UM11316

MIFARE SAM AV3 evaluation board

Rev. 1.2 — 12 April 2022 User manual
586312 COMPANY PUBLIC

Document information

Information	Content
Keywords	MIFARE SAM AV3, evaluation board, LPC, X-mode, S-mode, I2C, SPI, CLRC663
Abstract	This manual shows how to operate the MIFARE SAM AV3 evaluation board, how to jumper the interfaces and how to use the evaluation board with all different mode configurations of MIFARE SAM AV3

Revision history

Revision history

Rev	Date	Description
1.2	20220412	New graphics for final board design implemented, added Section 8 "Older revisions", bringing this application note in line with board revision 1V1
1.1	20200312	Added section about use with RFIDDiscover, added known Limitations, corrected typos
1.0	20200108	Initial version

1 Introduction

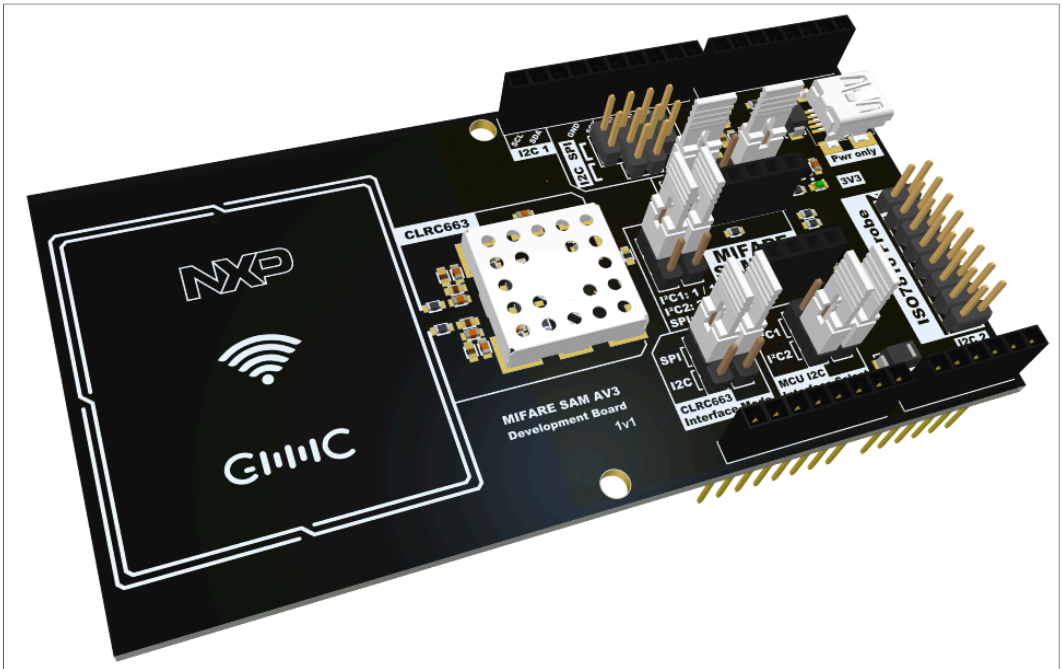

Figure 1. MIFARE SAM AV3 evaluation board 1V1

The MIFARE SAM AV3 offers various different modes of operation, interfaces and other configuration settings. The MIFARE SAM AV3 evaluation board shall help to evaluate these modes all on a single Arduino shield shaped board, in combination with any MCU. Additionally, the board features a CLRC663 NFC frontend for quick and easy design development and evaluation.

The current latest revision is 1V1, refer to Section 8 for older versions.

1.1 Scope

The scope of this document is to give an overview of all interfacing options, jumper settings and usage possibilities that the MIFARE SAM AV3 evaluation board offers.

1.2 Abbreviations

Table 1. Abbreviations

I2C	Inter-Integrated Circuit
MCU	Microcontroller Unit
NFC	Near Field Communication
PCB	Printed-Circuit Board
SAM	Secure Access Module
SPI	Serial Peripheral Interface
USB	Universal Serial Bus

2 FCC and IC Compliance Statement

2.1 FCC Compliance Statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

CAUTION: The grantee is not responsible for any changes or modifications not expressly approved by the party responsible for compliance. Such modifications could void the user's authority to operate the equipment.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

– Reorient or relocate the receiving antenna.

– Increase the separation between the equipment and receiver.

– Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

– Consult the dealer or an experienced radio/TV technician for help.

2.2 Canadian Compliance Statement

This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada license-exempt RSS(s). Operation is subject to the following two conditions:

(1) This device may not cause interference.

(2) This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licencecontenudans le présentappareilestconformeaux CNRd'Innovation, Sciences et Développementéconomique Canada applicables aux appareils radio exempts de licence. L'exploitationestautorisée aux deux conditions suivantes:

1. L'appareil ne doit pas produire de brouillage;
2. L'appareildoitaccepter toutbrouillageradioélectriquesubi, mêmesi le brouillageest susceptible d'encompromettre le fonctionnement.

2.3 Label Information

The necessary compliance information label can be found at the bottom of the PCB. There are to possible options. Silk screen and label or silk screen only.

