

++ATREF Account Transaction Reference for this transaction;

K$_{RD}$ REVOKE DEBIT key

MAC$_4$ The first 4 bytes of a MAC cryptographic checksum using K$_{RD}$ as the key.

ENC$_4$ The first 4 bytes of (MAC cryptographic checksum using K$_{RD}$, encrypted with the current Session Key K$_{S.}$)

Note: The transaction counter in the card is incremented before the transaction is being executed!

The sixteen bytes data string on which the MAC cryptographic checksum is calculated is composed as follows:

1st block			2nd block	
byte 1		byte 8	byte 1	byte 8
E8$_{HEX}$	Balance	TTREF-D	ATREF	00 00

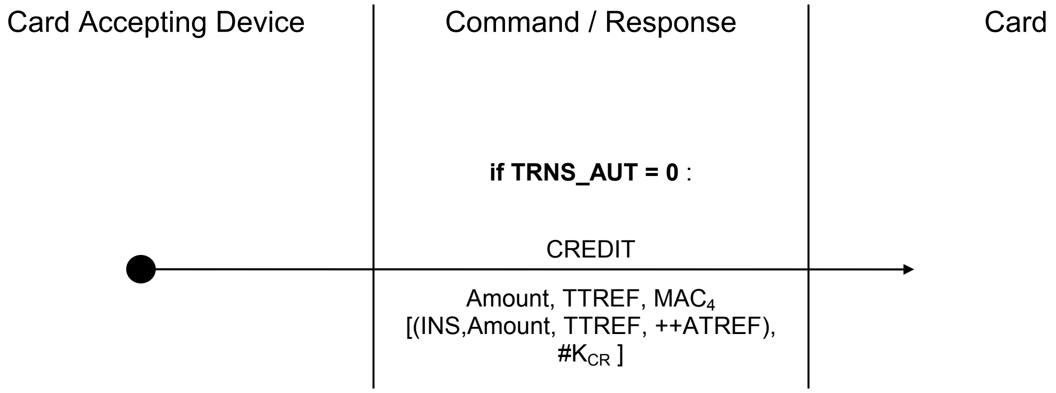
4.5.4. CREDIT

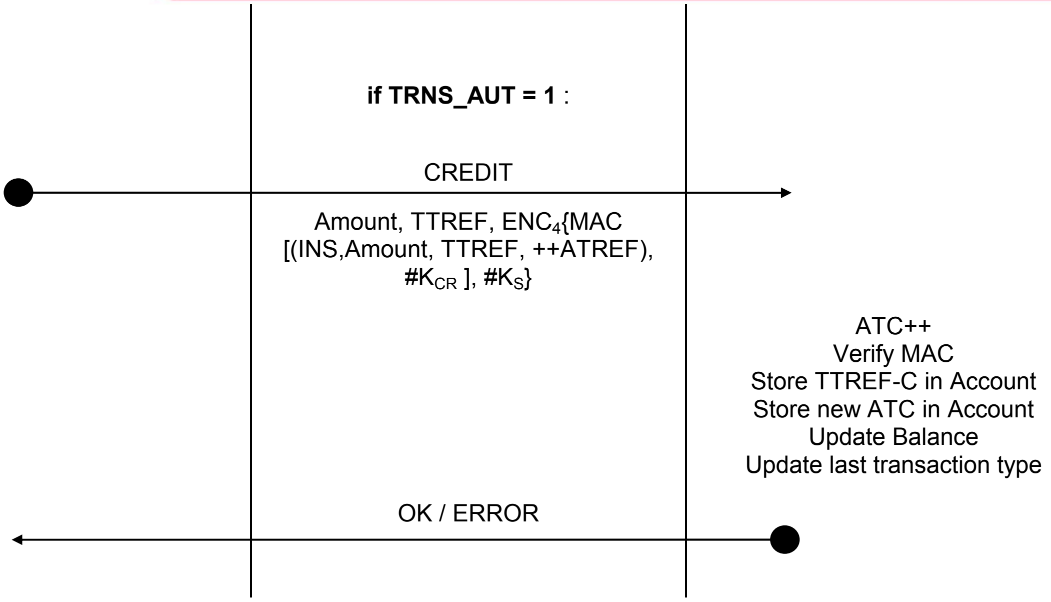
In a CREDIT transaction, the balance in the Account is increased by the specified amount. The maximum allowed the new balance must not exceed balance value MAXBAL as stored in the Account Data Structure. Otherwise, the card will reject the CREDIT command.

