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EFM32 USB Smart Card Reader

AN0820 - Application Note

Introduction

This application note gives an overview of the ISO/IEC-7816 smart card standard and a short introduction to the communication and protocol of a smart card. Along with this document there is a working example of a smart card-reader, implemented using the EFM32. The included software example implements a USB-CCID card reader device using the STK3700 Giant Gecko Starter Kit. The software example is developed and tested with an ACS (Advanced Card Systems Ltd.) ACOS-1/3 type of smart card.

This application note includes:

- This PDF document
- Source files (zip)
  - Example C-code
  - Multiple IDE projects

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1 Smart Card Introduction

A smart card, chip card or integrated circuit card (ICC) is a device that includes an embedded integrated circuit chip that can be either a secure microcontroller or equivalent intelligence with internal memory or a memory chip alone. The card is connected to a reader via direct physical contact or via a remote contactless RF interface. With the usage of an embedded microcontroller, smart cards have the ability to store large amounts of data, carry out their own on card functions (such as encryption and mutual authentication) and interact intelligently with a smart card reader.

Smart card technology conforms to international standards (ISO 7816 and ISO 14443) and is available in a variety of form factors, including plastic cards, fobs, SIM cards used in GSM mobile phones, and USB tokens.

Smart cards are used in many applications worldwide, including:

- Secure ID - employee ID badges, citizen ID documents, electronic passports, driver's licenses, online authentication devices
- Healthcare - citizen health ID cards, physician ID cards, portable medical records cards
- Payment - contact and contactless credit/debit cards, transit payment cards
- Telecom - GSM Subscriber Identity Modules, pay telephone payment cards

The scope of this application note is to give an overview of the different parts of the ISO 7816 standard, governing physical contact smart cards themselves and smart card interface devices or readers. The EFM32 microcontroller is used to implement a USB-enabled smart card reader and the included software example utilizes the EFM32 USART's 7816 smart card mode for automatic parity generation/check and ACK/NACK generation.

2 The ISO 7816 Standard

ISO/IEC 7816, (only referred to as ISO 7816 from here on) is an international standard related to electronic identification cards with contacts, especially smart cards, managed jointly by the International Organization for Standardization (ISO) and the International Electro-technical Commission (IEC). The full standard is available through www.iso.org, (See Reference 4 (p. 20)).

2.1 Different Parts of the 7816-Standard

The standard currently has 15 parts (or levels), but only 2 of them, part 3 and part 4, are relevant for this application note. The first 5 parts of the standard are listed here:

- 7816-1: Physical characteristics.

  Describes the physical characteristics of integrated circuit cards, from environment exposure limits to degree of bending or flexing; important for manufacturers in their choice of materials and establishing a process that embeds the integrated circuit into the card

- 7816-2: Cards with contacts - Dimensions and location of the contacts.

  The following table contains the contact definition of the electrical contacts, according to ISO7816-2:

Table 2.1. Smart Card Electrical Connection

Contact	Designation	Use
C1	V_{cc}	Power connection through which operating power is supplied to the microprocessor chip in the card (typically a reader must support up to 5V, max 200mA draw, but the device implemented in this example only supports 3.3V since that is the operating voltage of the EFM32 on the STK3700 starter kit.)
C2	RST	Reset line (from reader to card)
C3	CLK	Clock signal line (from reader to card)
C4	RFU	Reserved for future use
C5	GND	Common ground of contact reader and card
C6	V_{pp}	Higher voltage used to program EEPROM of older chips. Usually Not used.
C7	I/O	Input/output data line that provides a half-duplex communication channel between the reader and the smart card
C8	RFU	Reserved for future use

Figure 2.1. Smart Card Physical Connections

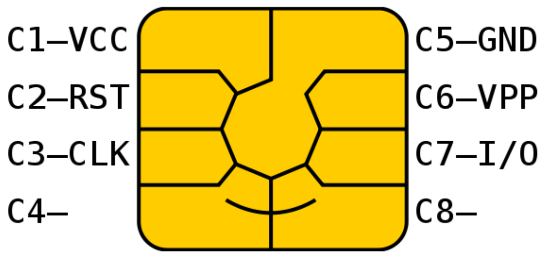


Figure 2.1 (p. 3) shows a typical pad layout of the contacts on the smart card.

- 7816-3: Cards with contacts - Electrical interface and transmission protocols.

  Describes the electrical levels and waveforms, as well as the physical layer of the communication protocol. This part includes specification of clock generation, reset sequence, baud rate, frame and parity check as well as negotiation of parameters related to the communication.

- 7816-4: Organization, security and commands for interchange.

  It specifies the contents of command-response pairs exchanged at the interface, means of retrieval of data elements and data objects in the card, applications and data in the card, access methods to files and data in the card including a security architecture.

- 7816-5: Registration of application providers.

  Defines how to use an application identifier to ascertain the presence of and/or perform the retrieval of an application in a card. ISO/IEC 7816-5:2004 shows how to grant the uniqueness of application identifiers.

The rest of the 7816 standard deals with security protocols, card management and life-cycle management, cryptographic considerations and also newer types of smart card interfaces, including synchronous communication and USB-enabled cards.

Since a USB CCID device operates as a bridge, relaying packets between host computer and smart card, this application note will mainly relate to the electrical waveforms and transportation of messages described in part 3 and 4 of the standard. These parts are discussed in detail in the following sections.

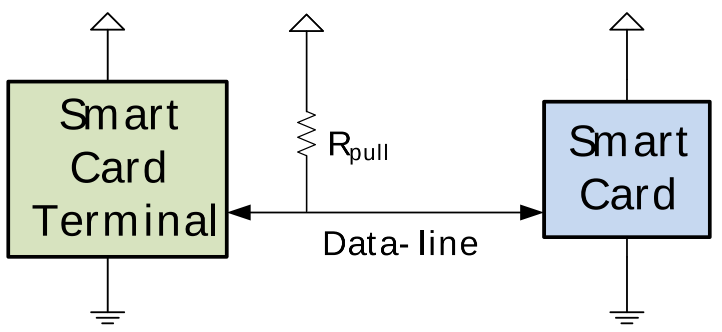
2.2 Part 3; Electrical Signal and Transmission Protocol

Communication with the smart card takes place over a single bi-directional, half-duplex data line. The voltage levels for high / low states is the same as the supply voltage to the smart card. The direction of communication is assumed to be known a-priori by both master (reader) and slave (smart card). Parameters such as protocol format, type of smart card, baud rate and other electrical parameters are read out of the smart card right after reset. This is known as the Answer to Reset or ATR. Based on the information given in the ATR, the reader can adapt to the transmission format supported by the card.

2.2.1 Electrical Connection of the Bi-directional Data Interface

Since the data communication is bi-directional, the terminal is often configured to transmit data through an open-drain output. This means that it can pull the data line low, but it needs a pull-up resistor to go high again. And in the same way, the smart card can pull the line low, but needs the pull-up to take the line high again. Some interface-devices use more clever ways of doing this to achieve faster rise-times, but for the EFM32 implementation of the bi-directional data line the following configuration is used:

Figure 2.2. Bi-directional Data Line with Pull-Up Resistor



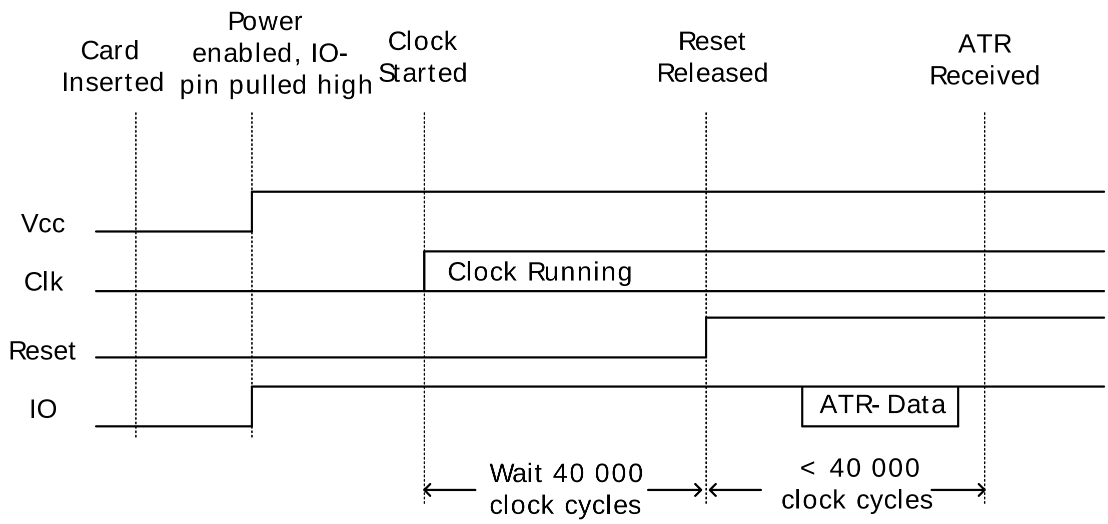
The pull resistor used in the EFM32-implementation is the internal pull-up in the EFM32's GPIO pin.

