HT32F61141 Smart Card Reader Application Guidelines

D/N: AN0645EN

Introduction

Holtek has released an Arm® Cortex®-M0+ Smart Card Reader Flash MCU, the HT32F61141, which includes two ISO 7816-3 Smart Card Reader Interfaces, hereinafter referred to as SCI. The communication protocol between the card reader and the smart card as well as relevant electrical characteristics need to pass the EMVCo certification. Different from other HT32 integrated SCI interfaces, the HT32F61141 also includes a card LDO which has passed the EMVCo ISO 7816-3 Contact Level 1 certification, eliminating the requirement for an external level shift device and therefore reducing the product cost. This integrated LDO can provide 5V, 3V and 1.8V output voltages to supply power for the SCI interface and chip card. This can meet the application requirements of three smart card voltage categories such as USB smart card readers, Bluetooth smart card readers and identity authentication card readers.

This text will describe the HT32F61141 integrated ISO 7816-3 features and the LDO application guidelines as well as the HT-SCR200 Demo Board related instructions to enable users to quickly get started for smart card reader development.

Functional Description

The SCI interfaces are compatible with the ISO 7816-3 standard. Users can refer to the official website or download the relevant specification from EMVCo for a detailed understanding of this standard. The SCI interfaces include functions of card insert/removal detection, data transfer control logic and data buffers, internal timer counters and corresponding control logic circuits to implement the required smart card operations. The smart card interface acts as a smart card reader to facilitate communication with external smart cards. The overall functions of the smart card interfaces are controlled by a series of registers including control and status registers together with several corresponding interrupts which are generated to get the attention of the MCU for the SCI transfer status.

SCI Interface Description

The HT32F61141 includes two SCI interfaces for developing card reader products to which both large and small types of cards are applied. Large cards refer to chip cards such as bank or credit cards, which can be read by the certificated SCI0 interface. Small cards generally refer to encryption chip cards. The corresponding card connector is on the PCBA and this type of cards can be read by the SCI1 interface which can be implemented on different GPIO ports by program.

The SCI0 interface includes the CLK, DIO, DET, RST, CC4 and CC8 complete pin functions and is powered by an internal LDO. For the detailed SCI and LDO function control, refer to the relevant chapter and registers described in the HT32F61141 User Manual. The SCI0 block diagram is shown below.

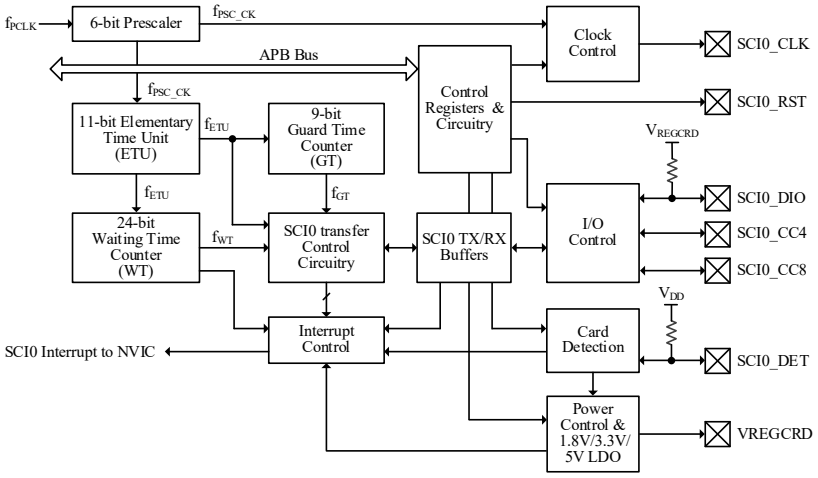


Figure 1. SCI0 Block Diagram

The SCI1 interface is powered by an external power through the VDDIO pin. It has the CLK, DIO and DET pin functions and the RST, CC4 and CC8 functions are implemented on other GPIO ports by software control. The following figure shows the SCI1 block diagram.

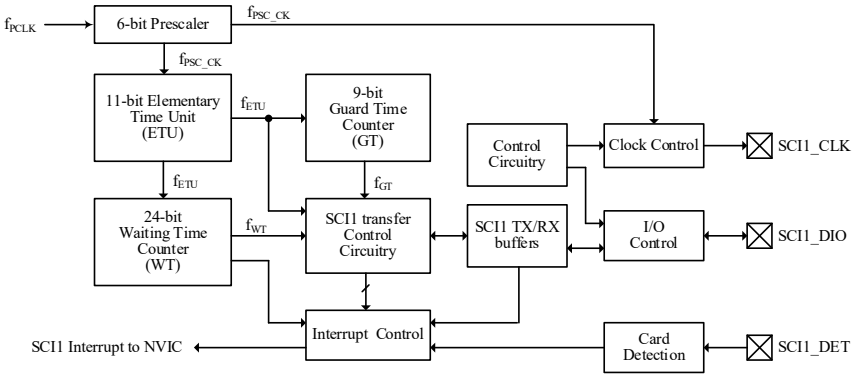


Figure 2. SCI1 Block Diagram

The clock source of both SCI interfaces comes from the f_{PCLK}, which passes through a 6-bit prescaler to generate a smart card clock of up to 4.8MHz. The following are some SCI interface features for user reference.