The CREDIT transaction is always carried out under high security processing.

If the option bit TRNS_AUT is set, the Mutual Authentication process must have been completed prior to the execution of the CREDIT command.

The CREDIT transaction is carried out as follows:





NOTE: ENC shall be DES or 3DES depending on selected *Option*

TTREF	Terminal Transaction Reference for this CREDIT transaction
++ATREF	Account Transaction Reference for this transaction;
INS	ACOS3 instruction code for CREDIT command
Amount	Amount to be credited to the Account
K_{CR}	CREDIT key
MAC$_4$	The first 4 bytes of a MAC cryptographic checksum using K_{CR} as the key.
ENC$_4$	First four bytes of (MAC cryptographic checksum using K_{CR}, encrypted with the current Session Key $K_{S.}$)

Note: The transaction counter in the card is incremented before the transaction is being executed!

The sixteen bytes data string on which the MAC cryptographic checksum is calculated is composed as follows:

1st block			2nd block	
byte 1		byte 8	byte 1	byte 8
E2$_{HEX}$	Amount	TTREF-C	ATREF	00 00

5.0. ISO COMPLIANCE AND ANSWER-TO-RESET

After a hardware reset (e.g., power up), the card transmits an Answer-To-Reset (ATR) in compliance with the standard ISO 7816, part 3. ACOS3 supports the protocol type T=0. The protocol type selection function is not implemented.

The direct convention is used for the coding of the bits in the communication with the card, i.e., logic level ONE corresponds to the Z state of the I/O line.

Fourteen bytes of data are transmitted in the historical bytes as described below.

The following data are transmitted in the ATR:

TS	T0	TA_1	TB_1	TD_1	14 Historical Bytes
$3B_H$	BE_H	11_H	00_H	00_H	

The 14 bytes string transmitted in the historical bytes is composed as follows:

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
41_H	01_H	10_H 20_H 38_H	Option registers			Personalization File bytes 4 – 8					Life-cycle Stage	90_H	00_H

Lifecycle Stage   Codes the current card lifecycle stage in a single byte
0 :   User Stage
1 :   Manufacturing Stage
2 :   Personalization Stage

Version Bytes   The contents of the version bytes are:
T1 = 41_H = ACOS
T2 = 01_H = Version 1
T3 = 10_H / 20_H / 38_H = Revision 1.0 / Revision 2.0 / Revision 3.8

Option Registers   The contents of the three bytes option registers:
T4 = Option Register
T5 = Security Option Register
T6 = N_OF_FILE

Personalization File   5 bytes following the Option Registers of the Personalization File in the EEPROM memory

NOTE: For compatibility reasons ACOS3 version bytes will stay the same as ACOS1 revision 3.8.

5.1. Customizing the ATR

There are two ways of customizing ACOS3's ATR. The first way is to add personalization information to the Personalization File FF 02_H byte 1 to byte 8. This will be fetched upon power-up in the default ATR's historical bytes stated in the previous section.

In ACOS3, additional capabilities allow for the modification to the card's transmission speed or completely customizing the historical bytes based on the application developer's preference. These ATR modifications are achieved by writing to the internal file FF 07_H after submission of the IC code.

As stated in Section 3.3.9, the first byte of the record in FF 07_H denotes the customized transmission speed of the card. More specifically, this field states the different clock rate conversion factor and baud rate adjustment factor that will appear on TA1 field of the ATR. When a smart card reader detects this field, it will do a Protocol and Parameters Selection (PPS) to set to a higher transmission rate. Note that the actual baud rate will depend on the card reader's capability and its oscillator.

The second byte states the length of the modified historical bytes. Notice that after the customizing the historical bytes this way, they will no longer correspond to Options Registers, Personalization File or the Life Cycle Stage.

ACOS3 interprets FF 07_H as follows:

Byte Number	Valid Values	Description
1	 96_H 95_H 94_H 93_H 92_H 11_H Any other values	The following are the reference baud rate* and their values: - 223,200 bps - 111,600 bps - 55,800 bps - 27,900 bps - 13,950 bps - 9,600 bps (default for backward compatibility reasons) - Use the default speed of 9,600
2	00_H – $0F_H$ Any other values	- The length of the modified historical bytes. - No modifications are made. The card will use the default historical bytes of the previous section.
3-17	Any	This field will depend on the length set in byte number 2. This can be used for customized historical bytes dependent on the application developer's preference.