2.2.2 Power Up, Clock and Reset

When a card is inserted into the reader, all the contacts are disconnected from the terminal/reader, including ground. The reason for this is that the contacts in the terminal slide over the smart card contacts while the card is inserted. Applying power to the wrong pins could in theory damage the card or the reader. When the card is properly inserted, there is usually an electrical contact that breaks connection, indicating to the reader that the card is fully inserted. Now the reader initiates a power on and reset sequence.

The interface is responsible for the timing of the sequence. The most important parameters are the clock-cycle count before and after reset is released. The interface should enable the clock and keep it running for 40k cycles before reset is released. After reset, the card must respond with its ATR within a window of 400-40000 clock cycles. The timing is illustrated in Figure 2.3 (p. 5)

Figure 2.3. Answer to Reset Sequence



2.2.3 Byte Transfers

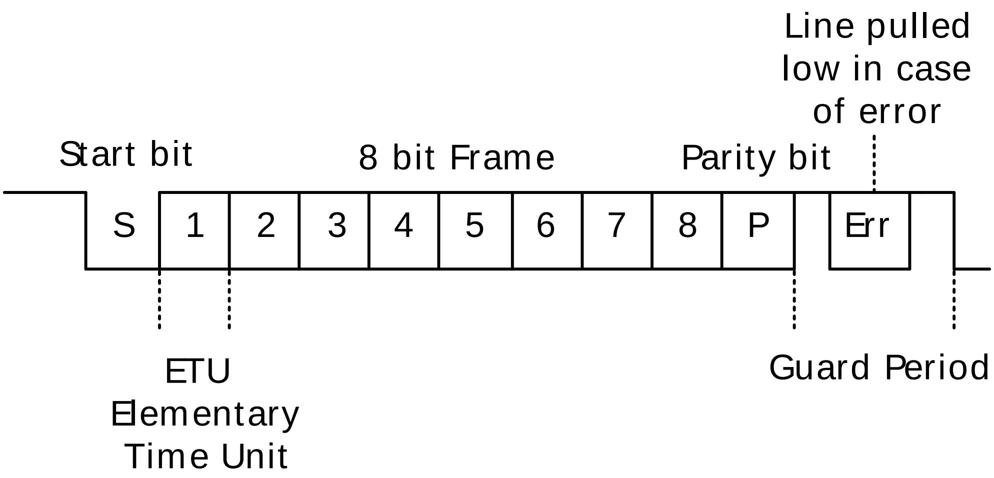
During the power on and reset sequence, the smart card answers with its "Answer to Reset". The transmission of this first data-packet is carried out with default communication parameters listed below:

- Baud rate = F_{clock}/372. Clock should be approximately 3.57 MHz, resulting in 9.6 kBaud/s.
- 8 data bits.
- 1 start bit.
- 1 parity bit, even.
- 1.5 stop bits (guard period for Ack/Nack).
- Coding of 0's and 1's: This can vary, the correct naming of this is: "Direct" or "Inverse" convention. It is based on the very first character transmitted, called TS. "Direct" indicated by TS=HLHHLHHHLLH (H = Vdd, L = GND) means that the following data is transferred as 0=GND, 1=Vdd and with the least significant bit first. For the Inverse convention, indicated by TS=HLHHLLLLLLH, data is transmitted with most significant bit first and 0=Vdd, 1=GND.

Using the above parameters, the interface must also adhere to the Ack/Nack of bytes, based on the parity bit. A Nack is indicated when the receiver pulls the data line low in the guard period after the parity bit is transmitted. If this happens, the transmitter should immediately retransmit the last byte.

One bit-period is called an "Elementary Time Unit" or ETU, this is used throughout the 7816 standard as a basis for defining the timing of the protocol. An illustration of one transmitted byte is given in Figure 2.4 (p. 6) .

Figure 2.4. Byte Transmission, Parity and Elementary Time Unit



Note that this byte-format with parity error detection is always used during the Answer to Reset, but only for further communication if the selected protocol is "T=0" (based on what is indicated in the ATR). What T=0 protocol means and why it is called that is explained in Section 2.3 (p. 6) .

2.2.4 Answer to Reset

The Answer to Reset is a string of 33 or fewer characters (bytes). With naming as defined in ISO 7816-3, the ATR consists of the following mandatory and optional characters:

- TS - a mandatory initial character, conveying byte-format, (the direct or inverse convention).
- T0 - a mandatory format character, indicating the contents of the ATR.
- TAi, TBi, TCi, TDi - optional interface characters, these characters indicate supported clock speeds, voltage levels and protocols supported by the card. Since they are optional, if not given, the card reader must continue with the default protocol used during the ATR sequence.
- T1, T2, TK - optional historical characters, these characters typically hold information about the card manufacturer, type of card (size etc.), version number and the state of the card.
- TCK - a conditional check character, presence of this byte is indicated by the optional interface characters, if present, it is exclusive OR of all the bytes in the ATR, excluding TS and TCK.

This document will not go further into the meaning of these characters, please refer to the ISO 7816-3 Standard for more information, (Reference 1 (p. 20)).

2.3 Part 4; Commands and Exchange of Data Packets

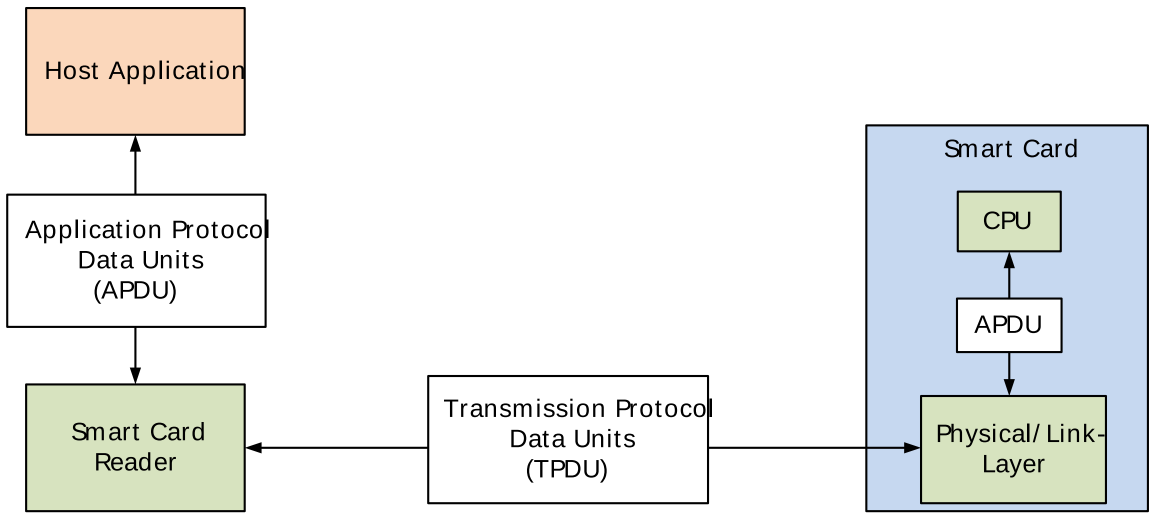
The previous section described how the first basic communication channel is established between the card and the reader. The channel is a half-duplex, physical channel. Part 4 of the ISO 7816 standard defines the link-level protocols on top of this physical channel. The link-level protocol provides an error-free communication channel for the application-level protocol. This section describes the message structure consisting of application protocol data units (APDUs), which are exchanged between the reader application and the smart card application by the link-level protocol. Since only one type of the link-level protocol is supported by the EFM32-reader-implementation (T=0), this will be described in more detail than the others.