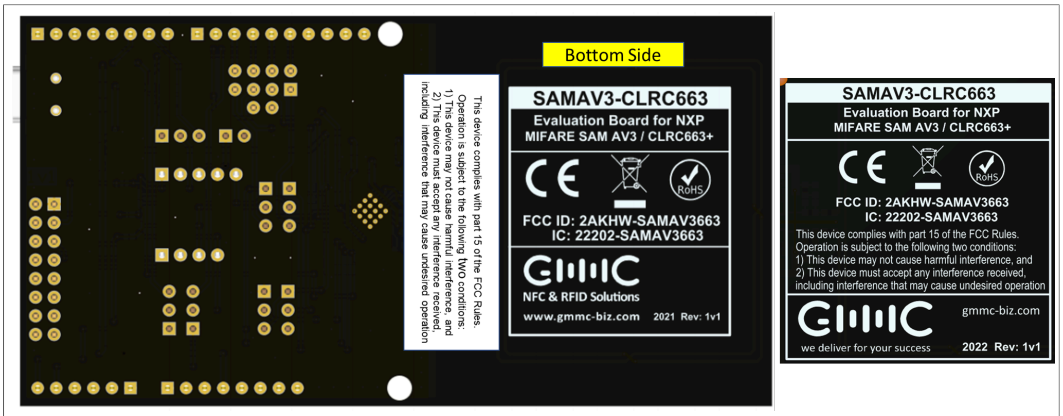

Figure 2. Label placement

3 Block diagram

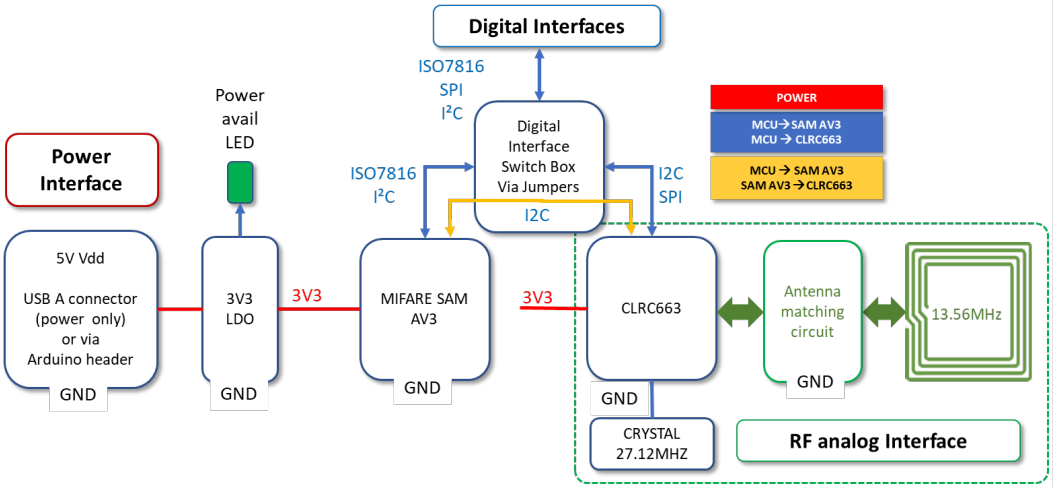

Figure 3. Block diagram

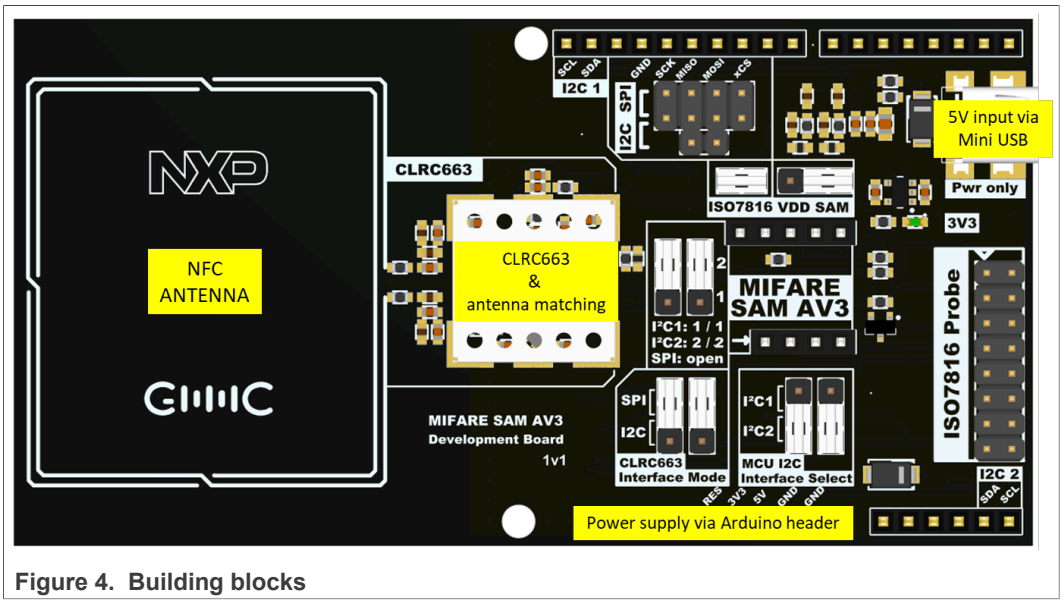

Figure 4. Building blocks

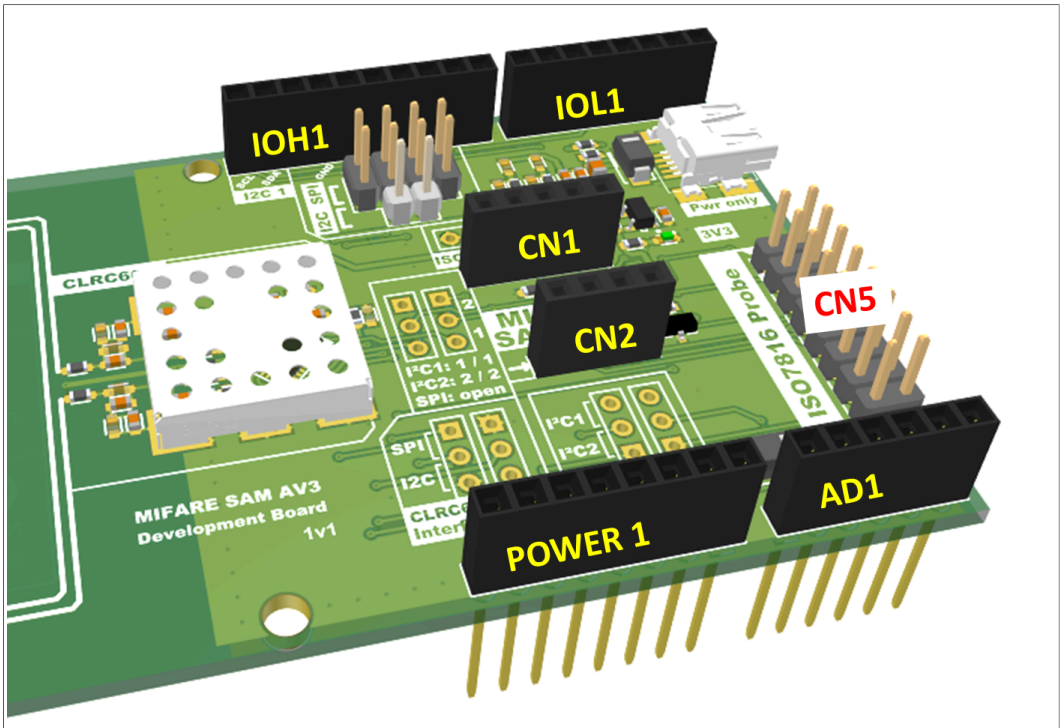

Figure 5. Connectors

4 Schematics

4.1 Power management

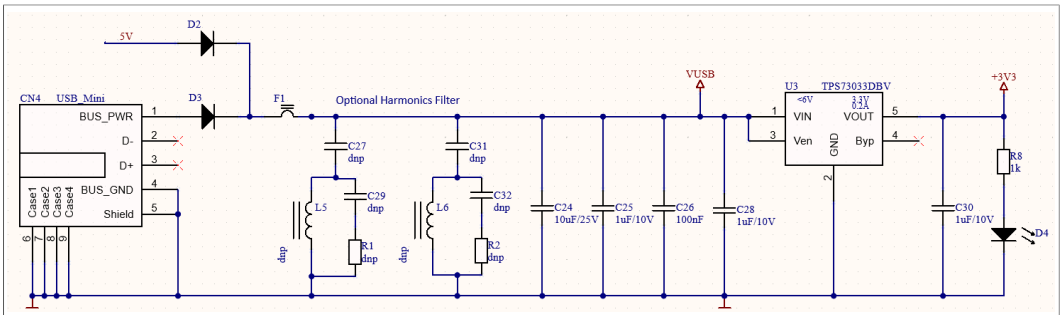

Figure 6. MIFARE SAM AV3 evaluation board - Power management

The MIFARE SAM AV3 evaluation board is equipped with a mini-USB port to power the system. The port is only used for power, it is not used for any communication/debug etc. The entire board can be powered by either the USB port or the 5 V line on the Arduino header. The power LED signalizes the properly powered state of the board.

4.2 CLRC663

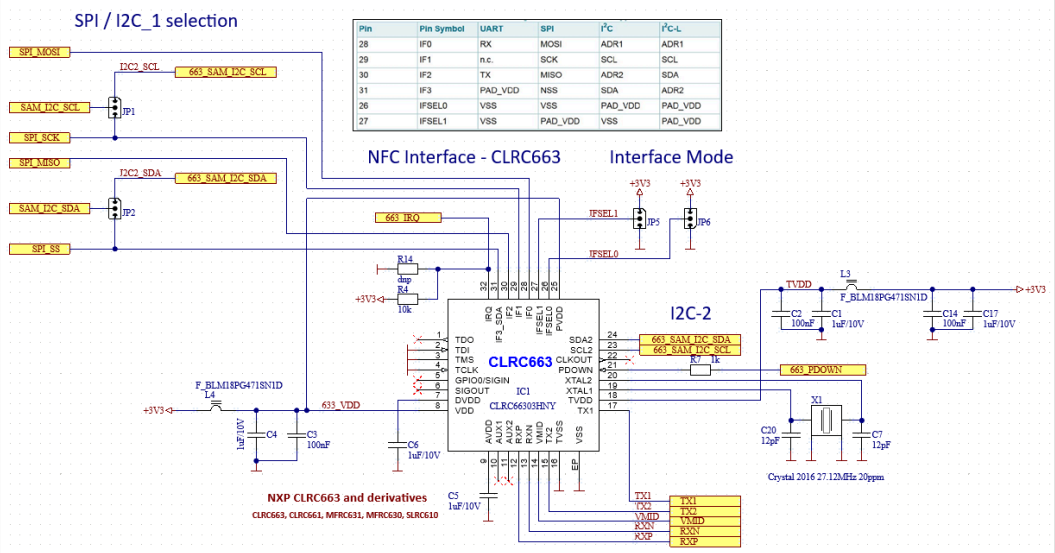

Figure 7. MIFARE SAM AV3 evaluation board - CLRC663

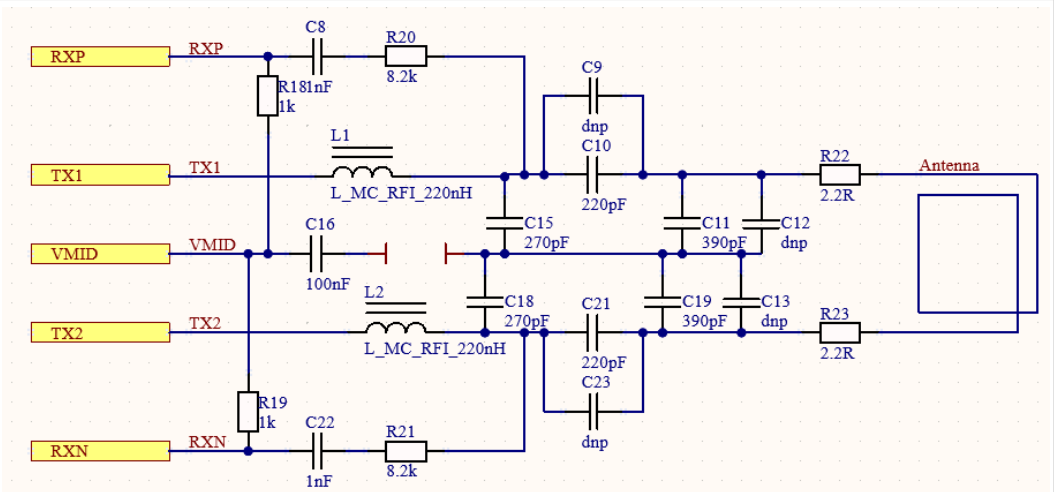

Figure 8. MIFARE SAM AV3 evaluation board - Antenna matching

The MIFARE SAM AV3 evaluation board also has a CLRC663 contactless frontend directly built-in, which can be interfaced via SPI, and I^2C. All Interfacing options are available and can be configured by jumpers. The SPI-Interface is directly connected to the Arduino® header, the I^2C interfaces are meant to be used by MIFARE SAM AV3 for X-mode. Detailed instructions for the jumper settings can be found in section Jumper setting.

4.3 Arduino R3 header

The MIFARE SAM AV3 evaluation board is equipped with a Arduino R3 compatible header. The evaluation board can be fully powered with the 5 V line from this header. All other voltages are directly generated on the board out of this 5 V line. The header also uses the SPI interface, which can be connected to the CLRC663 host interface for direct communication. For SAM communication, the user can choose between 2 I^2C interfaces: The default one on IOH1 (called I^2C1), as well as an alternative pinning on AD1 (called I^2C2). IO4 and IO5 are used for the CLRC663 PDOWN and IRQ, and IO6 can be jumpered to be the MIFARE SAM AV3 VDD.

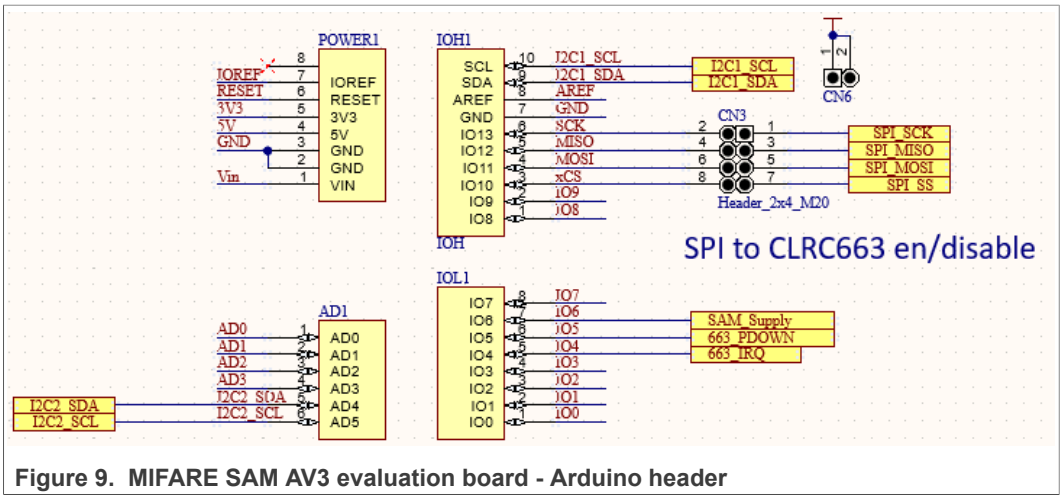

Figure 9. MIFARE SAM AV3 evaluation board - Arduino header

After the I^2C interface selection jumper from the MCU, the I^2C interface is forced to 3V3. This way, either 5 V or 3V3 MCU's can be used. As the MIFARE SAM AV3 is powered

by 3V3, the I^2C interface voltage on SDA must not exceed this value. The SCL line of this interface is shifted down to 1V8 directly on the MIFARE SAM Av3 add-on board. The reason for this additional shifting is described in the data sheet.

