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MIFARE SAM AV3 - Quick start up guide

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Keywords	MIFARE SAM AV3, Secure Key Storage, DES, TDEA, AES, RSA. Key Usage Counters.
Abstract	This application note introduces MIFARE SAM AV3 with some start up guidance.



Revision history

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1.4	20200615	Section 2.6 "Hardware design considerations" added
1.3	20200512	Evaluation board added
1.2	20200108	AN number changed, security status changed into "Company Public"
1.1	20190714	Update of delivery types and correction of typos
1.0	20190114	Initial version.

1 Introduction

MIFARE SAMs (**Secure Application Module**) have been designed to provide the secure storage of cryptographic keys and cryptographic functions for the terminals to access the MIFARE products securely and to enable secure communication between terminals and host (backend).

1.1 Scope

This application note presents the information on all the available support items for application development using MIFARE SAM AV3.

1.2 Abbreviations

These abbreviations are used in all the MIFARE SAM AV3 application notes.

Table 1. Abbreviations

Abbreviation	Meaning
AID	Application ID
APDU	Application Protocol Data Unit
API	Application Programming Interface
ATR	Answer To Reset
ATS	Answer To Select
C-APDU	Command APDU
CBC	Cipher-Block Chaining
CEK	Change Entry Key
CID	Card IDentifier
CLA	Class byte
CMAC	Cipher based MAC
CRC	Cyclic Redundancy Check
DES	Data Encryption Standard
DF	DESFire
FID	File ID
FSCI	Frame Size for proximity Card Integer
GPRS	General Packet Radio Service
HSM	Hardware Security Module
HVQFN32	Heatsink Very-thin Quad Flat-pack No-leads (32-pin)
INS	Instruction byte
IV	Init Vector
KST	Key Storage Table
KUC	Key Usage Counters
Lc	Length field for coding the Nc field

Abbreviation	Meaning
Le	Length field for coding the Ne field
LFI	Last Frame Indicator
LRC	Longitudinal Redundancy Check
LRU	Latest Recently Used
LSB	Lowest Significant Byte
MAC	Message Authentication Code
MSB	Most Significant Byte
Nc	Number of bytes in the command data field
Ne	Number of bytes expected in the response data field
P1	Parameter 1
P2	Parameter 2
PCB	Protocol Control Byte
PCD	Proximity Coupling Device (reader/writer unit)
PCM	Product Contact Module
PC/SC	Personal Computer Smart Card
PICC	Proximity Integrated Circuit Card
POST	Point of Service Terminal
PPS	Protocol and Parameter Selection
R-APDU	Response APDU
RATS	Request for Answer To Select
RFU	Reserved for Future Use
SAK	Select Acknowledge
SAM	Secure Application Module
SET	Setting
SDM	Secure Dynamic Messaging
SIM	Subscriber Identification Module
SUN	Secure Unique NDEF
SW	Status word
TDEA	Triple Data Encryption Algorithm
UID	Unique IDentification number
X -functions	The functions offered by SAM in direct connection to RC52X or PN51X using I2C.

2 MIFARE SAM AV3 Start up information

2.1 Introduction

Secure Application Module (SAM) is a piece of hardware where the cryptographic keys can be stored and used securely.

SAMs are available from NXP in the following formats:

- Sawn wafer on FFC
- Contact-only module as defined in ISO/IEC 7816-2 (figure a).
- HVQFN32.

The samples of SAM are delivered for your evaluation in SIM card format (ID-000) embedded in ID-1 size plastic card (figure b).