1. Conform to ISO 7816-3 standard and the SCI0 has EMVCo certification.
2. SCI0 supports 5.0V, 3.0V and 1.8V smart cards - Class A, B, C.
3. SCI0 supports smart card power over-current protection.
4. SCI1 supports the VDDIO pin for power supply.
5. 3 groups of I/O for the SCI1_CLK, SCI1_DIO and SCI1_DET pin functions decided by AF8.
6. Support both T=0 and T=1 protocols.
7. Character transfer mode.
8. Single transmit buffer and single receive buffer.
9. 11-bit ETU (Elementary Time Unit) counter.
10. 9-bit guard time counter.
11. 24-bit general purpose waiting time counter.
12. Parity generation and checking.
13. Automatic character repetition on parity error detection in transmission and reception modes.

LDO Description

The EMVCo certification institution has specified three smart card operating voltages, 5V, 3V and 1.8V. The HT32F61141 includes a programmable LDO which can output three regulated voltage levels to the SCI interface and card through the VREGCRD pin. The LDO also provides voltage detection and over-current protection functions to avoid abnormal conditions caused by smart card reverse insertions. Refer to the relevant chapter in the datasheet for detailed LDO voltage characteristics.

Communication Interfaces

In addition to these two SCI interfaces, the HT32F61141 also provides multiple other communication interfaces including the USB2.0 Full-Speed, SPI, I^2C and UART interfaces. This makes the device able to connect with an NFC reader IC BC45B4523 or a Bluetooth IC so as to implement data transfer with computers, mobile phones and tablets, etc.

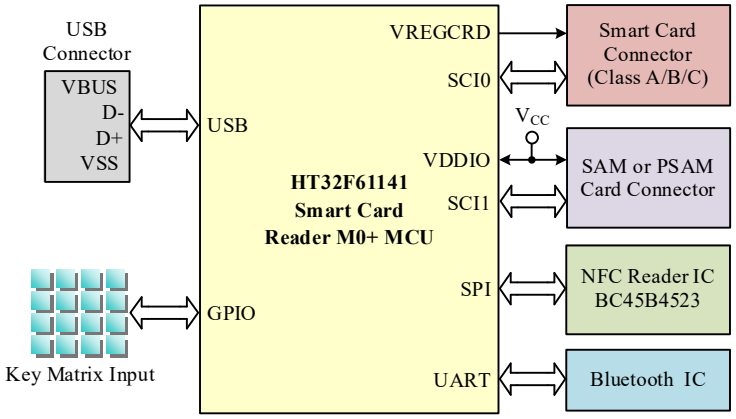


Figure 3. HT32F61141 Communication Interfaces

Application Description

Hardware Description

Holtek has developed an HT32F61141 smart card reader demo board - HT-SCR200 to assist users with development acceleration. The demo board hardware circuit is provided as a reference, as shown below.