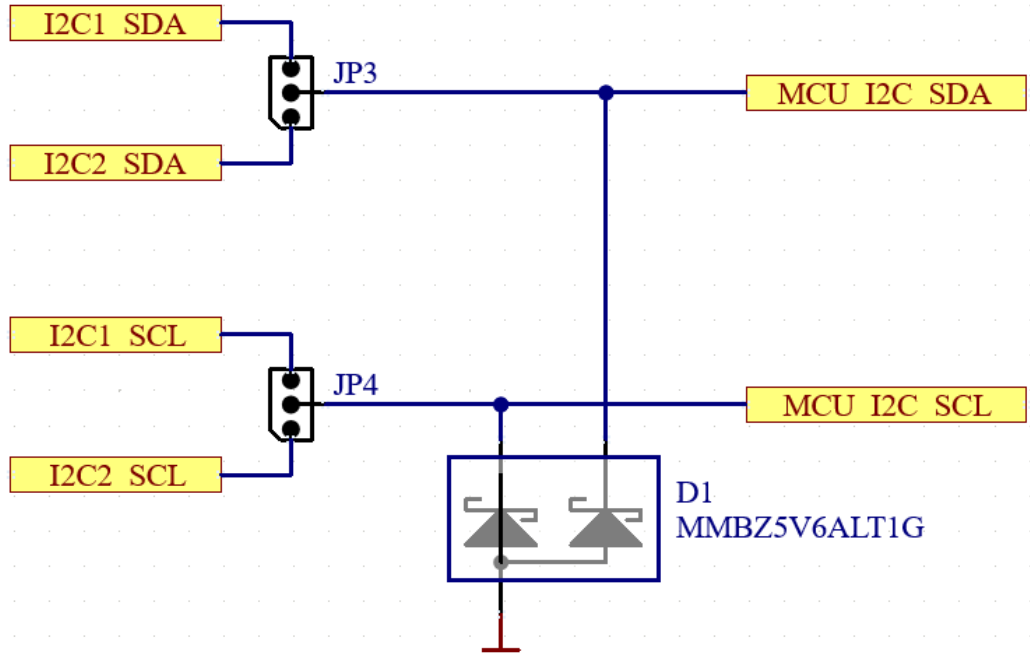

Figure 10. MIFARE SAM AV3 evaluation board - I2C interface selection

4.4 MIFARE SAM AV3

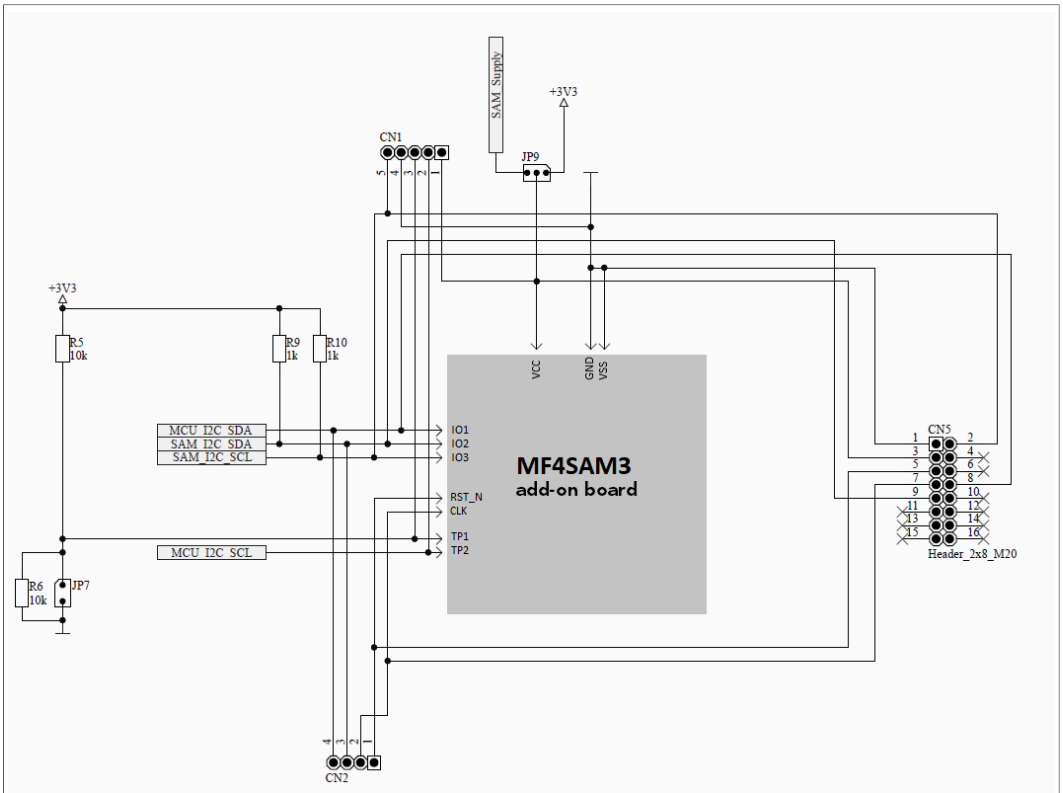

Figure 11. MIFARE SAM AV3 evaluation board - MIFARE SAM AV3

The MIFARE SAM AV3 can be accessed by either its I^2C_Slave(MCU_I2C_xxx) interface from the host MCU, or the ISO7816 interface via the additional 16-pin header CN5. This header is pin compatible to the Ashling IN_CLA7816 PCBs, and can be used with the SUBD-15 adapter cable.

4.4.1 Add-on board

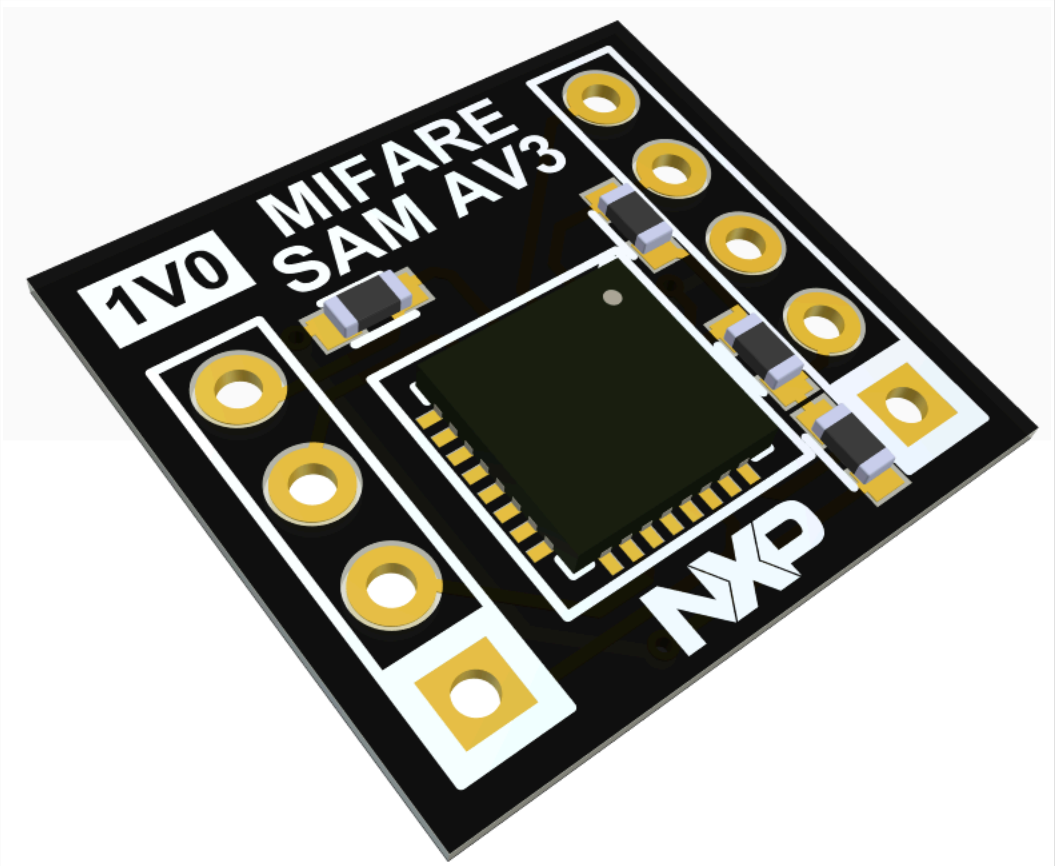

Figure 12. Add-on board

The MIFARE SAM AV3 itself is placed on an add-on board, to be able to easily exchange the MIFARE SAM AV3 in case it has been misconfigured. The pullups for the MCU_I2C_xxx interface, as well as the voltage level divider for the MCU_I2C_SCL is directly placed on the add-on board.

Note: The value for R3 is chosen as 22k, because of the internal resistance of the TP2 pin being ~32k, which results in R4 || R_{int} = ~24k.