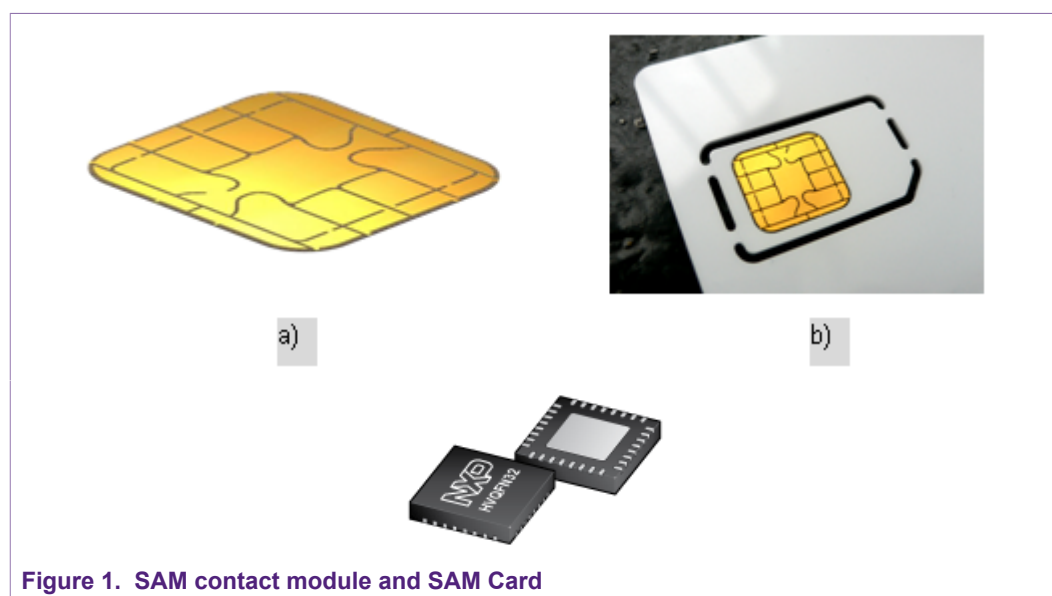


Figure 1. SAM contact module and SAM Card

The interface of SAM is ISO/IEC 7816-3 contact-only interface. It supports standard communication speed according to ISO/IEC 7816-3, protocol T =1, and also very high speed up to **1.5 Mbps**.

Additional to that, The MIFARE SAM AV3 in HVQFN32 package also provides an **I2C Slave interface** instead of the ISO7816.

From the interface point of view, SAMs are like a contact smart card, but from the functional point of view, it is not, as SAMs do not allow creating/storing user data/file structure. SAM offers crypto functions, the secret keys can be stored in the SAM securely and can be used for cryptographic functions securely.