Part 4 of the 7816 standard also defines a file system API to manipulate files and a security service API allowing smart card and reader to mutually authenticate with each other. This is not discussed further in this application note.

2.3.1 Protocol Data Units

The data units transmitted in the link-layer protocol is called transmission protocol data units (TPDUs). These are the packets of data going between the reader and the smart card. On top of these are the APDUs, which comes directly from the application layer of the protocol. The APDUs are usually transmitted unaltered by the smart card interface device, but this depends on the level of automatism supported by the reader. This naming convention is illustrated in Figure 2.5 (p. 7) .

Figure 2.5. Protocol Data Units and Where they Apply



2.3.2 T=0 Protocol Introduction

The link-layer protocol is usually one of two variants, either a byte-oriented protocol with error handling performed on each byte by using a parity bit, or a block-oriented protocol with checksum-based error detection. The first one, the byte-oriented protocol is called "T=0". The name comes from the indication of this protocol in the ATR by having one of the bits in one of the T-characters equal to 0. The block-oriented protocol is called "T=1". In fact there is even a T=2 protocol for full-duplex interfaces, with T=3-15 reserved for future protocols.

The T=0 protocol re-uses the same byte-transmission format used during the ATR-sequence. The parity error detection and retransmission at byte-level is also re-used. The TPDU-messages exchanged between reader and smart card has two distinct structures, based on the direction of communication:

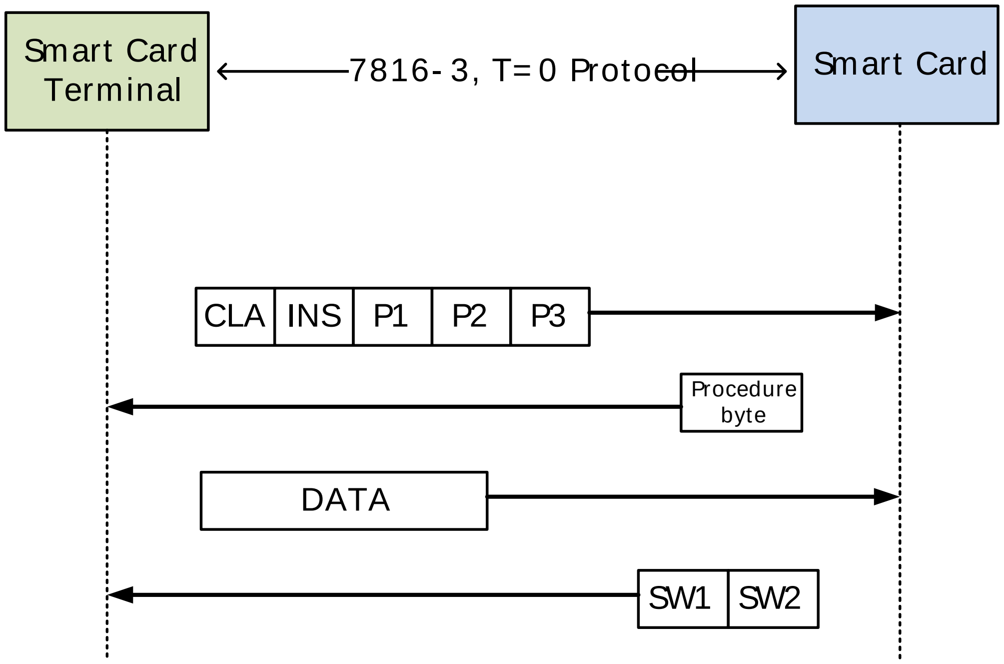
- A command, this is sent from reader to smart card. Consists of at least 5 characters named: CLA, INS, P1, P2, P3, in addition comes a number of data bytes if writing to the smart card.
  - CLA: Class designation of the command set to establish a collection of instructions.
  - INS: The INS byte is used to identify a specific instruction within a class of instructions identified by the CLA value.
  - P1: Used to specify the addressing used by the [CLA, INS] instruction.
  - P2: Also used to specify the addressing used by the [CLA, INS] instruction.
  - P3: Specifies the number of data bytes transferred to or from the card as part of the [CLA, INS] instruction execution.
- A response, this is sent from smart card to reader. Consists of 1 or 2 status characters named SW1 and SW2, in addition comes a number of data bytes if reading from the smart card. The SW1 byte is also called "procedure-byte" if it is just an ACK or NULL character, indicating that the card is not finished with the transaction.

- SW1: Status response of the current command. 0x90 means success for example. If this byte is equal to for instance 0x60=NULL or the INS sent in the command, it means the card need more time to process the command or that it has more data to receive/send. This character is then called a procedure byte.
- SW2: (optional) also conveys a status response to the reader

The flow of communication is handled by the reader depending on the first SW1 character of the smart card-response. All transfers are initiated by the reader and followed by a response from the smart card. In some cases, depending on SW1, the reader should wait for further bytes, in other cases it should forward the SW1 and possibly SW2 characters and any read data bytes to the host application.

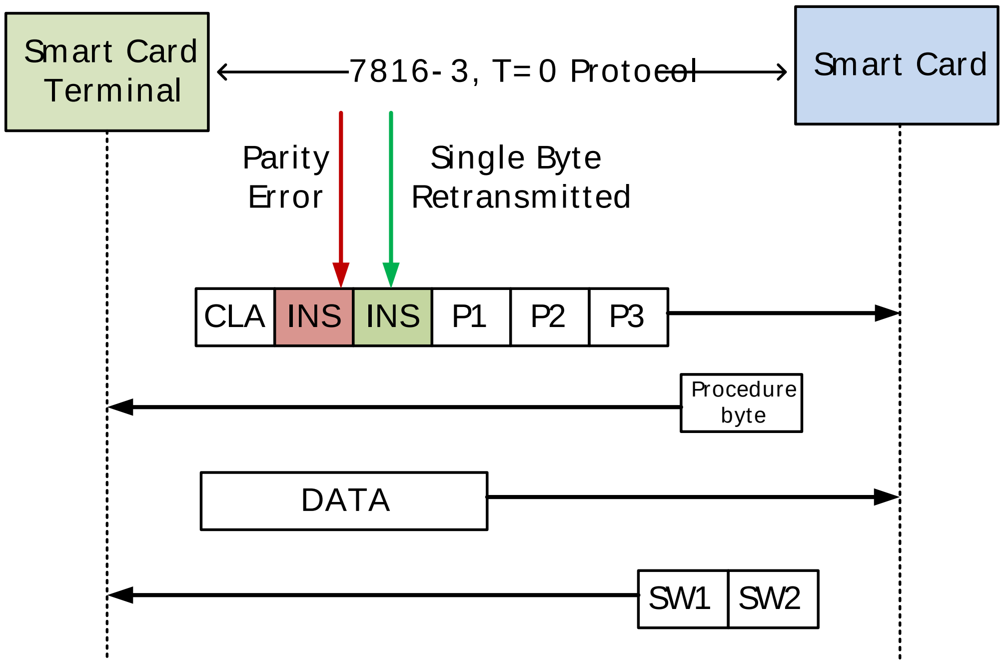
In the case of SW1 indicating that the reader should wait for further data or the smart card needs more processing time, the SW1 is called a "procedure byte", indicating that it should not be forwarded to the host application as a response. Figure 2.6 (p. 8) illustrates how transmission of a data packet to the smart card looks like, following the T=0 protocol. In fact, for the T=0 protocol, the bytes of the APDU directly overlays the bytes of the TPDU, this means that the APDU in Figure 2.6 (p. 8) simply consists of CLA, INS, P1, P2, P3 and DATA in that order. Further, the APDU going back to the application is simply SW1 and SW2.