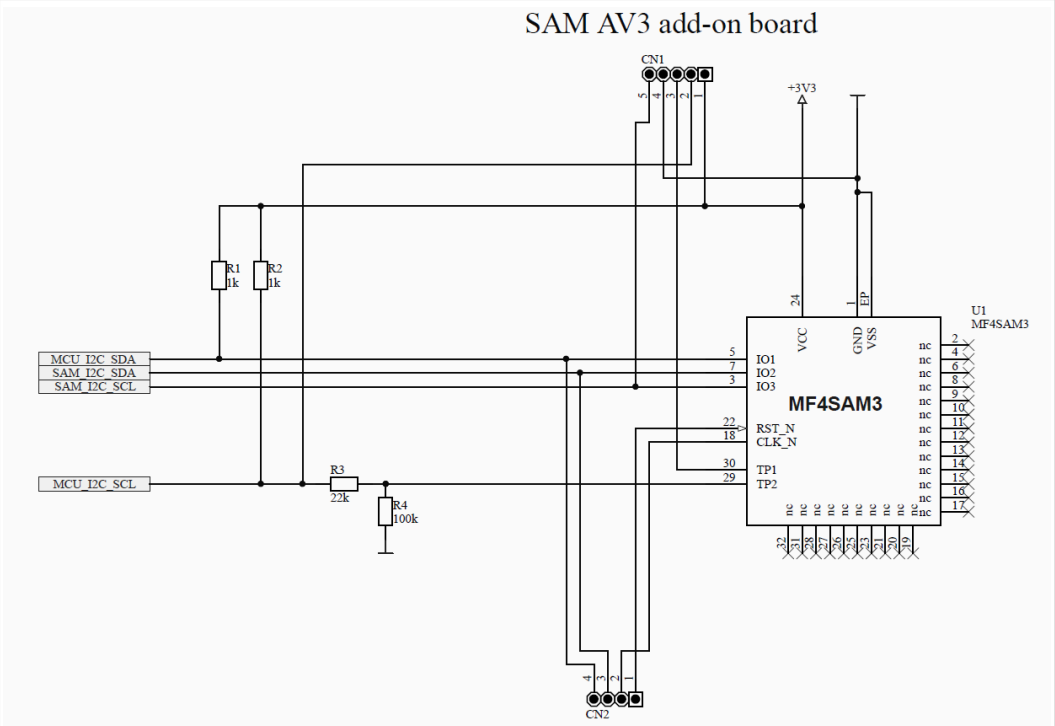

Figure 13. MIFARE SAM AV3 evaluation board - MIFARE SAM AV3 add-on board

5 Jumper setting

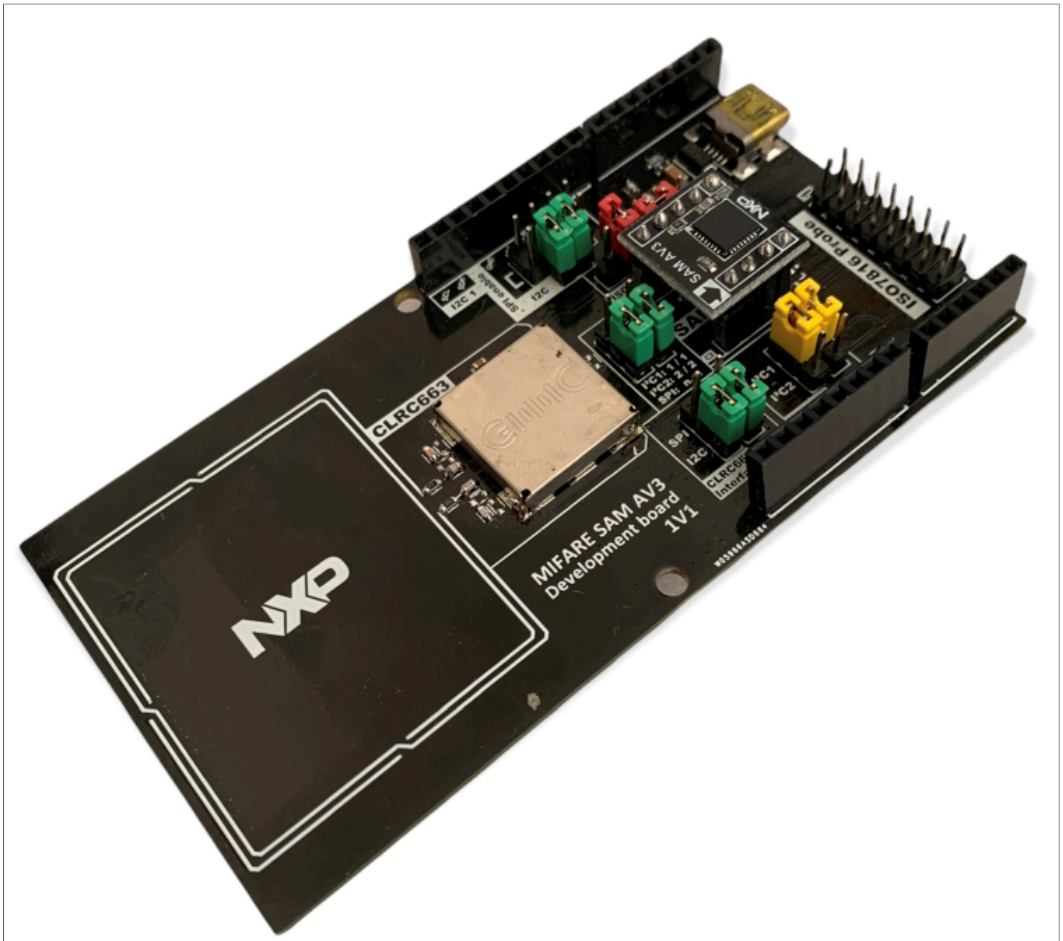

Figure 14. MIFARE SAM AV3 evaluation board - MIFARE SAM AV3

The MIFARE SAM AV3 evaluation board comes with 3 different colors of Jumpers:

- Green: Configuration of RC663 interfaces
- Yellow: MCU_I2C interface selection
- Red: MIFARE SAM AV3 configuration

5.1 CLRC663 Interface Selection

The CLRC663 NFC reader frontend generally has 2 interfaces: the Host interface and the SAM interface.

The Host interface can be configured to SPI or I^2C using the IFSEL0/1 pins of the CLRC663. This is done with JP5 and JP6.

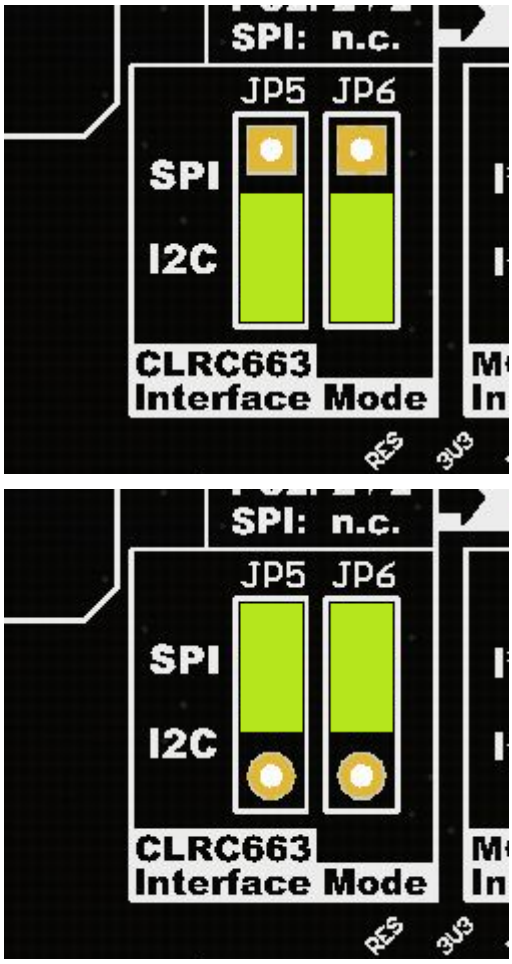

Figure 15. Host Interface Selection - top: I2C, bottom: SPI

5.1.1 SPI

In case SPI is selected, the jumpers on the SPI header need to be inserted, to connect the SPI interface from the MCU to the CLRC663. This setting is intended to use the MIFARE SAM AV3 in S-mode, or in an S/X mixed variant.

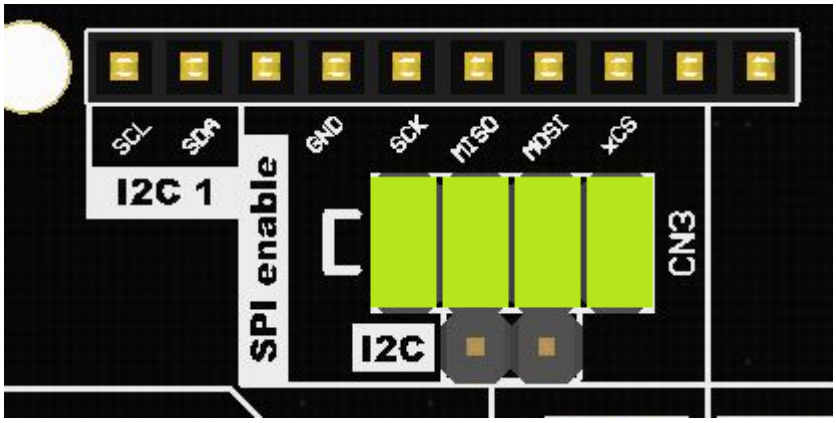

Figure 16. SPI header

At this point, the MCU can already control the CLRC663 via SPI.

5.1.2 I2C

In case I2C is selected, the CLRC663 will be controlled by the MIFARE SAM AV3 in X-mode. 2 jumpers need to be inserted in the SPI header, these correspond to the ADR0 and ADR1 pins on the CLRC663 host interface in I2C configuration.

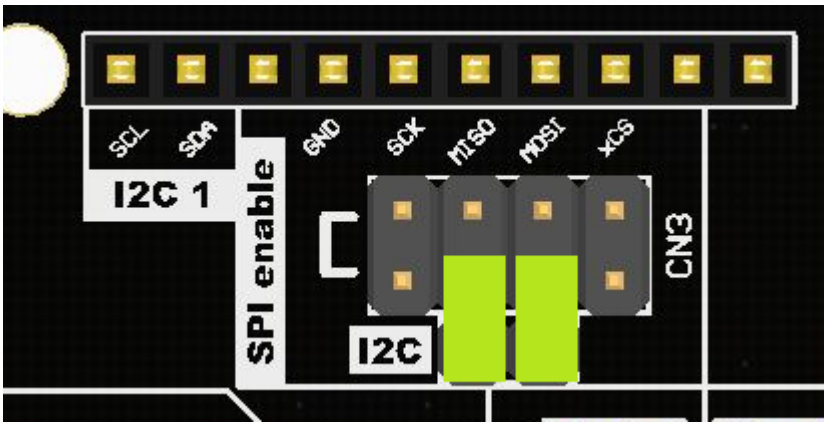

Figure 17. SPI header for I2C mode

Now, The host interface of the CLRC663 is configured as I2C and both ADR pins are pulled to low. The MIFARE SAM AV3 Master I2C interface (SAM_I2C_xxx) can be routed to the host interface of the CLRC663. This is done with JP1 and JP2.

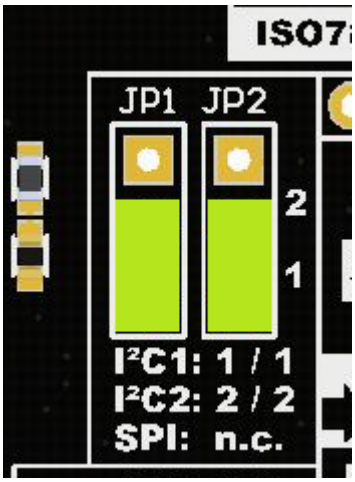

Figure 18. I2C Selection - these jumpers route the SAM_I2C interface to either the CLRC663 host interface (1) or the SAM interface (2)

5.1.3 SAM I2C

The SAM interface is a dedicated second interface for operation with a MIFARE SAM in X-mode. This interface is switched off per default. If a user wants to connect the MIFARE SAM AV3 via this interface, the I2C signal from the MIFARE SAM AV3 needs to be routed to interface 2 on JP1 and JP2.

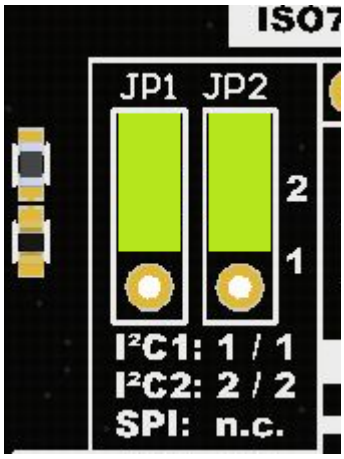

Figure 19. Selection of CLRC663 SAM interface

If this interface is already activated by setting the corresponding bits in the HostCtl register of the CLRC663, the above is enough to communicate between CLRC663 and the MIFARE SAM AV3. If not, then an additional SPI connection for the MCU to the CLRC663 is needed, to activate the SAM interface.

5.2 MCU Interface Selection

The connection between the MIFARE SAM AV3 and the MCU is done by either of the 2 supported I^2C interface locations on the Arduino® R3 header. The selection is done by JP3 and JP4, which are placed on the corresponding pins.