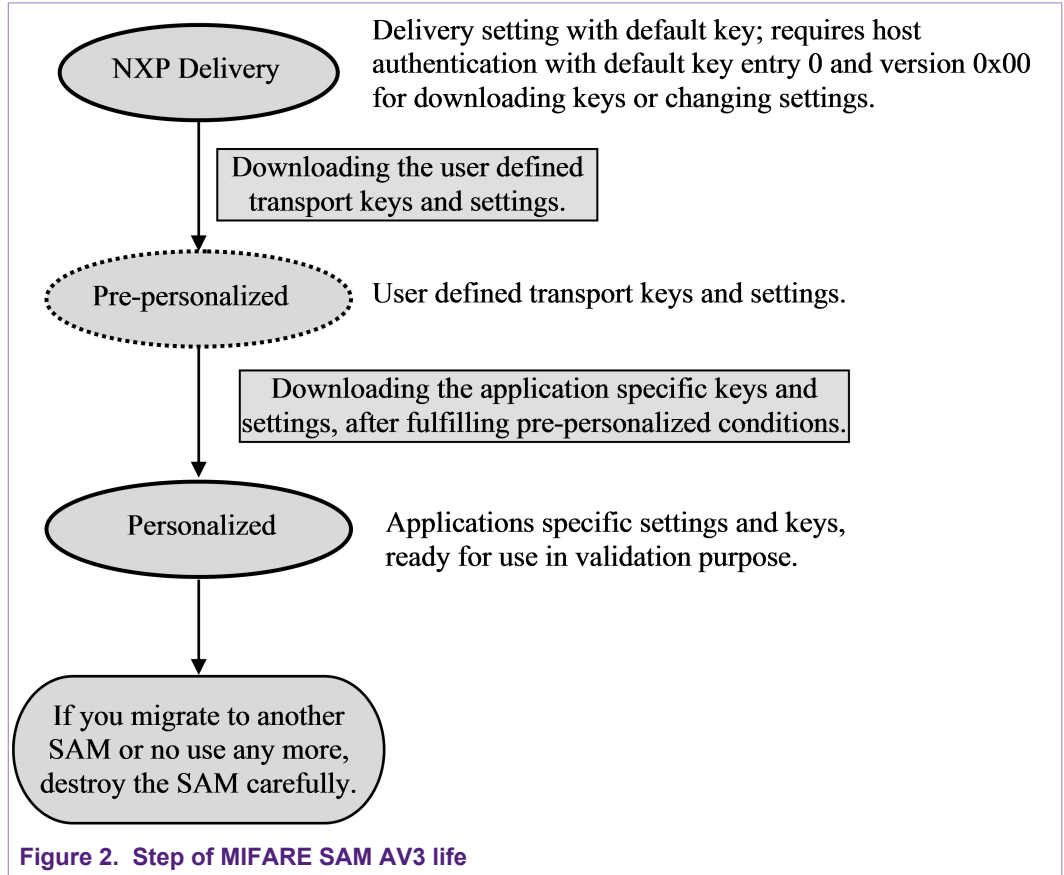
2.2 MIFARE SAM AV3 available types

For direct customers from NXP, samples can be requested from the local NXP representative over our secure sample desk in Hamburg.

ID	Name	Delivery Type
MF4SAM3	MF4SAM3X84/9Brrff	PCM1.5 - Full Variant - product delivery 10000 pcs
MF4SAM3	MF4SAM3X84/9BrrffS	PCM1.5 - Full Variant - product delivery 1000 pcs
MF4SAM3	MF4SAM3SX84/9Brrff	PCM1.5 - Limited variant Supports ICODE/UCODE and generic functionalities 10000 pcs
MF4SAM3	MF4SAM3SX84/9BrrffS	PCM1.5 - Limited variant Supports ICODE/UCODE and generic functionalities 1000 pcs
MF4SAM3	MF4SAM3HN/9Brrff	HVQFN32 – Full variant
MF4SAM3	MF4SAM3SHN/9Brrff	HVQFN32 – Limited variant Supports ICODE/UCODE and generic functionalities
MF4SAM3	MF4SAM3U15/9Brrff	150um wafer on FFC – Full Variant
MF4SAM3	MF4SAM3SU15/9Brrff	150um wafer on FFC – limited variant Supports ICODE/UCODE and generic functionalities

2.3 MIFARE SAM AV3 Life Circle

In the following different steps of MIFARE SAM AV3 life circle are shown.



Note: In some applications, SAM is personalized directly without any pre-personalization.

2.4 Available SAM

Currently there are three SAMs in NXP MIFARE SAM product portfolio. Some distinguished features are listed in the following table.

Table 2. Different SAMs

Distinguished features	MIFARE SAM AV2 (P5DF081)	MIFARE SAM AV3 (MF4SAM30)
Communication Interface	ISO/IEC 7816, T = 1, up to 1.5 Mbps. Class A, B. I ² C interface to MFRC52X and PN51X.	ISO/IEC 7816, T = 1, up to 1.5 Mbps. Class A, B and C or optional I2C slave mode host interface (only available on HVQFN package). I ² C interface to MFRC52X and PN51X.
Cryptographic Algorithms	TDEA 112-bit and 168-bit key, MIFARE Crypto1. AES-128 and AES-192. RSA-up to 2048-bit key.	MIFARE Crypto1, DES, TDEA (112 & 168 bits), AES (up to 256 bits), RSA (up to 2048 bits) and ECC (up to 256 bits)
Public Key Infrastructure (PKI)	Yes	Yes
Hash function	Yes, SHA -1, SHA -224 and SHA -256.	Yes, SHA -1, SHA -224 and SHA -256.
Supported Product's Cryptography	MIFARE Classic, MIFARE Ultralight C, MIFARE Plus, MIFARE DESFire. MIFARE DESFire EV1.	MIFARE DESFire, MIFARE DESFire EV1, MIFARE DESFire EV2 , MIFARE DESFire light MIFARE Plus, MIFARE Plus EV1 , MIFARE Classic, MIFARE Classic EV1, MIFARE Ultralight EV1, MIFARE Ultralight C, NTAG DNA , ICODE DNA , UCODE DNA
Secure host communication	Yes	Yes
X- functionalities	Yes	Yes
I2C Slave mode	No	Yes
Programmable Logic	No	Yes