* Based on an external clock frequency of 3.5712 MHz

See ISO7816 Part 3 for more information about ATR formation.

For example:

To set the ATR to high speed (95_H) and 2 bytes identifier (1234_H) in the historical characters, perform the following:

1. Submit IC code (Assuming default IC code): 80 20 07 00 08 41 43 4F 53 54 45 53 54_H
2. Select FF 07_H: 80 A4 00 00 02 FF 07_H
3. Write 4 bytes to the ATR file including the 1 byte for the speed, 1 byte for the length of the historical characters, and 2 bytes identifier:
   80 D2 00 00 04 95 02 12 34_H
4. Reset the card. The ATR is now 3B B2 95 00 00 12 34_H.

6.0. COMMANDS

The following section describes in detail the format of all ACOS3 commands and the possible responses.

The command descriptions use the TPDU representation. All numeric values are given in HEX.

A summary of the status codes returned by the card is given in Seciton 8.0. Secure messaging can be added to any commands except START SESSION, MUTUAL AUTHETNCATION and GET RESPONSE. To use SM on any commands, please see Section 4.4 for more information.

START SESSION	Start the Mutual Authentication Process
AUTHENTICATE	Authenticate the Card Accepting Device, authenticate the card and compute the Session Key
GET RESPONSE	Get response data available in the card
SUBMIT CODE	Submit a secret code
CHANGE PIN	Change the PIN secret code
CLEAR CARD	Clears the cards back to manufacturer stage
SELECT FILE	Select a data file for reading and writing
READ RECORD	Read data from a record of the currently open data file
WRITE RECORD	Write data to a record of the currently open data file
INQUIRE ACCOUNT	Read the balance and other Account information
CREDIT	Credit the Account
DEBIT	Debit the Account
REVOKE DEBIT	Revoke the preceding Debit transaction

6.1. START SESSION

To get a random number from the card and start the mutual authentication process the result of which is the Session Key K_S.

Command:

CLA	INS	P1	P2	P3
80	84	00	00	08

Response:

Data	SW1 SW2
RND_C	Status

RND_C Eight bytes card random number

Status Codes:

SW1	SW2	Meaning
69	83	Terminal Authentication Key K_T is locked, authentication process cannot be executed

6.2. AUTHENTICATE

To submit the encrypted random number to the card and initiate the computation of the session key. Please see Section 4.2 for more information.

Command:

CLA	INS	P1	P2	P3	DATA	
80	82	00	00	10	ENC(RND_C,#K_T)	RND_T

ENC(RND_C,#K_T) Eight bytes card random number encrypted with Terminal Key K_T

RND_T Eight bytes terminal random number

NOTE: ENC shall be DES or 3DES depending on the selection in *Option* Register

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	85	START SESSION not executed immediately before AUTHENTICATE command
63	Cn	Key K_T not correct; n = remaining number of re-tries
61	08	Issue GET RESPONSE with P3 = 8 to get the encrypted terminal random number

To get the response, execute the GET RESPONSE command:

Command:

CLA	INS	P1	P2	P3
80	C0	00	00	08

Response:

Data	SW1 SW2
ENC(RND_T,#K_S)	Status

DES(RND_T,#K_S) Eight bytes terminal random number RND_T DES-encrypted with Session Key K_S

NOTE: ENC shall be DES or 3DES depending on the selection in *Option* Register

Specific Status Codes:

SW1	SW2	Meaning
69	85	AUTHENTICATE not executed prior to the GET RESPONSE command

6.3. GET RESPONSE

To retrieve the response data to an APDU case 4 command (incoming and outgoing data).

Command:

CLA	INS	P1	P2	P3
80	C0	00	00	Len

Len The expected response data length

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
90	00	O.K.
6C	nn	Wrong expected data length - issue command again with P3 = nn
69	85	No data available
62	81	Part of the data may be corrupted

The GET RESPONSE command must be issued **immediately** after the receiving 61 nn from a previous command.

6.4. SUBMIT CODE

To submit a secret code – Application Code, PIN or Issuer Code – to the card.

Command:

CLA	INS	P1	P2	P3	DATA
80	20	Code No.	00	08	Code or ENC(Code,#K_S)

Code No.	Code reference:	1...5	=	AC1...AC5
		6	=	PIN
		7	=	IC

Code Eight bytes Code

DES(Code,#K_S) Eight bytes Code encrypted with Session Key

NOTE: If the corresponding option bit xx_DES in the Security Option Register is set, code XX is submitted DES encrypted. If the option bit is not set, the code is submitted in plain without encryption.