Figure 2.6. Host Sends Data to Card



In the case of error on one byte using the T=0 protocol, the failing byte is retransmitted immediately by the reader, this is illustrated in Figure 2.7 (p. 9). Since the error detection is a single parity bit, this will fail if there is an even number of bits flipped in the character transmitted. This is one of the limitations of the T=0 protocol.

Figure 2.7. Parity Error and Re-transmission for the T=0 Protocol



For further explanation of CLA the (class byte), INS (instruction) and P1-3 (parameters) and their contents in the T=0 protocol, please see the 7816 standard, (Reference 4 (p. 20)).

2.3.3 T=1 Protocol Introduction

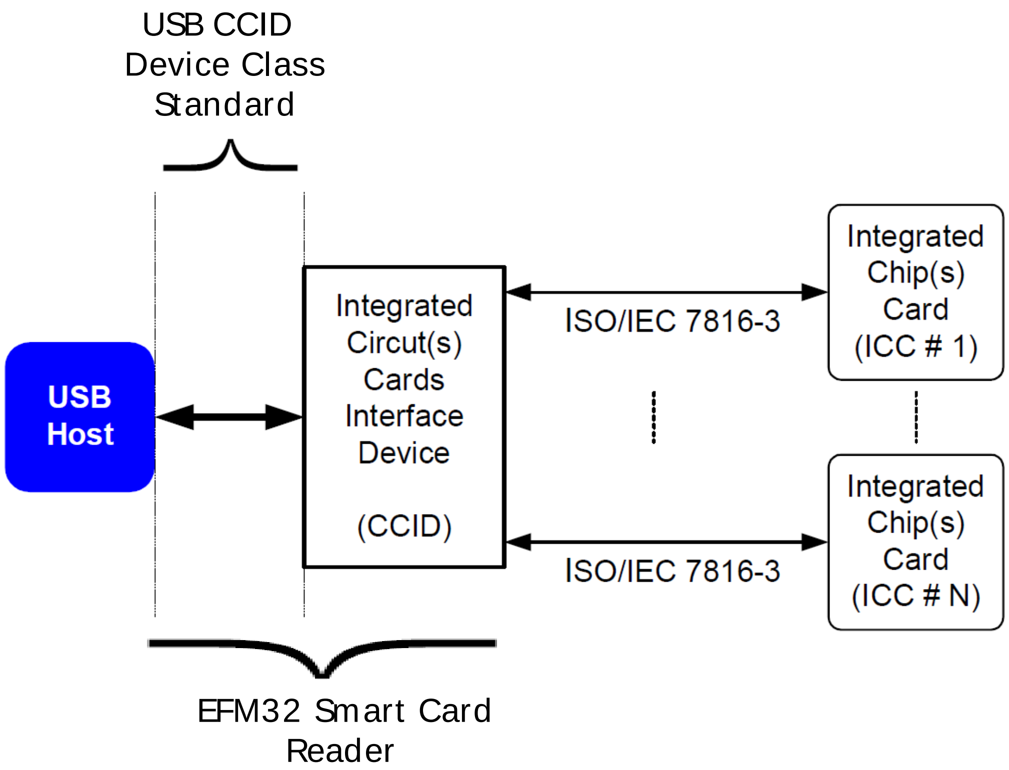
The T=1 protocol is more complex than the T=0 protocol. The physical interface is still half-duplex and uses the same configuration as T=0. T=1 is actually built on top of T=0, but it does not use the T=0 error correction functionality, rather it uses a block oriented protocol. The main benefits of T=1 is the block-oriented error detection mechanism which provides much better error detection and correction capabilities than T=0. For more information about this protocol, please see Reference 2 (p. 20) .

3 EFM32 USB CCID Implementation

The USB CCID (Circuit Card Interface Device) smart card reader in the attached software example, implements a T=0 interface device only (byte-level transmission protocol, as defined in ISO/IEC 7816-3). This means that the higher level details of the communication with the smart card (authentication, file access etc.) is handled by the USB Host, which usually is a PC. Most of the protocol negotiation is also handled by the host. The EFM32's job is to act as a USB - smart card bridge, transferring data packets between the two and only handle T=0 protocol error conditions. For a complete implementation, other error conditions such as electrical faults should also be detected and responded to accordingly, usually by disconnecting the card immediately.

Figure 3.1 (p. 10) gives an overview of what is covered by the USB CCID standard (see Reference 1 (p. 20)). It only covers the interface and protocol handling the transmission of APDU-packets between the card reader and the USB host. The EFM32 implementation also includes the T=0 interface protocol for communication with the smart card itself. From here on the EFM32 card reader is referred to as the CCID.

Figure 3.1. Smart Card USB CCID Device Class Standard



3.1 USB CCID Standard

The CCID Standard (Reference 1 (p. 20)) covers the USB communication including USB pipes used, message formats, as well as all error conditions needed for conveying APDUs between the application running on the USB host and the CCID. The format of the messages, message sizes and error-conditions change according to the protocol used to communicate between the CCID and the smart card. This makes it possible for the CCID to implement a high degree of automatism in the interaction with the smart card. For instance, for T=1, which is block oriented, larger blocks of data can be transferred in each USB packet to increase speed.

The CCID uses one Bulk-OUT Endpoint, one Bulk-In Endpoint and also one optional Interrupt Endpoint to communicate with the host. Each message sent between Host and CCID contains a header which has a fixed length and a data field with variable length. Many of the messages consists only of the header. Since the implementation in this application note only implements the T=0 protocol, the data field in the USB messages typically map directly to the APDU-message going to/from the smart card.

A detailed description of the CCID standard is outside the scope of this document. For detailed description of the CCID Class Descriptor, exact message format, status/error codes and sequence diagrams, please refer to the specification, (Reference 1 (p. 20)). An overview of some implementation details, state-diagrams and sequence diagrams are given later in this chapter.

3.2 Connection of Smart Card to the STK

The EFM32 peripheral used for the physical layer is the USART which has a special 7816 smart card mode to make the T=0 error detection and retransmission happen in hardware. An additional clock signal is also required for the card, which is generated using a timer. As the serial communication is a single line, half duplex, both the TX and the RX pins of the interface are tied together to the smart card I/O line, this is done internally in the EFM32, using the loop back feature of the asynchronous serial interface.

According to ISO-7816 part 3, the nominal bit duration used on the I/O line is defined as one Elementary Time Unit (ETU) and the initial ETU is 1/9600 s. For simplicity reasons, only the 9600 bps speed is implemented. Further the bytes are transmitted using 8 data bits, 1 bit even parity and 1.5 stop bits, as this matches the required format of the 7816 standard.

USART1 in asynchronous mode is used and TIMER0 provides the required clock signal. The clock frequency is fixed to 3.5712 MHz which is the baud rate multiplied by 372. This is the default factor of difference between baud rate and clock speed in the 7816 standard.

Further there is a reset pin and power pins allocated as well as a card-insertion detection pin. The 7816 standard defines that the card reader should physically power off the card if ordered to do so by the host or if card-removal is detected.

The insertion detection pin is usually a separate electrical switch within the smart card socket. It is not connected directly to the smart card. It is usually a normally closed switch, which opens when a smart card is inserted all the way in the socket. In this example it is connected to both EFM32 GND and a gpio-pin with a pull-up. When a card is inserted and the switch breaks the connection, it is expected that this pin is pulled up. Therefore make sure to connect the other side of the insertion detection switch of the card socket to EFM32-ground, not the GND pin of the smart card, as this can be tri-stated when the card is not inserted.