2.5 SAM Distinction

The historical bytes of the SAM ATR tell the type of the product. Previous SAM versions are listed for reference only.

Table 3. Historical bytes of different SAM

SAM	Historical bytes	corresponding ASCII
MIFARE SAM	6D69666172652053414D00000000	MIFARE SAM
MIFARE SAM AV1	44455346697265382053414D2D58	DESFire8 SAM-X ^[1]
MIFARE SAM AV2	4D494641524520506C75732053414D	MIFARE Plus SAM ^[1]
MIFARE SAM AV3	4D49464152452053414D20415633301100	MIFARE SAM AV30

[1] Internal project name.

The response of the “GetVersion” command gives all the detail information about the SAM.

Table 4. Answer to GetVersion Command

Mode/Model	Version string
MIFARE SAM AV1	04 01 01 00 02 21 01 04 01 01 00 02 21 01 02 03 04 80 06 07 08 CF BB 21 21 03 00 00 34 00
MIFARE SAM AV1 compatibility mode T1AD2060	04 01 01 03 02 28 01 04 01 01 03 02 28 01 04 3F 22 29 A8 28 80 91 55 16 00 00 03 0C 09 00 A1
MIFARE SAM AV2 mode T1AD2060	04 01 01 03 02 28 01 04 01 01 03 02 28 01 04 3F 22 29 A8 28 80 91 55 16 00 00 03 0C 09 00 A2
MIFARE SAM AV1 compatibility mode T1AR1070	04 01 01 04 01 28 01 04 01 01 04 01 28 01 04 3F 22 29 A8 28 80 91 55 16 00 00 03 0C 09 00 A1
MIFARE SAM AV2 mode T1AR1070	04 01 01 04 01 28 01 04 01 01 04 01 28 01 04 3F 22 29 A8 28 80 91 55 16 00 00 03 0C 09 00 A2
MIFARE SAM AV3	04 01 01 05 00 23 01 04 01 01 05 00 1F 01 04 22 5D BA 54 52 80 99 10 53 00 00 0E 08 12 00 A3

2.6 Hardware design considerations

The MIFARE SAM AV3 is built on NXP's P60 secure smart card controller platform. Initially, this IC was intended for use in smart cards (e.g. banking and eGov) mainly, therefore some parts of the hardware are working according to smart card usage rules.

The platform was extended for MIFARE SAM AV3 with 2 I²C interfaces (X-mode and I²C slave interface), and this results on some considerations to be made when designing a system with MIFARE SAM AV3, especially when using the I²C slave host interface:

1. The I²C slave interface needs a special voltage configuration: while SDA (IO1) must be operated at VCC voltage Level, the SCL (TP2) needs to be fixed to 1V8, regardless of VCC. E.g.: VCC is 3V3, then SDA needs to be pulled up to 3V3, and SCL needs to be pulled up to 1V8, so a voltage Level shifter may be needed. As SCL is only one-directional (always controlled by the host), a simple voltage divider, or a transistor level shifter (e.g. BSS138) can be used. Details can be found in [\[3\]](#)