NOTE: ENC shall be DES or 3DES depending on the selection in *Option* Register

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
63	Cn	Wrong Code; n = remaining number of re-tries
69	83	The specified Code is locked
69	85	Mutual Authentication not successfully completed prior to the SUBMIT CODE command

6.5. CHANGE PIN

To set a new PIN code in the card.

Command:

CLA	INS	P1	P2	P3	DATA
80	24	00	00	08	PIN or ENC^{-1}(PINnew, #K_S)

PINnew	New PIN
Ks	Session Key

NOTE: If the option bit PIN_DES is 0, the PIN code is not DES encrypted with K_S!

NOTE: ENC shall be DES or 3DES depending on the selection in *Option* Register

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	82	PIN not submitted prior to issuing this command
69	85	Mutual Authentication not completed immediately prior to this command
69	66	Command not available; option bit not set

6.6. CLEAR CARD

To clear the card back to its virgin state. All keys, file structures and data will be erased. This function is only available after successful verification of IC code and when the card is in Manufacturer Stage or Personalization Stage.

Command:

CLA	INS	P1	P2	P3
80	30	00	00	00

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	82	IC code not satisfied or card is in user stage.

6.7. SELECT FILE

To select a data file for subsequent READ RECORD and WRITE RECORD commands.

Command:

CLA	INS	P1	P2	P3	DATA
80	A4	00	00	02	File ID

File ID Two bytes file identifier

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
6A	82	File does not exist
90	00	Internal Data File has been selected
91	nn	User Data File has been selected. The corresponding File Definition Block is stored in record no. nn in the User File Management File (FF 04 $_H$)

6.8. READ RECORD

To read a number of bytes – from an offset up to the record length – from one record in the currently selected file.

Command:

CLA	INS	P1	P2	P3
80	B2	Rec No.	Offset	Len

Rec No. Logical record number to be read.
0..N-1 if RECORD_NUMBERING flag in Manufacturer file is zero
1..N if RECORD_NUMBERING flag in Manufacturer file is one

Offset Offset from that record to start reading from.

Len Number of data bytes to be read.

Response:

Data	SW1 SW2
Byte 1 ... Byte N	Status

Byte 1 ... Byte N Data bytes read from the record

Specific Status Codes:

SW1	SW2	Meaning
67	00	Specified Len plus Offset is larger than record length
69	81	Command incompatible with file structure
69	82	Security status not satisfied – Secret code(s) not submitted
69	85	No file selected
6A	83	Record not found – file too short
6F	00	I/O error; data to be accessed resides in invalid address

6.9. WRITE RECORD

To write a number of bytes – from an offset up to the record length – to one record in the currently selected file.

Command:

CLA	INS	P1	P2	P3	DATA
80	D2	Rec No.	Offset	Len	Byte 1 ... Byte N

Rec No. Logical record number to be read.
0..N-1 if RECORD_NUMBERING flag in Manufacturer file is zero
1..N if RECORD_NUMBERING flag in Manufacture file is one

Offset Offset from that record to start writing from.

Len Number of data bytes to be written to the record *Rec No.*

Byte 1 ... Byte N Data bytes to be written.

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
67	00	Specified Len plus Offset is larger than record length
69	81	Command incompatible with file structure
69	82	Security status not satisfied – Secret code(s) not submitted
69	85	No file selected
6A	83	Record not found – file too short
6F	00	I/O error; data to be accessed resides in invalid address

6.10. READ BINARY

To read a number of bytes – from an offset up to the record length – from one record in the currently selected file.

Command:

CLA	INS	P1	P2	P3
80	B0	Offset High	Offset Low	Len

Offset Offset from the start of file to start reading from. High is the most significant byte. While Low is the least significant

Len Number of data bytes to be read

Response:

Data	SW1 SW2
Byte 1 ... Byte N	Status

Byte 1 ... Byte N Data bytes read from the record

Specific Status Codes:

SW1	SW2	Meaning
67	00	Specified Len plus Offset is larger than file length
69	81	Command incompatible with file structure
69	82	Security status not satisfied – Secret code(s) not submitted
69	85	No file selected
6A	83	File too short – Offset is larger than the file length
6F	00	I/O error; data to be accessed resides in invalid address

6.11. WRITE BINARY

To write a number of bytes – from an offset up to the file length – to the currently selected file.