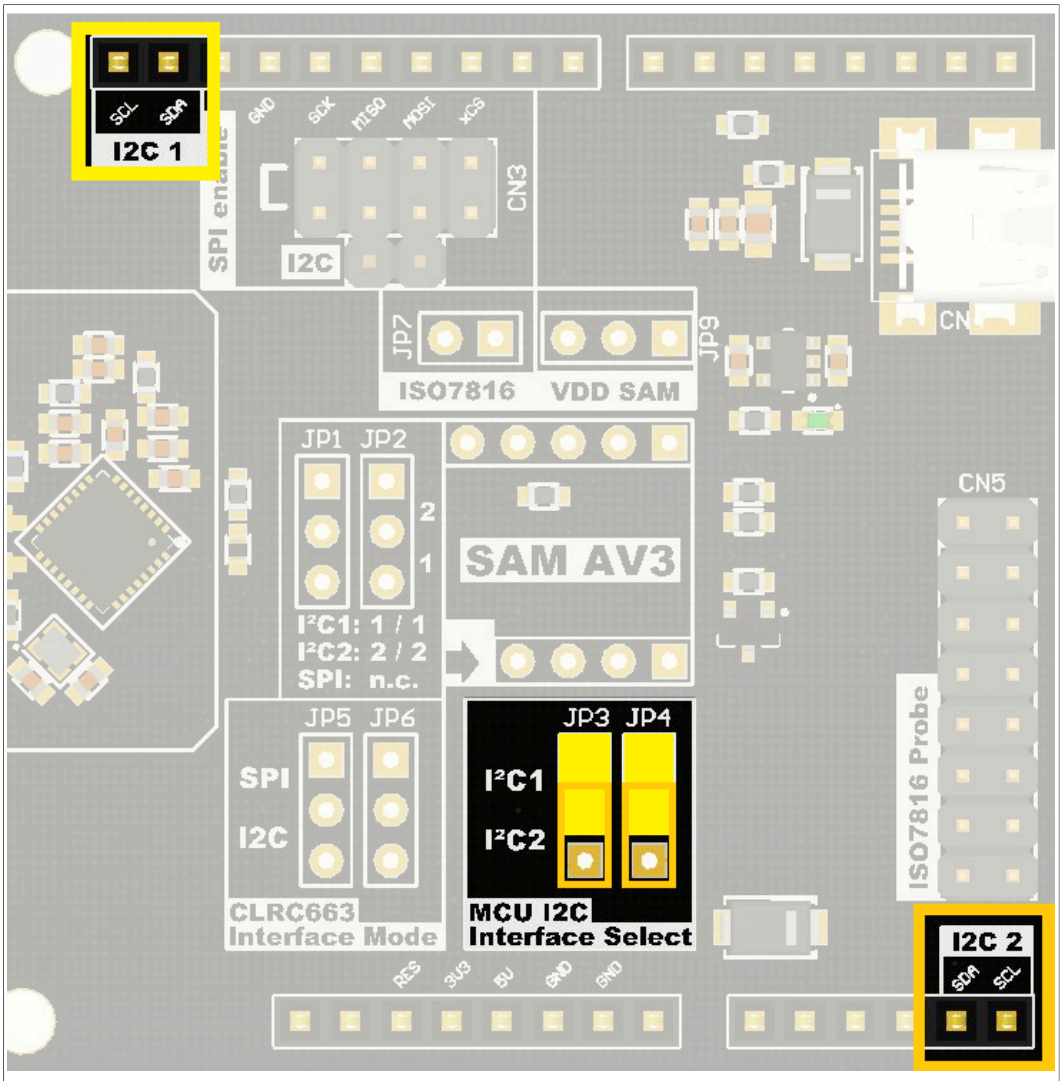

Figure 20. MCU_I2C selection

5.3 MIFARE SAM AV3

The MIFARE SAM AV3 evaluation board offers two options to interface the MIFARE SAM AV3: I^2C and ISO7816. All the preparation for I^2C was already done in the previous chapters. The only thing left to do is the VDD of the MIFARE SAM AV3. VDD is selected on JP9, the options are permanent 3V3 or IO6 on the Arduino header. Permanent 3V3 means that the MIFARE SAM AV3 will stay in the state it is, until the whole board is power cycled. The ATR of the SAM only needs to be retrieved once. Using IO6 as VDD gives the user the possibility to only power cycle the MIFARE SAM AV3, therefore having the option of a reset, without resetting the MCU.

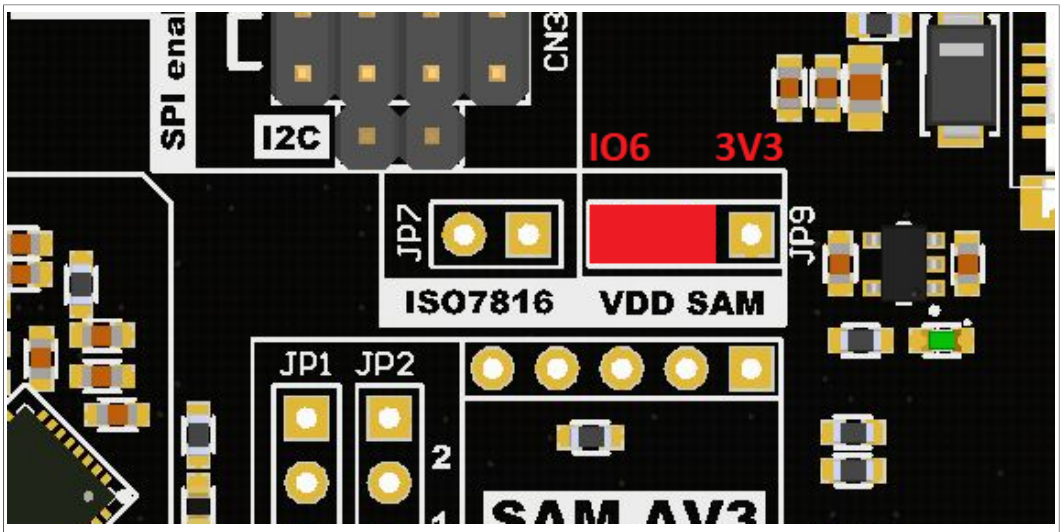

Figure 21. VCC selection of MIFARE SAM AV3

In case a user wants to access the MIFARE SAM AV3 via the ISO7816 SmartCard interface, a Jumper needs to be placed on the ISO7816 header (JP7). **Important:** In this case, the VDD selection jumper needs to be removed, as the MIFARE SAM AV3 VDD needs to be controlled by the ISO7816 interface!

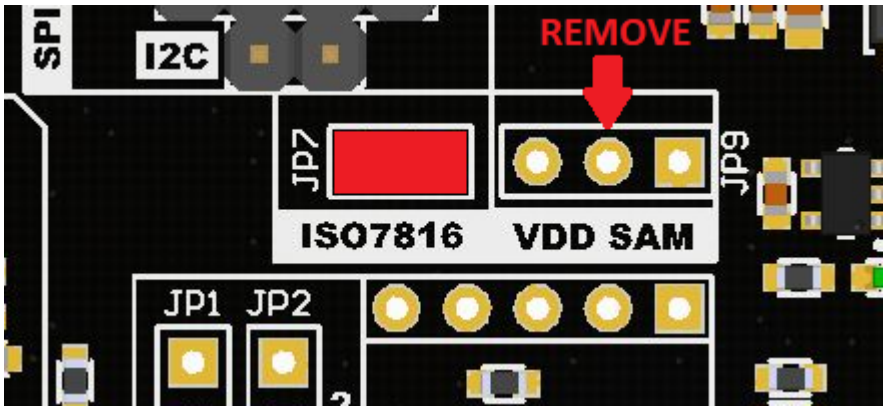

Figure 22. ISO7816 configuration of the MIFARE SAM AV3 evaluation board

6 MIFARE SAM AV3 Configuration

In the default configuration of MIFARE SAM AV3, it expects a PN523 reader frontend for X-mode communication. This needs to be changed using the SAM_SetConfig command once. The command looks like the following:

```
80 3C 01 00 01 03
```

Table 2. SetConfiguration for reader frontend selection

Byte	Value	Meaning
CLA	0x80	Class
INS	0x3C	Instruction: SAM_SetConfiguration
P1	0x01	Reader IC configuration
P2	0x00	RFU
Le	0x01	Length of subsequent data field
INF	0x03	X-mode frontend CLRC663

Along with this, the I^2C processing clock speed needs to be adjusted. Per default, this is set to I^2C fast mode (12 MHz processing clock speed) and needs to be reduced for CLRC663.

```
80 3C 02 00 01 06
```

Table 3. SAM_SetConfiguration for I^2C processing clock speed

Byte	Value	Meaning
CLA	0x80	Class
INS	0x3C	Instruction: SAM_SetConfiguration
P1	0x02	I^2C processing clock speed
P2	0x00	RFU
Le	0x01	Length of subsequent data field
INF	0x06	I^2C processing clock speed: 6 MHz

This reduces the I^2C communication speed on the X-mode interface to ~400 kbit/s

7 Modes of Operation

7.1 X-mode

The easiest way to get started with the MIFARE SAM AV3 evaluation board is to operate the MIFARE SAM AV3 in X-mode. An example configuration for this would look like the following

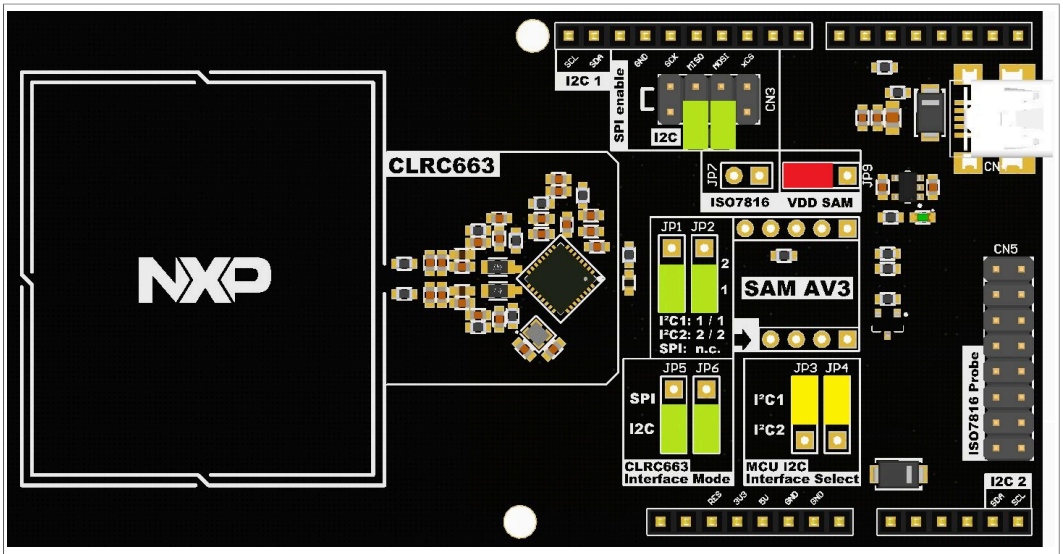

Figure 23. X-mode example configuration

In the configuration from image Figure 23, the SAM can be accessed via the I^2C1 interface from the MCU, and will communicate to the CLRC663 via its host interface, configured as I^2C. The SAM VCC in this case is connected to IO6.

7.2 S-mode

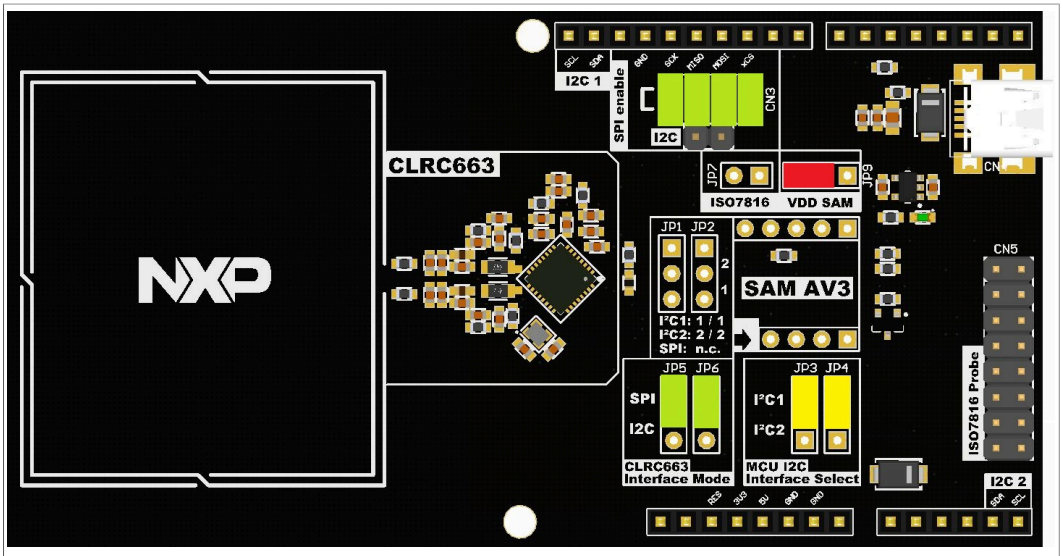

Figure 24. S-mode example configuration

In this S-mode configuration, the MIFARE SAM AV3 is not connected to the CLRC663. The host MCU controls the CLRC663 via the SPI interface, and the MIFARE SAM AV3 via I^2C1.