2. The MIFARE SAM AV3 features 2 host interfacing options: ISO7816 and I²C slave interface. The ISO7816 interface (smart card interface) is using the ISO7816 protocol, in the same way an ordinary contact smart card would do. The involved pins in this interface are IO1 (data), CLK and RST_N. The IC is supplied by VCC and GND. It is important to stick to the start-up sequence described in [\[4\]](#)
In I²C slave mode uses only IO1 as SDA and TP2 (SCL). The pins CLK and RST_N have no effect in this configuration, and should be left unconnected (open). The RST_N is not a general reset pin, as it is known from other MCU's, it is just the RST_N pin defined in the ISO7816 interface.
The used interface is selected by evaluating the voltage level on TP1 (either 0V for ISO7816 or 1V8 for I²C) during boot-up of the MIFARE SAM AV3.
3. As the MIFARE SAM AV3 is a high security device, it has implemented various sensors inside to detect any attack on the hardware. Therefore it is necessary to be careful with the voltage levels on the IO pins, especially when using the I²C slave host interface. As the MIFARE SAM AV3 has no reset pin in I²C slave mode, it can only be reset by turning off VCC. In this case, the voltage on the IO pins (especially IO1(SDA) should follow the VCC of the SAM, and not stay on a high level. (Meaning: the I²C pull-up of SDA should go to SAM_VCC, and not permanent VCC, same hold for SCL). In case this is not considered, it could lead to a permanently locked SAM.
Also, some MCU's support internal pullups for I²C. Also in this case, it needs to be ensured, that the voltage on the SAM IO's is going low before turning off the SAM VCC.

2.7 MIFARE SAM AV3 Product Support Package

There are several HW, SW and documents to support you for your MIFARE SAM AV3 application development, known as Product Support Package (PSP).

2.7.1 Evaluation hardware

Table 5. MIFARE SAM AV3 PSP Hardware

SI	Item	Short description	Order Info
1	MIFARE SAM AV3 Sample	PCM1.5 module in ID-1 size plastic card with SIM knockouts	Contact your NXP support engineer
2	HVQFN32 Package	The SMD package of MIFARE SAM AV3	Contact your NXP support engineer
3	Reference reader	Pegoda 2 with the option of using MIFARE SAM AV3 in non-X and X interface	Contact your NXP support engineer
4	MIFARE SAM AV3 Evaluation board	Evaluation board with SAM AV3 in S- and X-mode and CLRC663.	Contact your NXP support engineer

2.7.2 Evaluation Software

Table 6. MIFARE SAM AV3 PSP Software

SI	Item	Short description	Order Info
1	NXP reader library	NXP Reader Library, export controlled	SW1717xx ^[1]
2	RFIDDiscover v4.7+	A GUI for evaluation the MIFARE SAM AV3 functions.	SW1866xx ^[2]
3	RFIDDiscover - User manual	User manual for RFIDDiscover	UM2538xx ^[1]

[1] xx is the version number

[2] xx is the version number, MIFARE SAM AV3 is supported in 4.5+

2.7.3 Documents

Table 7. MIFARE SAM AV3 PSP Documents

SI	Item	Short description	Order Info
1	Data sheet	MIFARE SAM AV3 (MF4SAM30) data sheet stating all functions.	DS3235
2	System Guidance, Delivery and Operation Manual	The manual for using MIFARE SAM AV3 in the right way.	AN5385
3	AN MIFARE SAM AV3 – Quick Start up Guide	The first information to start with MIFARE SAM AV3 development.	AN5210
4	AN MIFARE SAM AV3 – Interface and architecture	Explaining the different interface and architecture of MIFARE SAM AV3.	AN5211
5	AN MIFARE SAM AV3 – Key Management and Personalization	Explaining different options of downloading different keys to MIFARE SAM AV3.	AN5212