All the pins used are located on the STK3700 expansion header, the exact pins used are described by the following table:

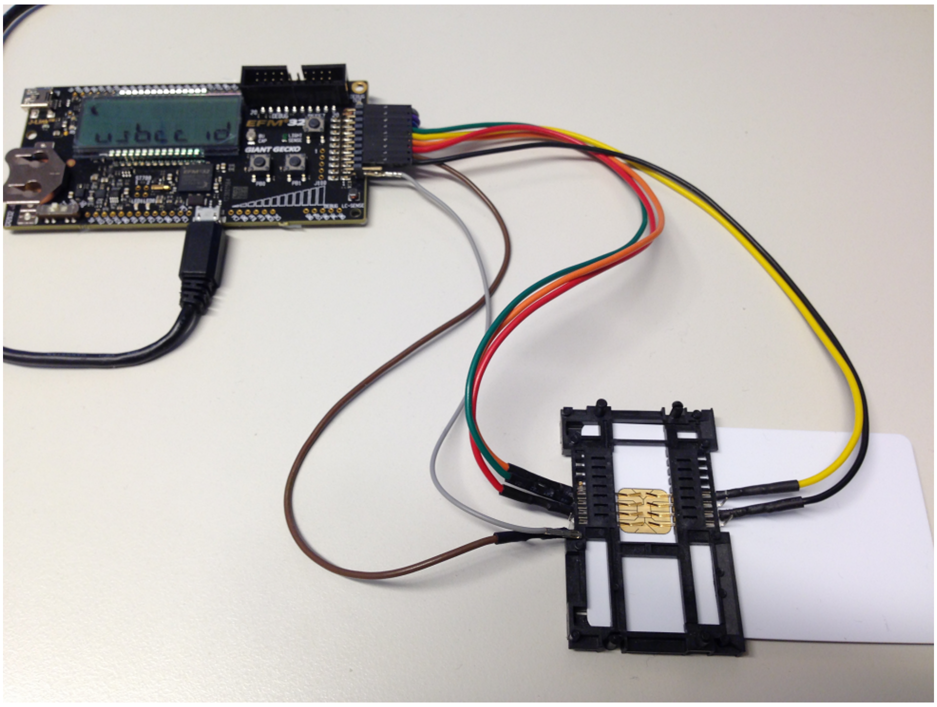
Table 3.1. STK3700 Smart Card Pinout Description

EFM32GG990F1024	Smart Card Pin		Functionality
PD2	C3	CLK	Clock
PD0	C7	I/O line	TX/RX Serial Data
PD5	C2	Reset	Card reset
PD3	C1	V_{cc}	Card Power Supply[1]
PD4	C5	GND	Ground pin of card
PD1	Insertion Detection		Insertion Detect Pin, high side
GND	Insertion Detection		Insertion Detect Pin, low side

[1]In this application example, a GPIO pin is used directly as the card power supply, hence the card Vcc is limited to 3.3V. For 5V cards, the same application can be used with GPIO pin driving a hardware switch that provides Vcc=5V to the card.

The following picture illustrates how a physical smart card connector can be hooked up to the starter kit on the above mentioned pins with some short wires.

Figure 3.2. Physical Connection of Card Socket with EFM32 Starterkit



3.3 Software Implementation

3.3.1 Supported Protocols and Cards

To make the software example as simple as possible, only a single communication protocol is supported, the T=0 protocol. The CCID-standard also has optional lengths of APDU-packages, only the short type is supported in this implementation. During development of the software, only cards from ACS, specifically ACOS1 smart cards where used for testing. Other cards that support the same protocol should however work, depending on host-side smart card driver and software.

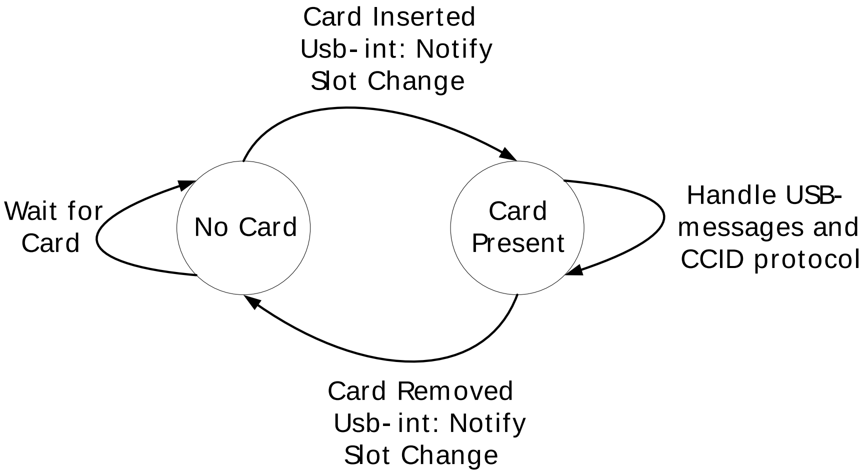
Since the firmware on the EFM32 itself is basically only shuffling data-packets back and forth between the smart card and the host computer, virtually any card supporting the correct speed and T=0 protocol should be able to communicate with the host computer.

3.3.2 Software Algorithm

The software algorithm is based on a simple state machine function executed at regular intervals. About every 10ms in this implementation, but anything down to 5-10 times per second should be OK. There are no strict limitations on response time in the USB CCID-standard. The only time USB-interrupt messages are sent, are upon card insertion or removal. All other communication happens through BulkIN/OUT-endpoints.

Every time the `CCID_Handler()`-function is called, it steps the state-machine in Figure 3.3 (p. 13) one step forward. All the actual CCID operations and communication with the smart card happens in the "Handle USB-messages and CCID protocol"-transition.

Figure 3.3. Card Detection and Notification Interrupt



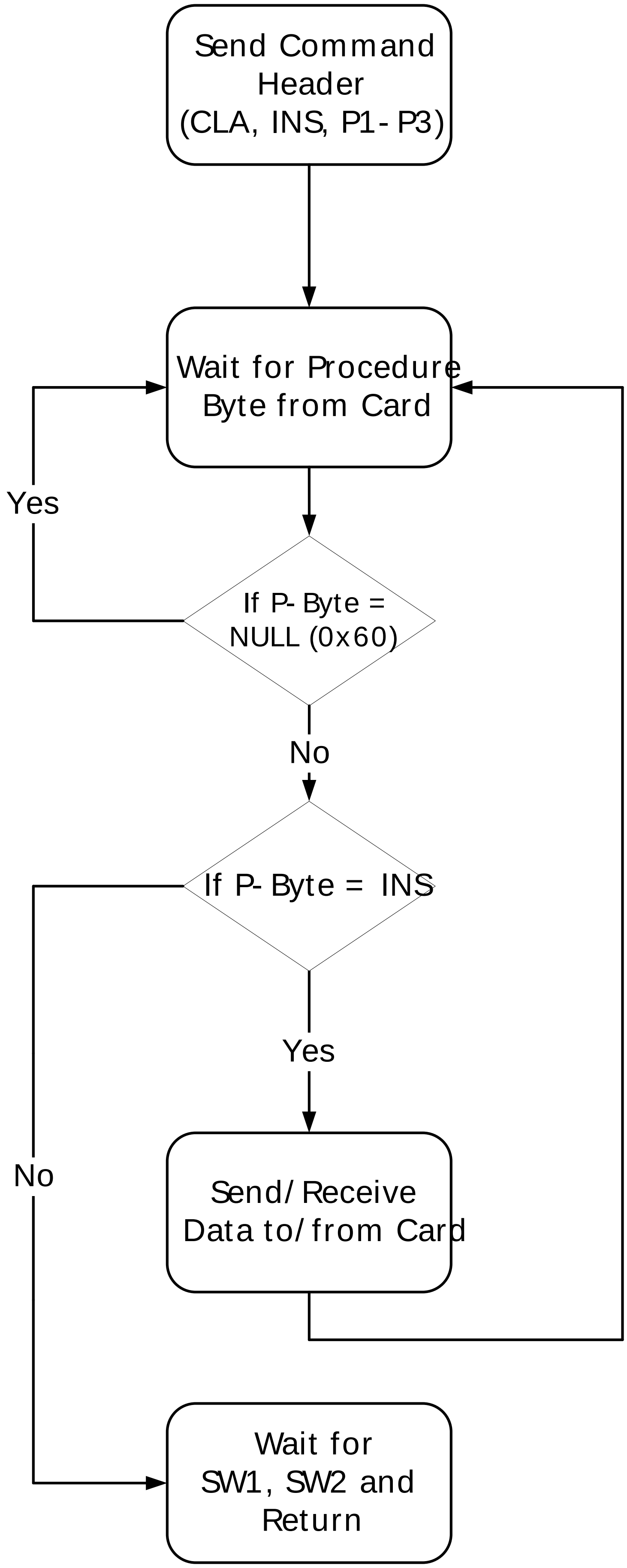
When one loop of the CCID_Handler is executed and the CCID either waits for a card or a card is present, it reads one incoming USB-message and takes the necessary action. The three BulkOUT-message-types requiring any interaction with the card is the PC_to_Rdr_PowerOn/Off and PC_to_Rdr_XfrBlock-messages, see Reference 1 (p. 20) for more info.