7.3 Mixed mode

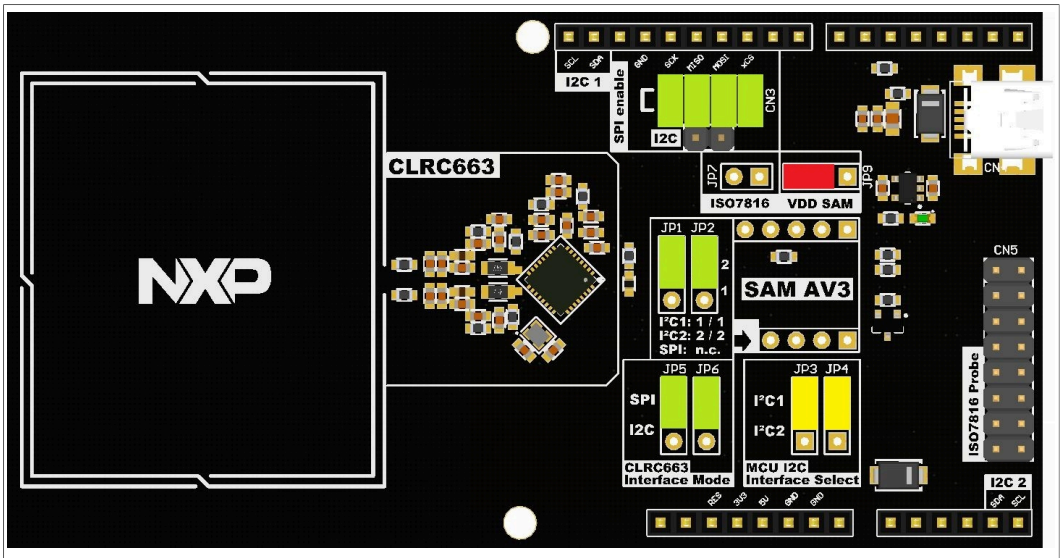

Figure 25. X/S mixed configuration

In this configuration, the CLRC663 is connected on its host interface via SPI to the MCU, and on the second interface via I^2C to the SAM. The MIFARE SAM AV3 is connected via I^2C1 to the MCU. In this way, the MCU can control the CLRC663's LPCD procedure, and if a card is detected, the SAM can be switched on and take over the control over the CLRC663.

7.4 ISO7816 Interface

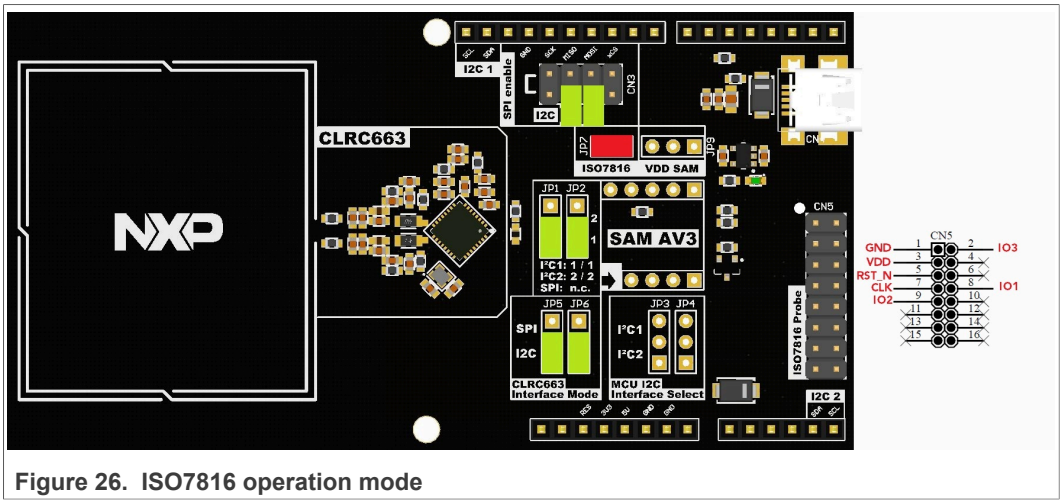

Figure 26. ISO7816 operation mode

In this configuration, the MIFARE SAM AV3 is controlled via the ISO7816 Interface, which is available on the 16-pin header. The pinning there is compatible to the Ashling IN-CLA7816USB-CL1 Antenna PCB, which is widely used with several contactless and contact SmartCard products. Additionally, a separate PCB with a SIM-Card holder is

available. In case the SIM card form factor SAM is used, the add-on board needs to be removed.

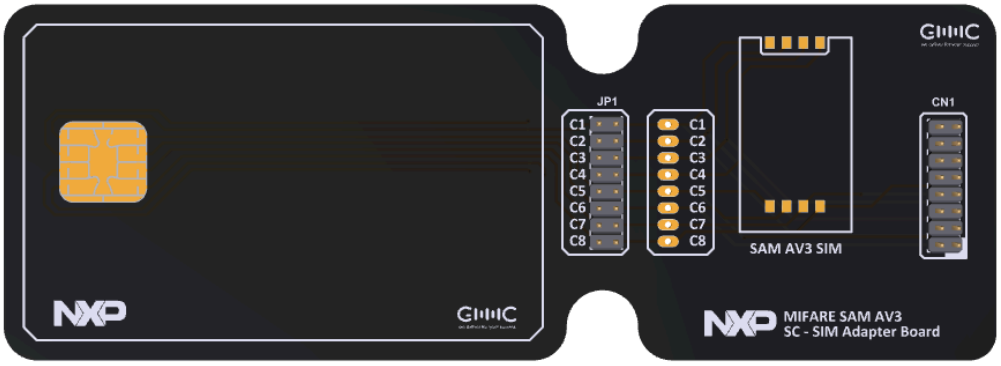

Figure 27. ISO7816 Probe

The green jumpers can be used as described above, all X-mode interfaces are available in this mode as well.

If the CLRC663 frontend is used in this configuration, it must be powered via the USB connector or via the 5 V power line on the Arduino header. The SAM VDD is controlled via the ISO7816 interface. This opens up the possibility of also performing cold resets on the MIFARE SAM AV3, while the CLRC663 stays powered.

In this configuration, The MIFARE SAM AV3 evaluation board can be used with a PC/SC reader together with RFIDDiscover, to fully explorer all features of MIFARE SAM AV3 in X-mode.

7.4.1 RFIDDiscover

When the MIFARE SAM AV3 board is configured to ISO7816 communication, the board can be connected to an Ashling IN-CLA7816 adapter and inserted in a compatible PC/SC reader.

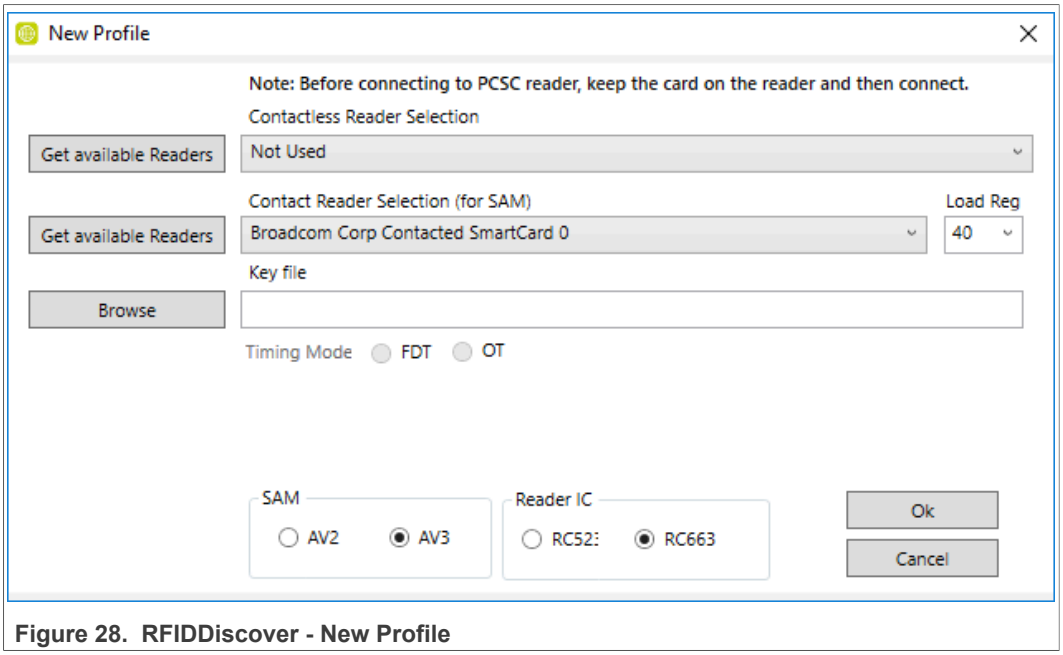

Figure 28. RFIDDiscover - New Profile

In the New Profile dialog, use the settings as shown in Figure 28. Once OK is clicked, RFIDDiscover performs a Host Authentication, as well as an RC_Init command. From this point, the MIFARE SAM AV3 evaluation board can be used with RFIDDiscover as any other reader. Details can be found in UM2538. Please ensure that the SetConfiguration commands have been executed before, as described in Section 6

7.4.1.1 First Steps on a new MIFARE SAM AV3 Evaluation Board

The easiest way of getting stared with the MIFARE SAM AV3 evaluation board is using the tool RFIDDiscover v. 4.7+ and the Evaluation Board Connected via the ISO7816-probe and a contact reader.