Command:

CLA	INS	P1	P2	P3	DATA
80	D0	Offset High	Offset Lo	Len	Byte 1 ... Byte N

Offset Offset from the start of file to start writing from. High is the most significant byte. While Low is the least significant

Len Number of data bytes to be written.

Byte 1 ... Byte N Data bytes to be written.

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
67	00	Specified Len plus Offset is larger than file length
69	81	Command incompatible with file structure
69	82	Security status not satisfied – Secret code(s) not submitted
69	85	No file selected
6A	83	File too short – Offset is larger than the file length
6F	00	I/O error; data to be accessed resides in invalid address

6.12. INQUIRE ACCOUNT

To read the relevant information from the Account,

Command:

CLA	INS	P1	P2	P3	DATA
80	E4	Key No.	00	04	Reference

Key No. Reference to the key to be used in the calculation of the MAC cryptographic checksum

Reference Four bytes arbitrary reference data

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
6A	86	Key No. invalid
69	85	Mutual Authentication has not been completed
61	19	Issue GET RESPONSE with P3 = 19

To get the response, execute the GET RESPONSE command:

Command:

CLA	INS	P1	P2	P3
80	C0	00	00	19

Response:

Data							SW1 SW2
MAC4	Trans. Type	Balance	ATREF	Max. Balance	TTREF-C	TTREF-D	Status

MAC4 First 4 bytes of MAC cryptographic checksum on the account data and the reference

Trans. Type	One byte coding the type of the most recent transaction
Balance	Three bytes current balance value
ATREF	Six bytes Account Transaction Reference
Max. Balance	Three bytes maximum allowed balance value
TTREF-C	Four bytes Terminal Transaction Reference – Credit
TTREF-D	Four bytes Terminal Transaction Reference – Debit

Specific Status Codes:

SW1	SW2	Meaning
69	85	No data available; the INQUIRE ACCOUNT command was not executed immediately prior to the GET RESPONSE command
62	81	Account data may be corrupted

6.13. CREDIT

To credit the Account.

Command:

CLA	INS	P1	P2	P3	DATA
80	E2	00	00	0B	MAC : Amount : TTREF

MAC	Four bytes MAC cryptographic checksum on the command
Amount	Three bytes value of amount to be credited
TTREF	Four bytes Terminal Transaction Reference.

Response:

W1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	F0	Data in account is inconsistent – no access unless in Issuer Mode
6A	82	Account does not exist
6F	10	Account Transaction Counter at maximum – no more transaction possible
63	Cn	MAC cryptographic checksum is wrong n = remaining number of retries
6B	20	Amount too large
69	83	Credit Key locked
69	85	Mutual Authentication has not been completed

6.14. DEBIT

To debit the Account.

Command:

CLA	INS	P1	P2	P3	DATA
80	E6	00 01	00	0B	MAC : Amount : TTREF

If P1 is 01, ACOS3 will return a 4-byte Debit Certificate.

MAC	Four bytes MAC cryptographic checksum on the command
Amount	Three bytes value of amount to be debited
TTREF	Four bytes Terminal Transaction Reference.

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	F0	Data in account is inconsistent – no access unless in Issuer Mode
6A	82	Account does not exist
6F	10	Account Transaction Counter at maximum – no more transaction possible
63	Cn	MAC cryptographic checksum is wrong n = remaining number of retries
69	82	Security status not satisfied – PIN not submitted
6B	20	Amount too large
69	82	PIN not submitted
69	83	Debit Key locked
69	85	Mutual Authentication has not been completed
61	04	Debit successful, issue GET RESPONSE with P3=04 to get Debit Certificate.

6.15. REVOKE DEBIT

To revoke the most recent Debit command.

Command:

CLA	INS	P1	P2	P3	DATA
80	E8	00	00	04	MAC

MAC Four bytes MAC cryptographic checksum on Balance, TTREF-D, ATREF

Response:

SW1 SW2
Status

Specific Status Codes:

SW1	SW2	Meaning
69	F0	Data in account is inconsistent – no access unless in Issuer Mode
6A	82	Account does not exist
6F	10	Account Transaction Counter at maximum – no more transaction possible
63	Cn	MAC cryptographic checksum is wrong n = remaining number of re-retries
6A	82	Account does not exist
69	F0	Data in account is inconsistent – no access unless in Issuer Mode
69	66	Command not available (option bit not set)
69	83	Revoke Debit Key locked

7.0. CARD PERSONALIZATION

This section describes the general procedure in the personalization of an ACOS3 smart card. While the card personalization may be carried out in separate processing steps, the personalization process generally requires the execution of the steps described below.