The PowerOn message from the PC, requests the CCID to apply power to the smart card and it expects the ATR in response.

The PowerOff message from the PC, requests the CCID to power off the smart card and expects only a status message in return, indicating the new powered off state.

All actual communication with the card after the Answer to Reset, happens upon XfrBlock messages from the PC. Each XfrBlock message contains one APDU which the CCID must send to the smart card and in turn receive a response from the smart card which is sent back to the PC. Many APDUs only expects the two status-bytes SW1 and SW2 as response. Some requests additional data and some has data to write to the card. Figure 3.4 (p. 14) illustrates the communication procedure that the CCID performs when it has an APDU that is to be sent to the smart card. Note that procedure byte 0x60 has preference over 0x6X. "INS" refers to the instruction character in the APDU received from the host.

Figure 3.4. Function Handling Command and Data Transfer with Smart Card



3.4 Typical Transaction Sequences

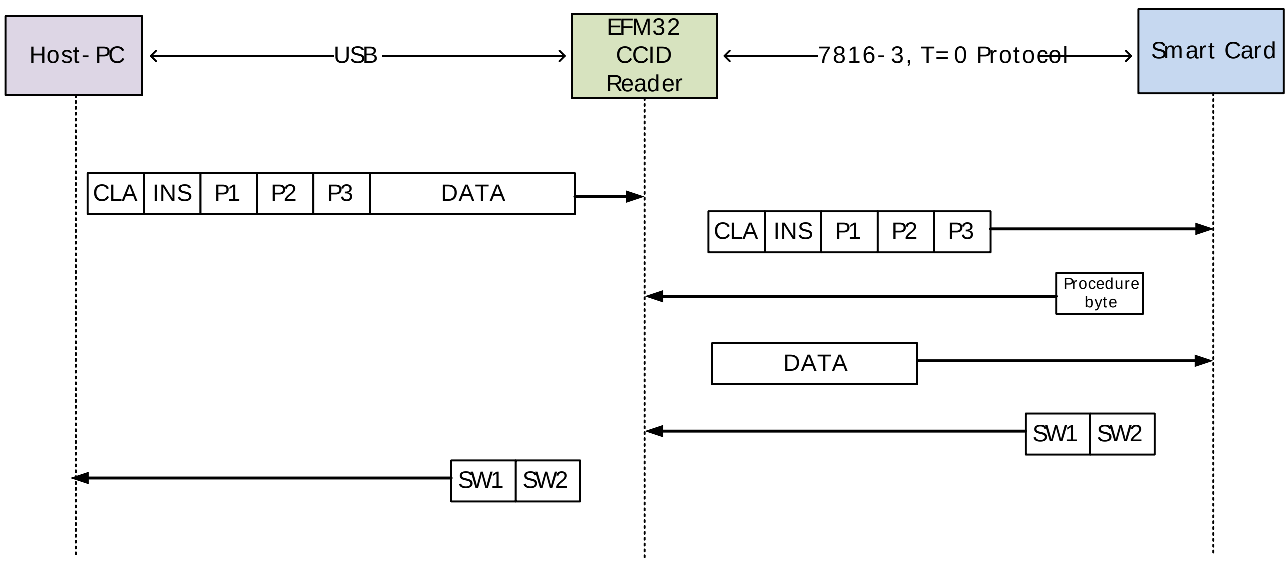
To further understand the typical communication pattern between both the PC and the CCID and between the CCID and the smart card, it helps to look at how the transaction sequences play out over time. This section has a couple of example-sequences indicating the difference between the APDU- and TPDU-exchanges. Notice that all of these sequences follows the T=0 protocol. Also note that the transaction diagram on the USB-side is simplified to only show the APDU-content of the PC_to_RDR_XfrBlock USB-BulkOut messages, in addition these USB-messages actually contains a fixed-length header-field with message-type, sequence numbering, status-bytes and so forth.

3.4.1 Sending Data to Card

When the host has data it wants to write to the smart card, it sends an APDU with data appended after the mandatory CLA,INS,P123-header. The CCID sends first only the header to the smart card, it then waits for a procedure byte, indicating what further action the CCID should take. See state-diagram in Figure 3.4 (p. 14) for how the send-APDU function is implemented in the EFM32-based CCID.

If the procedure byte indicates that the smart card is ready to receive data, the CCID proceeds with sending the data to the smart card. It then waits for a further procedure byte. Note that in the case of successful transaction, the procedure byte is in fact the SW1-character and therefore part of the response expected from the host. The CCID fetches the SW2 character as well and sends both SW1 and SW2 back to the host. See Figure 3.5 (p. 15) for an example-transaction of this sequence.

Figure 3.5. Host Sends Data to Card

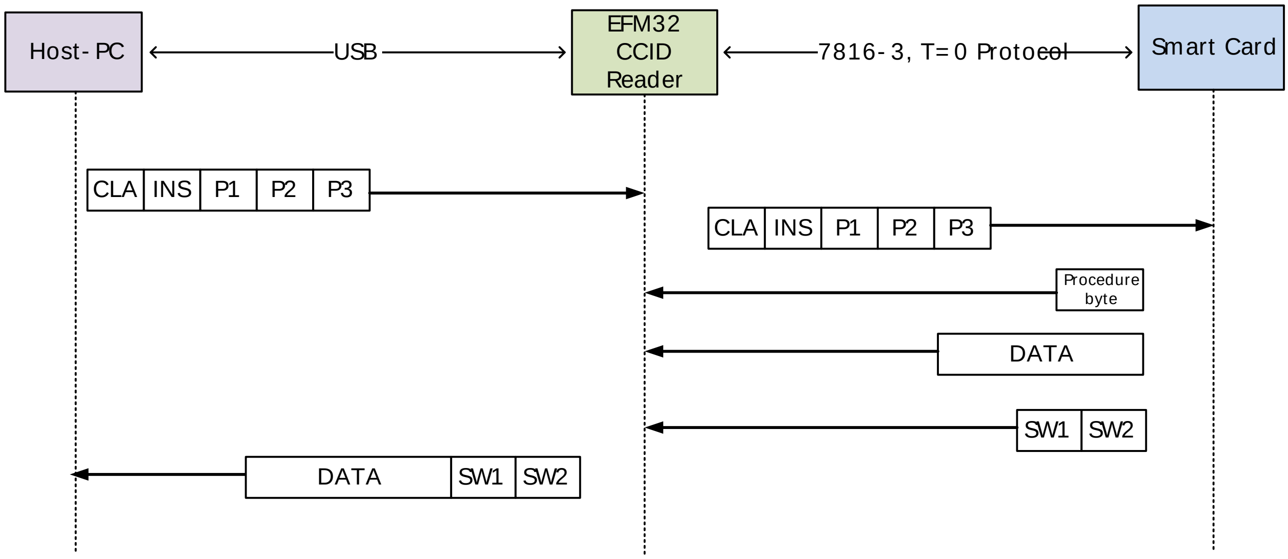


3.4.2 Receiving Data from Card

When the host has data it wants to read from the smart card it sends an APDU containing just a header, which the CCID forwards directly to the smart card. The CCID must interpret the content of the APDU to know that it is supposed to read data from the smart card and how many bytes it is supposed to read. The CCID then waits for a procedure byte, and if indicating a data transmission the smart card proceeds to send data after that the procedure byte. At the end of the data, the two status bytes, SW1 and SW2 are appended.