Preliminary: Connect MIFARE SAM AV3 Evaluation Board using ISO7816 Probe to a contact reader, and power the board using the USB-Slot. Jumper configurations must be as shown in Figure 26

Step 1: Open RFIDDiscover and choose following settings

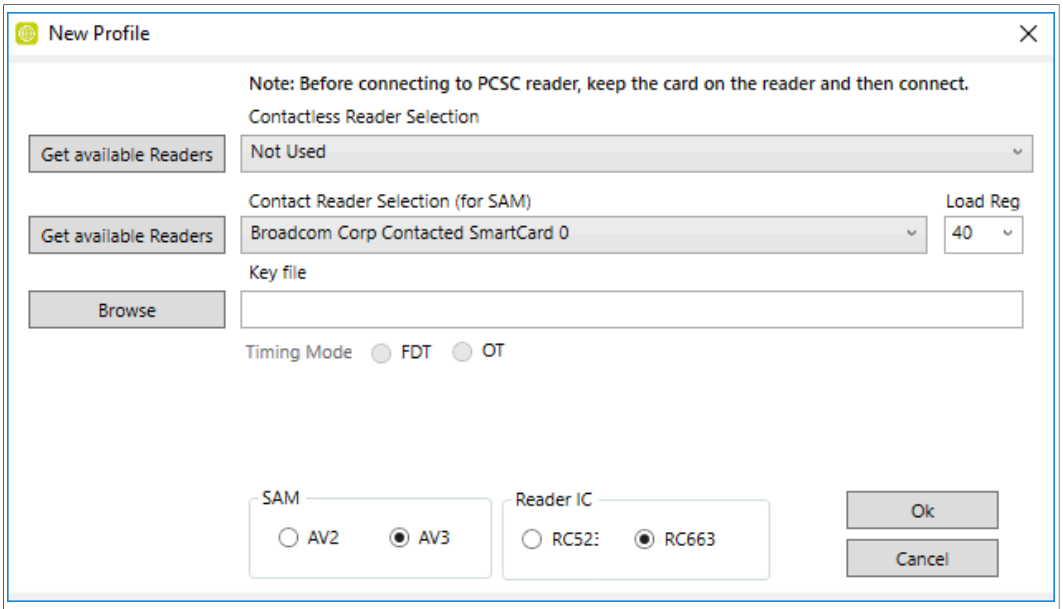

Figure 29. Open Profile Dialog - Select your contact reader, click OK

A new MIFARE SAM AV3 is in unactivated state, and needs activation first. This is done by using the Lock/Unlock command with the activation option. More details can be found in the datasheet. As RFIDDiscover does some steps like host authentication and RC_Init automatically upon connection, the very first connection attempt will give an error message, as these operations are not possible with an unactivated MIFARE SAM AV3.

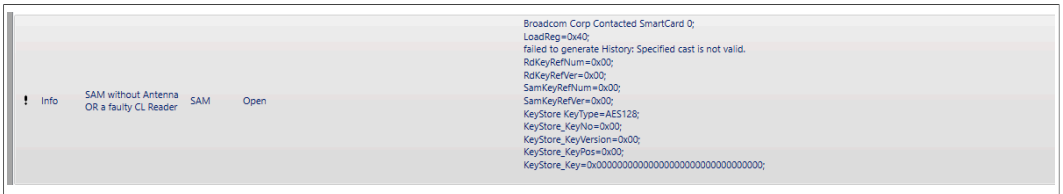

Figure 30. Error message

Step 2: Activate MIFARE SAM AV3

To activate the MIFARE SAM AV3, navigate to the MIFARE SAM AV3 tab, which can be found in the top right of the window. In the menu on the left, choose "SAM AV3 → SAM Host Communication → Lock / Unlock". Use the settings as in below screenshot. Note: the "Reference Key" needs to point to an all 0x00 AES-128 Key in the RFIDDiscover KeyStore. Click "LockUnlock"

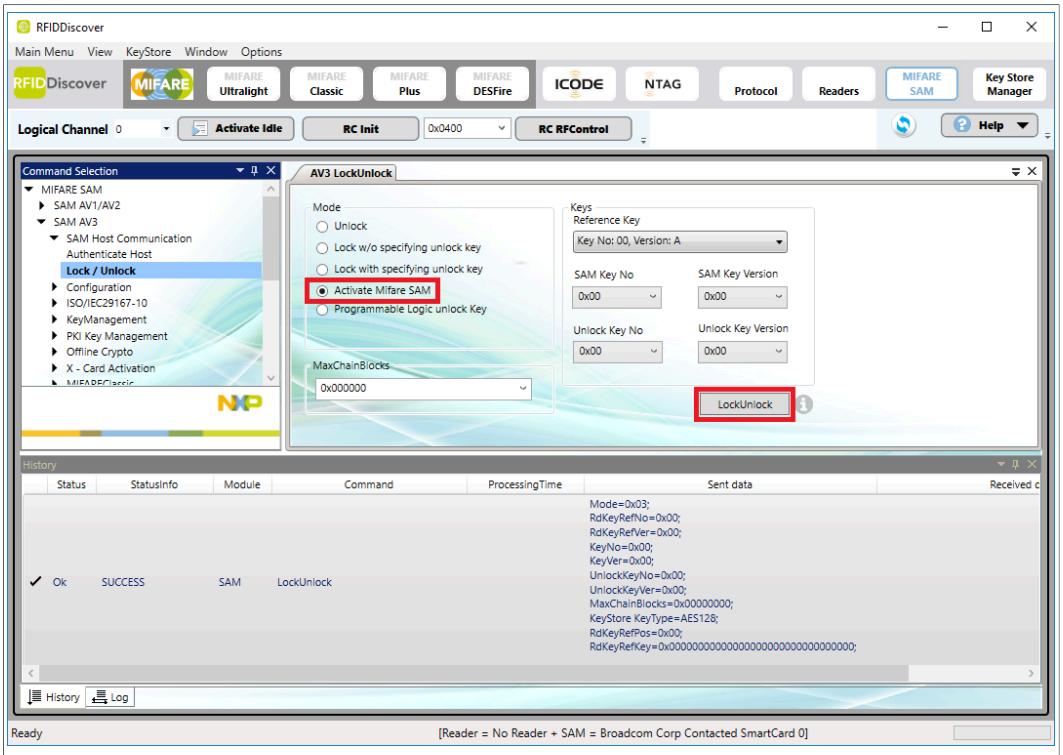

Figure 31. MIFARE SAM AV3 Activation

Step 3: Host Authentication

Now, the MIFARE SAM AV3 is activated and ready to use. An active Host Authentication is needed to use the SetConfiguration command. Navigate to "SAM Host communication → Host authentication", and click on "AuthHost". The "Ref Key" can be the same key as used before to activate the MIFARE SAM AV3. The "H/W Keystore" (→ MIFARE SAM AV3) Ref Key needs to be No. 00, version 00, which is the MIFARE SAM AV3 master key.

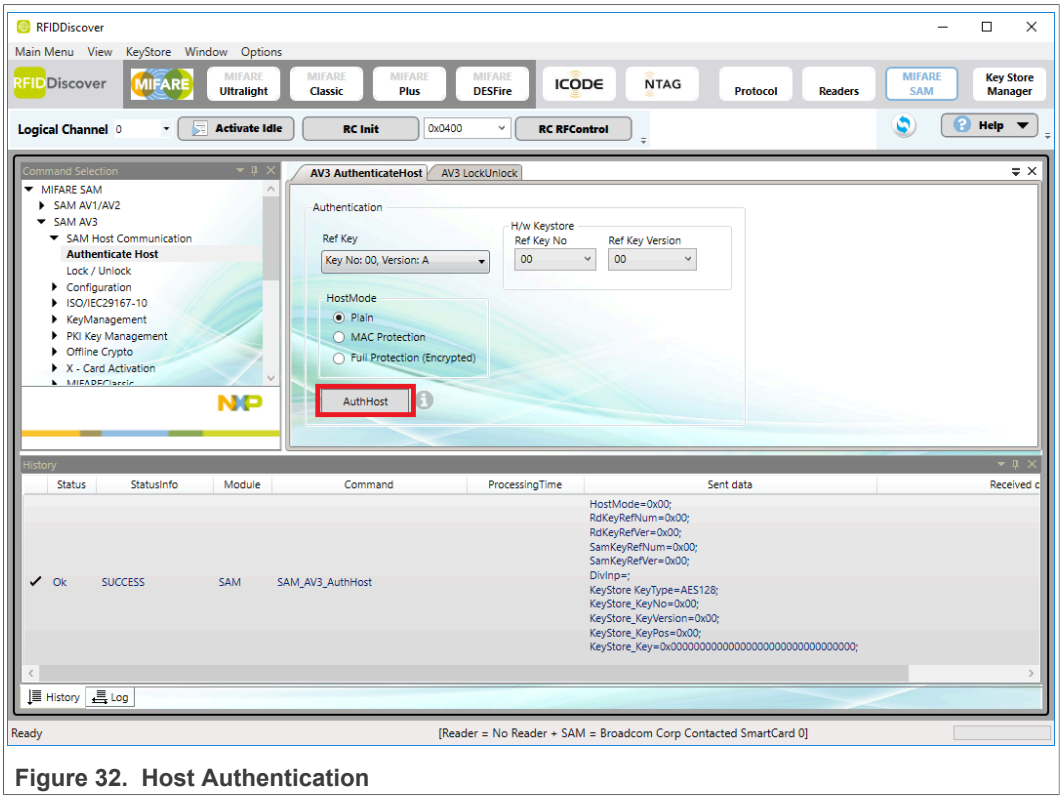

Figure 32. Host Authentication

Step 4: Set the configuration

Now, the SetConfiguration command can be used to configure the MIFARE SAM AV3 to the correct parameters for the Evaluation Board. The reader IC needs to be set to RC663, the I^2C processing clock speed to 0x06. The SetConfiguration command is located under "Configuration → Set Configurations"