SI	Item	Short description	Order Info
6	AN MIFARE SAM AV3 – Host Communication	Explaining secure messaging between host and MIFARE SAM AV3.	AN5213
7	AN MIFARE SAM AV3 – For MIFARE Plus	Explaining the use of MIFARE SAM AV3 in non-X interface for MIFARE Plus.	AN5214
8	AN MIFARE SAM AV3 – For MIFARE DESFire	Explaining the use of MIFARE SAM AV3 in non-X interface for MIFARE DESFire EV1.	AN5215
9	AN MIFARE SAM AV3 – For MIFARE Ultralight C	Explaining the use of MIFARE SAM AV3 in non-X interface for MIFARE Ultralight C.	AN5216
10	AN MIFARE SAM AV3 – For MIFARE Classic	Explaining the use of MIFARE SAM AV3 in non-X interface for MIFARE Classic.	AN5217
11	AN MIFARE SAM AV3 – For NTAG4xx DNA	Explaining the use of MIFARE SAM AV3 in non-X interface for NTAG4xx DNA.	AN5218
12	AN MIFARE SAM AV3 – For ICODE/UCODE DNA	Explaining the use of MIFARE SAM AV3 in non-X interface for ICODE DNA/UCODE DNA.	AN5220
13	AN MIFARE SAM AV3 – X functionalities	Explaining the use of X-interface.	AN5219
14	AN MIFARE SAM AV3 – General-purpose cryptography	Explaining the use of MIFARE SAM AV3 for general-purpose cryptography.	AN5221
15	AN MIFARE SAM AV3 – Programmable Logic Development guide	How to use the restricted Programmable Logic feature.	AN4496
16	AN Symmetric key diversifications	Explaining MIFARE SAM AV3 key diversification algorithms.	AN10922 - AN1653
17	AD MIFARE SAM AV3 - PL Interface specification	Datasheet addendum: Interface specification for Programmable Logic code	AD4518
18	UM MIFARE SAM AV3 evaluation board user manual	User manual for the MIFARE SAM Av3 evaluation board	UM11316

2.7.4 MIFARE SAM AV3 Application notes

Application notes have been published to explain the features of SAMs together with implementation hints and examples. There is a set of application note for MIFARE SAM AV3, listed in [Table 7](#), each of them is describing a specific feature.

(Contact your NXP support engineer regarding the availability of the application notes).

3 Starting with your MIFARE SAM AV3 sample

For easy start up, follow the steps:

- Connect any contact PC/SC reader to your PC (Note book).
- Insert your MIFARE SAM AV3 sample (ID-1) to the contact slot of the PC/SC reader.
- Run RFIDDiscover, the evaluation SW tool from NXP.
- Follow the user manual of RFIDDiscover to evaluate and play with your MIFARE SAM AV3 samples.

3.1 Start using MIFARE SAM AV3 with MIFARE DESFire EV3

For the default MIFARE SAM AV3, the steps are explained as follows:

- Execute SAM_AuthenticateHost command with SAM key entry 0 and version 0x00.
- Change Key entry number n (n can be any value, preferably other than 0 as key entry number 0 is SAM Master key entry) to AES-128 type.¹
- Execute SAM_AuthenticatePICC with key entry n and correct version to authenticate your MIFARE DESFire EV3. (Activate and prepare MIFARE DESFire EV3 in the right state before). Use the AuthenticateFirst variant without any diversification options.

The commands are explained in [1].

3.2 Start MIFARE SAM AV3 with MIFARE Plus EV2

For the default MIFARE SAM AV3, the steps are explained as follows:

- Execute SAM_AuthenticateHost command with SAM key entry 0 and version 0x00.
- Change Key entry number n (n can be any value, preferably other than 0, as key entry number 0 is SAM Master key entry) to AES-128 type.
- Execute SAM_AuthenticateMFP with key entry n and correct version to authenticate your MIFARE Plus EV2. (Activate and prepare MIFARE Plus in the right state before).

The commands are explained in [1].

All the commands you can play using the RFIDDiscover GUI, refer to the user manual [2] of RFIDDiscover. See detail in other relevant application notes and product functional specification for the right use of the SAM.

¹ MIFARE DESFire EV3 supports other key type as well, here AES-128 key type has been taken as example.

4 References

- [1] MF4SAM30 MIFARE SAM AV3 functional specification, document number DS3235xx.
- [2] RFIDDiscover user manual, document number UM2538xx.
- [3] UM11316 MIFARE SAM AV3 demo board user manual UM5863xx
- [4] ISO/IEC 7816-3 Identification cards — Integrated circuit cards — Part 3: Cards with contacts — Electrical interface and transmission protocols

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