The personalization of a new ACOS3 smart card is suggested to be carried out according to the following sequence:

1. Power up and reset the card
2. Submit the default Issuer Code IC (the code is communicated to the card issuer by ACS; the code may be different for different batches of cards supplied)
3. Select Manufacturer File (File ID = FF 01_H) and set the related flags in the 1st byte of the 1st record.
4. Select the Personalization File (File ID = FF 02_H) and write the required settings to the Option *Register* and the parameter N_OF_FILE. **Caution: Do not accidentally set the Personalization Bit and do not change the *Security Option Register* at this stage!**
5. Perform a card reset. After the reset, ACOS3 reads the Personalization File and accepts the new value of N_OF_FILE and the option bits stored in the *Option Register,* as well as the new settings in the Manufacturer File.
6. Submit the default Issuer Code IC.
7. Select the User File Management File (File ID = FF 04_H) and write the File Definition Blocks for the required User Files (WRITE RECORD command) with the security attributes set to ‘Free Access’.
8. Select the individual User Files and initialize the data in the files as required (WRITE RECORD command).
9. Select the User File Management File (File ID = FF 04_H) and write the required security attributes for all User Files (WRITE RECORD command). Verify the contents of the User File Management File (READ RECORD command). **Caution: Do not accidentally change the other parameters in the File Definition Blocks.**
10. If applicable, select the Account File (File ID = FF 05_H) and initialize the relevant data in the Account File (WRITE RECORD command). Verify the contents of the Account File (READ RECORD command).
11. If applicable, select the Account Security File (File ID = FF 06_H) and initialize the account processing keys (WRITE RECORD command). Verify the contents of the Account Security File (READ RECORD command).
12. Select the Security File (File ID = FF 03_H) and initialize all keys and codes (WRITE RECORD command). Verify the contents of the Security File (READ RECORD command)
13. Select the Personalization File (File ID = FF 02_H) and initialize the *Security Option Register* and the remaining bytes of the Personalization File. **Set the Personalization Bit** (WRITE

RECORD command). Verify the contents of the Personalization File (READ RECORD command). **Caution: Do not accidentally change the value of the *Option Register* and N_OF_FILE.**

14. Perform a card reset. The chip life cycle stage as indicated in the ATR should be 'User Stage'.

15. The correct personalization can be verified by submitting the secret codes and keys programmed in the card (AUTHENTICATE, SUBMIT CODE commands) and reading/writing the allocated data files and executing the Account commands.

8.0. STATUS CODES

The following is a summary of the status codes returned by the card.

SW1	SW2	Meaning
90	00	Internal Data File has been selected.
91	nn	User Data File has been selected. The corresponding File Definition Block is stored in record no. nn in the User File Management File (FF 04 $_H$)
61	nn	Command Successful – Issue GET RESPONSE command with P3 = nn to get response data
62	81	Data returned in response to the INQUIRE ACCOUNT command may be incorrect due to corrupted data in the Account Data Structure
63	Cn	Security related command failed – EXTERNAL AUTHENTICATION failed; incorrect Secret Code submitted; incorrect key used in CREDIT MAC generation; n = number of remaining trials
67	00	Wrong P3
68	82	Secure messaging not allowed.
69	66	Command not available (Manufacturing Stage, option bit not set, etc.)
69	81	Command incompatible with file structure
69	82	Security status not satisfied - Secret Code, Issuer Code or PIN not submitted - Secure Messaging required but not present.
69	83	Key or Secret Code is locked - no more verification or submission possible
69	85	Conditions of use not satisfied - no data for GET RESPONSE command available; CREDIT/DEBIT command executed without previous START TRANSACTION; Mutual Authentication not completed; no file selected; Session Key not established for Secure Messaging; Secure Messaging Command expected.
69	87	Expected secure messaging data objects missing
69	88	The Secure Messaging MAC$_{cmd}$ does not match the data.
69	F0	Account data inconsistent / transaction interrupted - access to account only in privileged mode possible

6A	82	File does not exist; account not available
6A	83	Record not found - file too short
6A	86	P1-P2 incorrect
6B	20	Invalid amount in CREDIT/DEBIT command
6C	nn	Issue GET RESPONSE command with P3 = nn to get response data
6D	00	Unknown INS
6E	00	Invalid CLA
6F	00	I/O error; data to be accessed resides in invalid address
6F	10	Account Transaction Counter at maximum - no more DEBIT or CREDIT transaction possible