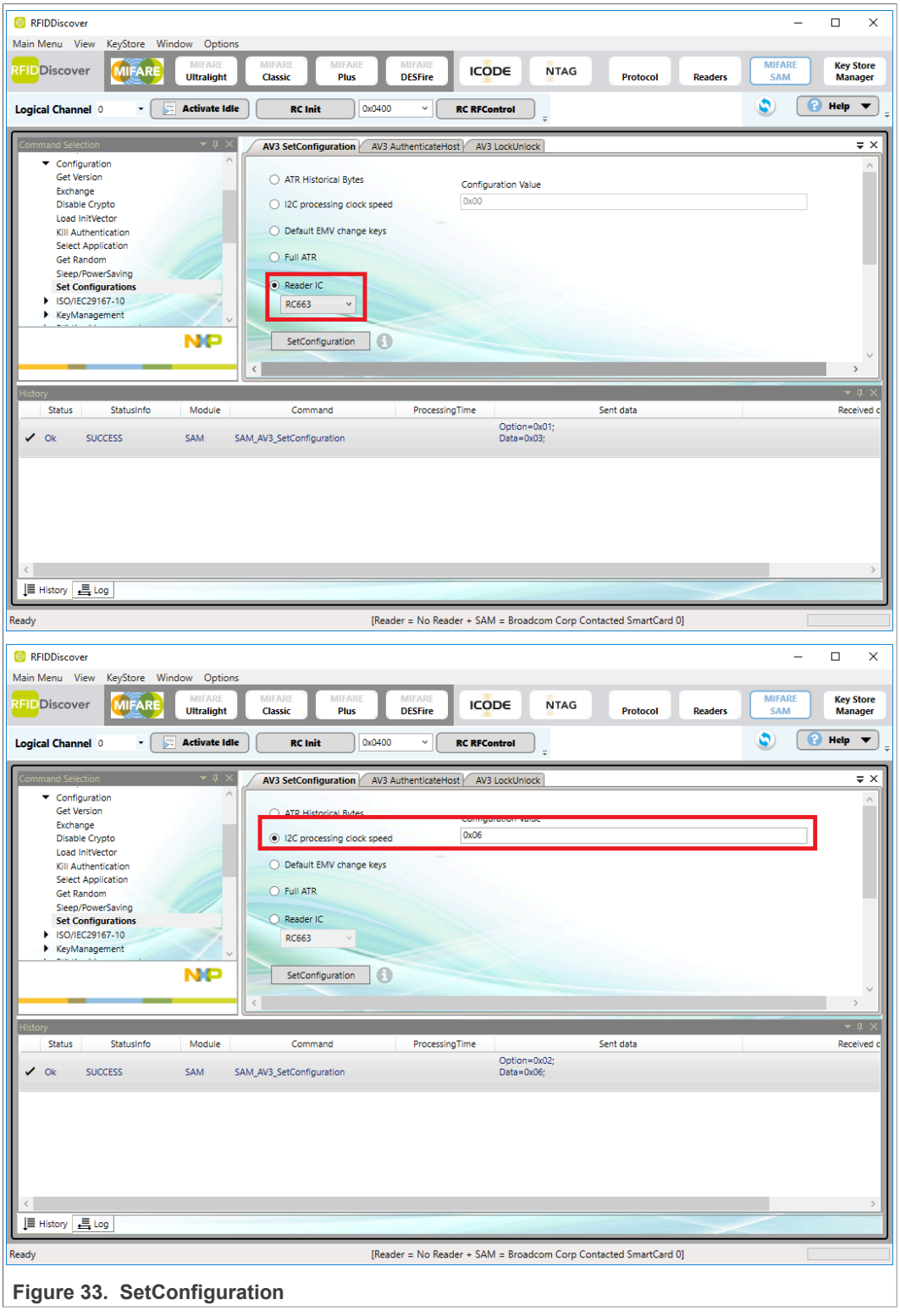

Figure 33. SetConfiguration

Step 5: RC_Init

As a last step, the MIFARE SAM AV3 needs to establish an I^2C connection to the CLRC663 reader frontend. This is done via the RC_Init command. If all above steps were successful, just press the button "RC_Init", which should result in a SUCCESS.

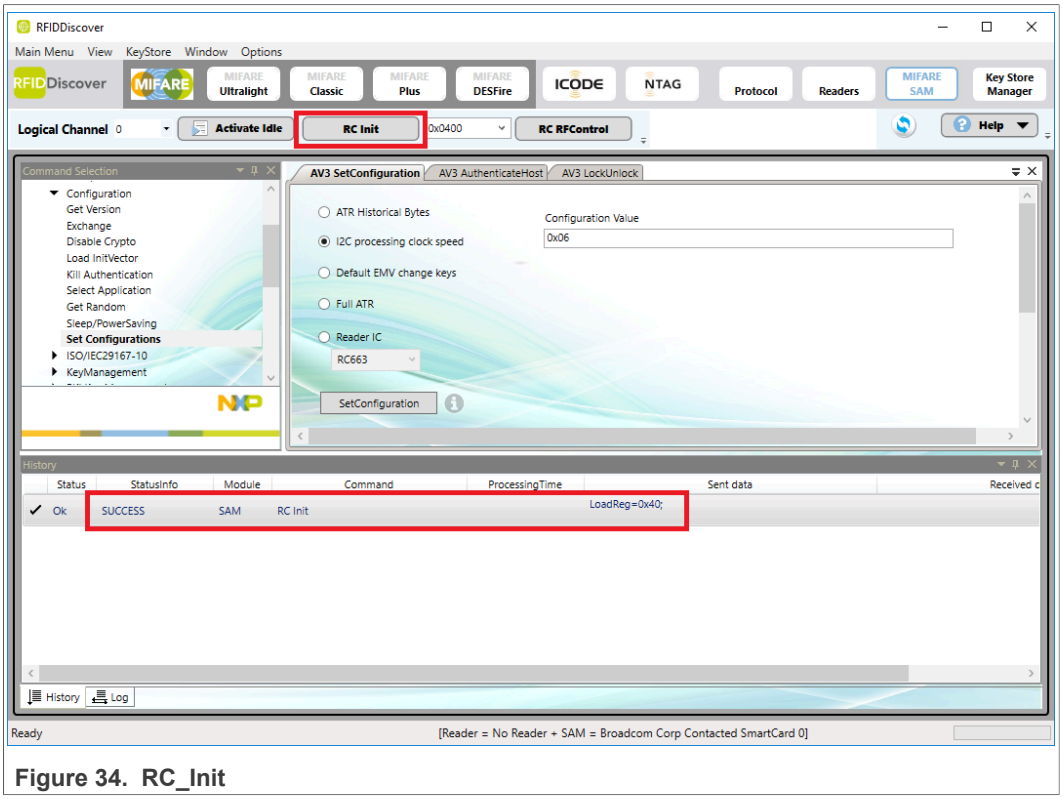

Figure 34. RC_Init

From now on, the Evaluation Board will connect to RFIDDiscover already after the "New Profile" dialog without an error message. The software automatically performs a Host Authentication and RC_Init, therefore the board is ready to use right after connecting.

7.4.1.2 Hints and tips for troubleshooting

Once all the setup steps from previous chapters are done, the MIFARE SAM AV3 evaluation board should be up and running. A card placed on the antenna should be able to be activated using the "Activate Idle" button in RFIDDiscover. If this returns an error, most likely the supply voltage of SAM AV3 is too low for the I2C interface between SAM and CLRC663 to work. The reason for this is, that MIFARE SAM AV3 supports all 3 voltages classes defined in ISO7816, thus it will run also with VCC of 1V8 (Class C). The PC/SC reader may activate the SAM in which voltage class is announced in the SAM's ATR, and some readers use the lowest possible. To mitigate this, either change the voltage class used for activation in the PC/SC driver of the particular reader used, or change the SAM's ATR to not advertise "Class C". This change can be done in the SetConfiguration tab, similar to the previous executed SetConfiguration commands.

Figure 35. Change SAM full ATR

The ATR to set is:

```
3B DF 18 FF 81 F1 FE 43 00 3F 03 83 4D 49 46 41 52 45 20 53 41
 4D 20 41 56 33 30 15
```

This ATR removes "Class C" from the advertised voltage classes, so that PC/SC readers will not activate the SAM using this voltage.

8 Older revisions

The currently available revision of the board is **1V1**. The revision number of the board is printed on the board.

8.1 Changes in 1V1

- I2C pullup for SAM AV3 I2C Slave interface was corrected. This fixes Section 9.1
- Shielding is added over CLRC663+
- Antenna matching optimized

9 Known limitations

9.1 Limitation 1

Affected board version: 1V0

Due to the behavior of some MCU's during firmware flashing or resetting, the MIFARE SAM AV3 can be brought in a Security reset condition, which will after some time end in a permanent mute of the device. When in reset condition, the MCU's GPIOs are floating, and therefore creating a situation where the X-mode I2C interface pins (IO2 and IO3) of the SAM AV3 are at a higher voltage level as VCC, due to the I2C pullups. This is not allowed according to the MIFARE SAM AV3 data sheet, and results in security reset events.

Known affected MCUs:

- K64
- LPC51U68

To mitigate this, the I2C pullups of the SAM's X-mode interface can be removed and replaced by new resistors between the I2C lines to the middle pin of the SAM VCC jumper. This makes sure, that the IO's will never have a higher voltage level than VCC of the MIFARE SAM AV3.

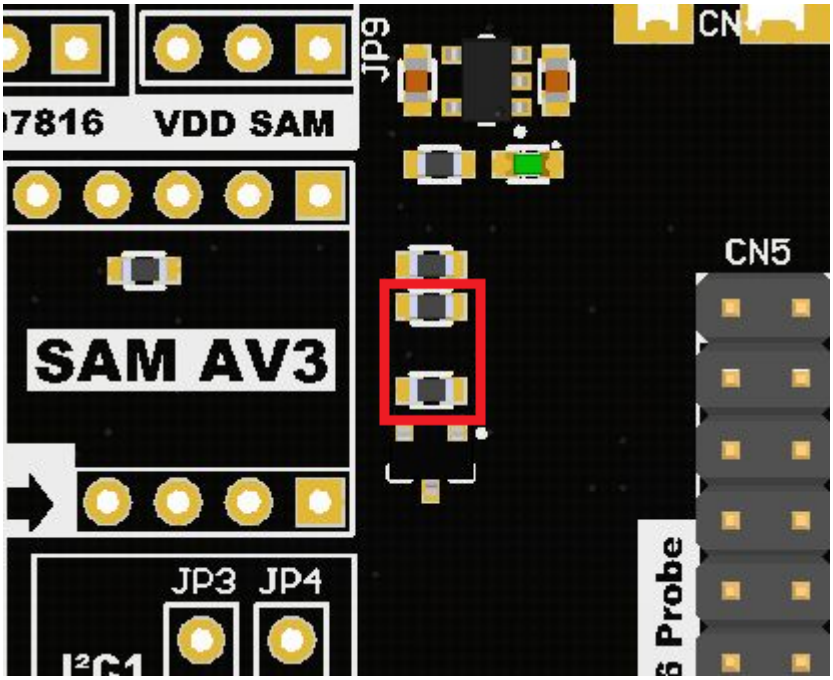

Figure 36. Remove these 2 resistors

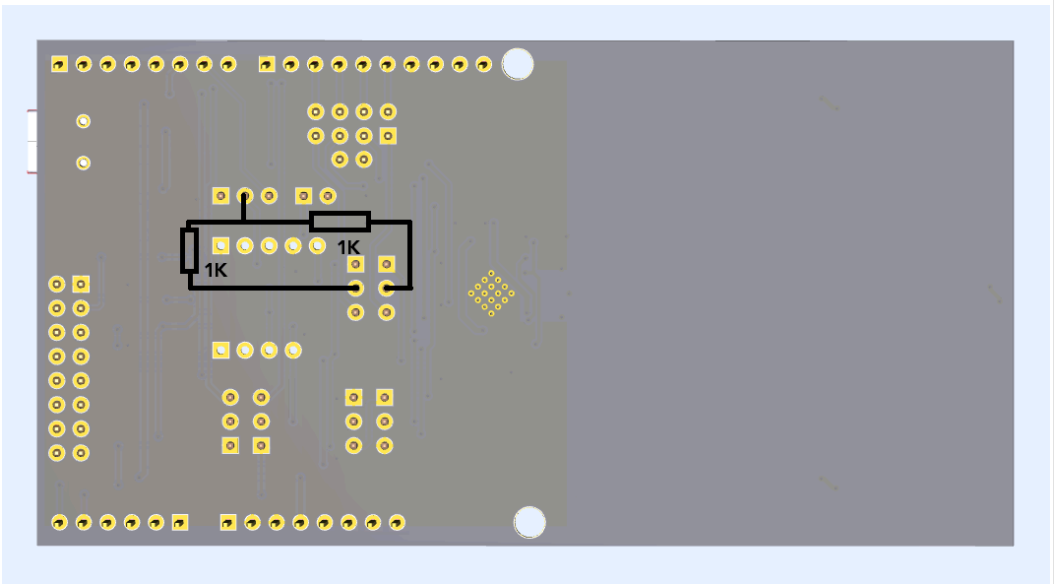

Figure 37. Add new I2C pullups to SAM VCC on bottom side of the PCB

This modification has no influence on any mode of operation.

10 References

1. **Data sheet –** MIFARE SAM AV3, document number DS3235xx.
2. **User manual –** RFIDDiscover, document number UM2538xx.
3. **RFIDDiscover –** RFIDDiscover v 4.7+, software number SW186647, available on DocStore

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