The CCID-response to the host is the data it received and the SW1 and SW2 bytes appended to the end of the data. Figure 3.6 (p. 16) illustrates this smart card read transaction.

Figure 3.6. Host Requests and Receives Data from Card

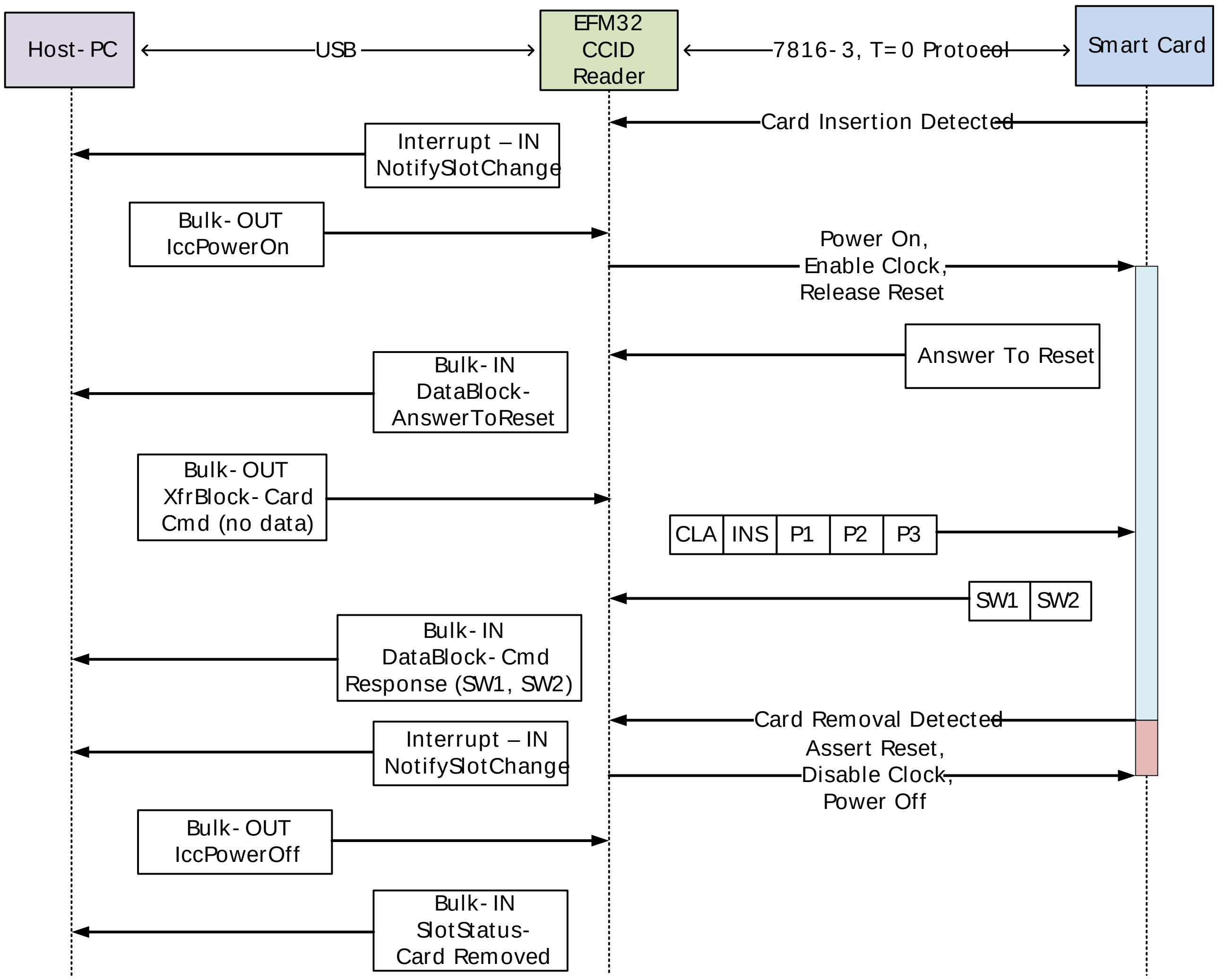


3.4.3 Insertion and Removal of Card

Figure 3.7 (p. 17) Illustrates the transaction patterns in the previous section with the addition of insertion and removal of the card. Notice that the CCID does not power up the card until it receives a PowerOn messages from the host. The CCID can implement automatic power on at insertion of a card, but must then also advertise this feature in the USB-descriptor.

When the card is removed, the CCID should power off the card to protect from damage. It advertises that the card is removed, and typically receives a power off message from the host. The CCID then replies with a slotStatus message indicating that the card is not in the slot and that the slot is powered off.

Figure 3.7. Sequence with Card Insertion, Removal and Simple Command



3.4.4 Timeout and Error Conditions

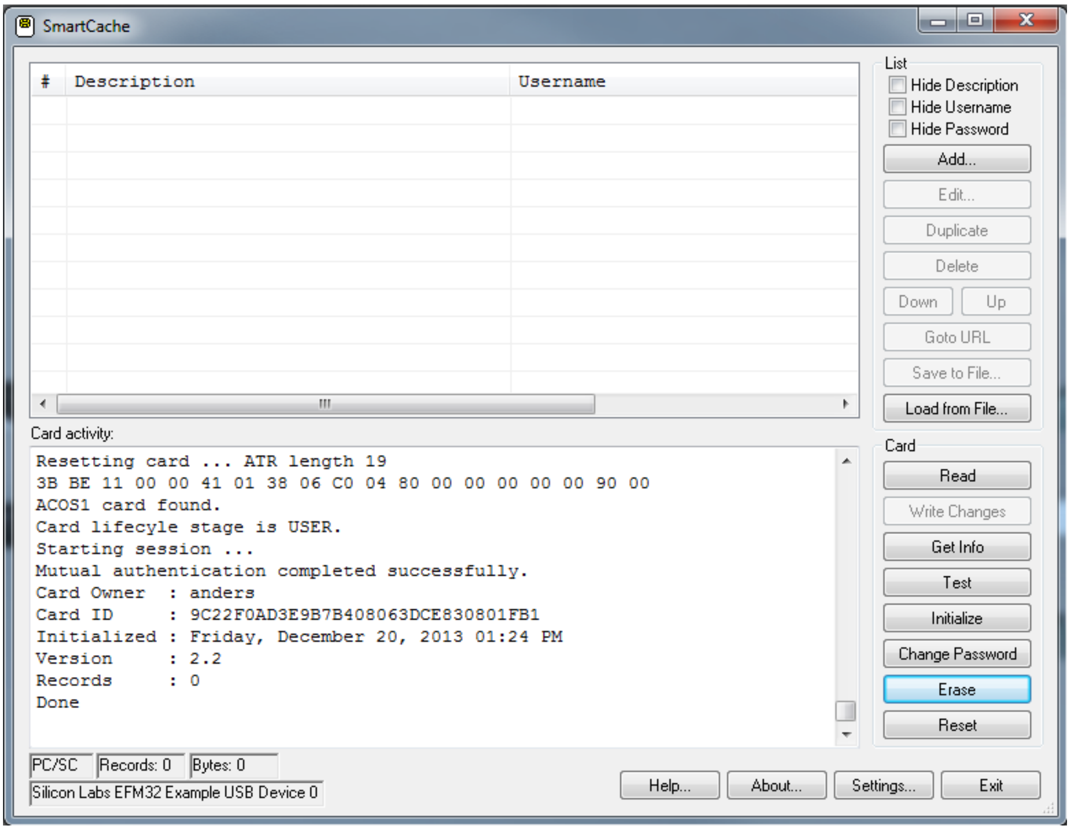
It can happen that the smart card stops responding or is malfunctioning in another way. To handle this, the CCID should implement timeouts and error counters that signals the host with the appropriate messages in the event of a malfunction. The EFM32 CCID-implementation includes some simple error counters and timeout counters for this purpose, but it does not implement all the error conditions indicated in the USB-CCID standard. It is usually ok to escalate many of the specific errors to timeout error as this will trigger a power off of the smart card, which is always safe to do upon error conditions.

3.5 Use the Smart Card Reader with a PC

In order to make useful communication between a PC and the smart card happening, the host-computer need software that can interact with the card. Typically, a windows PC will recognize the card-reader as a smart card interface device. To get further, special software adapted to each different smart card is needed. For the ACOS1/3 type of cards, there exists simple example software to store and retrieve data on the smart card. One such software, available for free at the time of writing, which works with this implementation is the "SmartCache"-software, (see Reference 3 (p. 20)). This enables initialization of the card, simple authentication with the card and storing/retrieving of data on the smart card itself.

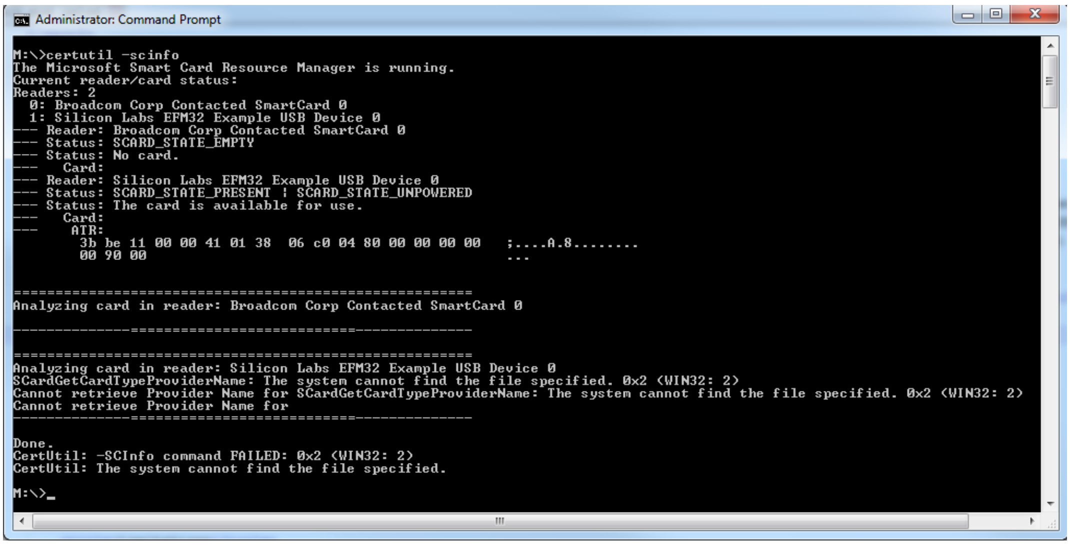
Below is a screenshot of the "smart cache" application in action. The output is the result of probing an already initialized ACOS1 smart card and reading out the answer to reset (ATR), as well as initialization date and card-ID and card owner. Notice the authentication happening after the ATR is read out, but before card ID and owner is available. It is necessary to put in the pin/password that was configured when the card was initialized to get past the authentication. The pin/password can be changed later.

Figure 3.8. SmartCache Application, result of "Get Info"-command



From the command prompt in windows, one can also retrieve the "Answer to Reset" of the smart card by typing "certutil -scinfo".

Figure 3.9. Windows Command Prompt with output from "certutil -scinfo"



The screenshot above demonstrates use of the windows certutil function to read the smart card answer to reset. This will verify that the USBCCID-device registered correctly with the Windows USBCCID-driver. The errors above is likely to pop up if the inserted card is not initialized and prepared for further certificate handling in Windows.

3.6 Limitations

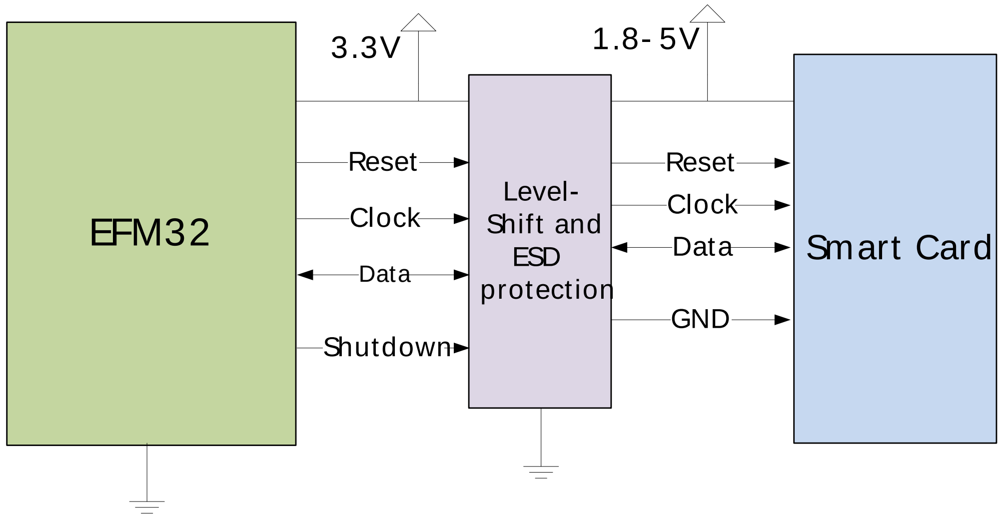
There are some limitations with this implementation of a smart card reader that is important to be aware of. First, the software only handles error- and warning-messages from the card in a simple way. Most of the responsibility of detecting errors is left to the host-computer, based on the responses given by the card. There are no automatic negotiation of parameters and only a minimum sub-set of communication protocols are implemented.

3.6.1 Adding a Level Translator and Protection Circuit

When connecting the smart card directly to the EFM32, it will only support 3.3V cards, smart cards requiring 5V will not work when connected directly. Some cards need Vpp (programming voltage pin) to be set to a higher programming voltage when writing to the card. This functionality is not supported by the software and the Vpp pin is in fact not connected at all in this implementation. Also, there are no additional ESD-protection or signal-conditioning when directly connected to the EFM32, which might make the implementation more prone to electrical faults. There exists conditioning-devices that can be connected between the mcu and the smart card, which handles ESD, signal conditioning and the different voltage levels in a proper manner, see Figure 3.10 (p. 19) .

For further protection of the interface device and also adding support for different voltage levels, a level translator circuit can be added between the EFM32 and the smart card itself. A typical connection diagram for such a circuit is exemplified below.

Figure 3.10. Typical Connection Diagram with Level Translator and Protection Circuit



Some simple level translators and protection devices for smart card interfaces exists. Two examples of such a circuits are the Maxim DS8313/DS8314 devices and the Micrel MIC4555. These are analog interface circuits with higher ESD protection than a typical microcontroller and also level-translating up to 5V.

4 References

1. Universal Serial Bus Device Class: Smart Card CCID Specification for Integrated Circuit(s) Cards Interface Devices, Rev 1.1, 2005.

   http://www.usb.org/developers/devclass_docs/DWG_Smart-Card_CCID_Rev110.pdf

2. Online version of ISO 7816 Standard:

   http://www.cardwerk.com/smartcards/smartcard_standard_ISO7816.aspx

3. "Smart Cache" Windows software tool for storing data on ACOS-1/3 smart cards:

   http://www.smartcache.net/

4. The home of the ISO-7816 standard:

   http://www.iso.org

5. ACOS3 Smart Cards:

   http://www.acs.com.hk/en/products/19/acos3-microprocessor-card/

5 Revision History

5.1 Revision 1.01

2014-05-07

Updated example code to CMSIS 3.20.5

Changed source code license to Silicon Labs license

Added project files for Simplicity IDE

Removed makefiles for Sourcery CodeBench Lite

Changed descriptors.h to Silicon Labs VID/PID

5.2 Revision 1.00

2014-01-23

Initial revision.

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