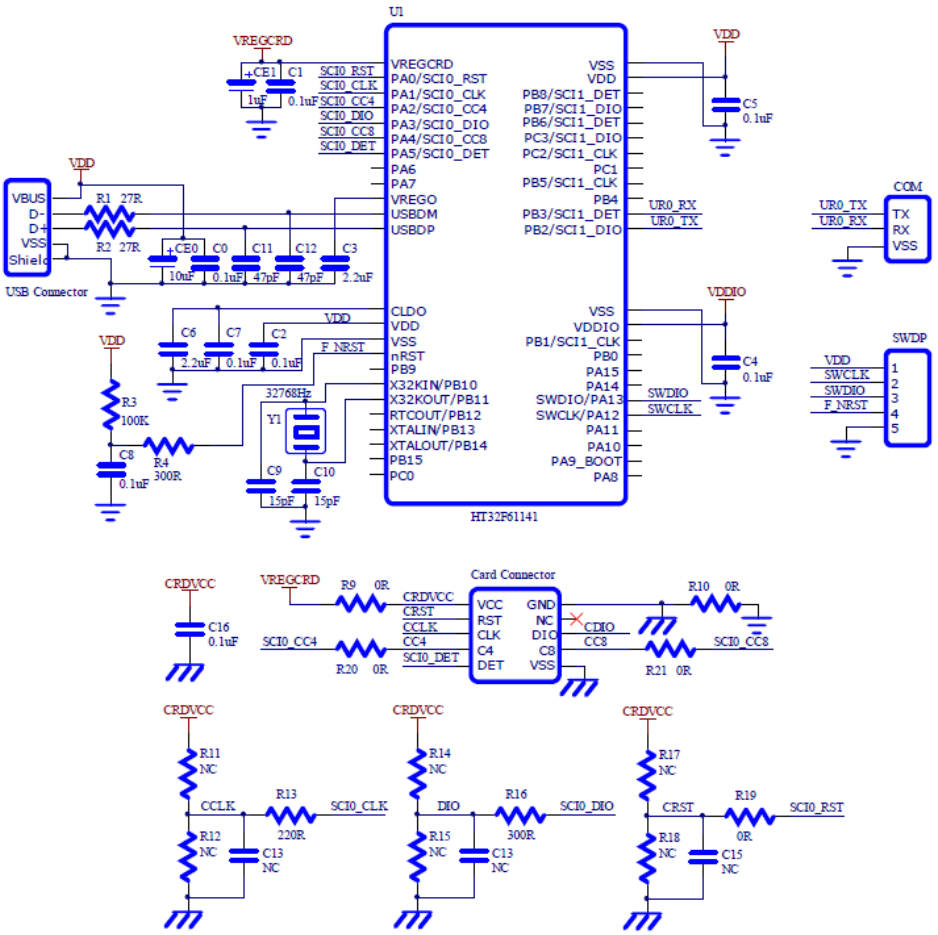


Figure 4. HT-SCR200 Smart Card Reader Circuit Diagram

When planning the circuit, it is recommended to place the LDO filter capacitors as close to the MCU as possible and reserve a card connector and an RC filter circuit to facilitate signal quality adjustment during the EMVCo certification. If an external 32768Hz oscillator is connected to the RTC pins, external capacitors are required and should be placed as close to the MCU as possible. Refer to the datasheet for the recommended capacitance value. The hardware circuit is mainly composed of the following parts.

1. USB power and filter circuits.
2. LDO circuit.
3. Smart card connector and RC filter circuit reserved for certification.

Software Description

Holtek has passed the smart card reader Contact Level 1 certification at the FIME Laboratory in Taipei. Therefore, the ISO 7816-3 example program can be provided to complete the communication transfer protocol so that developers can have the best efficiency and shorten the development period. Users can contact the Holtek business unit for assistance.

The following describes the example program from the aspects of resource download and preparation, MCU operating environment and resource occupation, directory structure, variable settings and software main flowchart, so that users can get started with the example program more quickly.

Resource Download and Preparation

1. Install the Keil 5 software before using it for development.
2. Download https://mcu.holtek.com/pack/Holtek.HT32_DFP.latest.pack.zip and decompress it. Then open the Keil to manually install the pack: File > Import > Holtek.HT32_DFP.x.x.x.pack.
3. Link to https://www.holtek.com/development-kit to download the HT32F5xxxx (M0+) Standard Peripheral Firmware Library. Note that the library version should be HT32_STD_5xxxx_FWLib_v022_5673 or above. Then decompress the project to the application\SmartCard_APDU folder of the library.

Figure 5

MCU Operating Environment and Resource Occupation

Item	HT32F61141
V_{DD}	5V - USB power supply
System Clock	48MHz
ROM	64K×8 - EMV+CCID occupies 13K×8 with a percentage of 20.3%
RAM	16K×8 - EMV+CCID occupies 3456×8 with a percentage of 21.1%
Other Peripherals	1. UART: configure PB2 and PB3 as COM pins to view the test items and results. 2. LDO: configure the LDO to output a V_{REGCRD} voltage to the SCI0 interface and the card when a card insertion has been detected. 3. SCI0_DET: configure the SCI0_DET pin function for card insertion detection. 4. SCI0 clock source: configure the clock output according to the smart card specification.

Table 1

Directory Structure

As this project is based on the Holtek HT32F5xxxx series library and the example program uses a large number of library functions, users must not arbitrarily change the relative location of the project directory. The following is only an introduction to the relevant files of the CCID_EMV_APDU example program. For information about the MCU and library, download the relevant documents from the Holtek official website.

HT32_STD_5xxxx_FWLib_v0nn_mmm

--[application]

--[SmartCard_APDU]

--[CCID_EMV_APDU]

--[MDK_ARMv5]	Project located directory
--gpio.h	Pin definitions
--main.c	USB enumeration and EMV test process
--osicc	7816 protocol related functions
--ostmr	EMV Level 1 time related settings
--SysTick	Time delay functions
--type.h	Basic variable type definitions
--ht32f5xxxx_01_it	Interrupt vector related functions
--ht32_usbd_class	USB enumeration class command related functions
--ht32_usbd_descriptor	USB enumeration information
--ccid	USB CCID Class related command

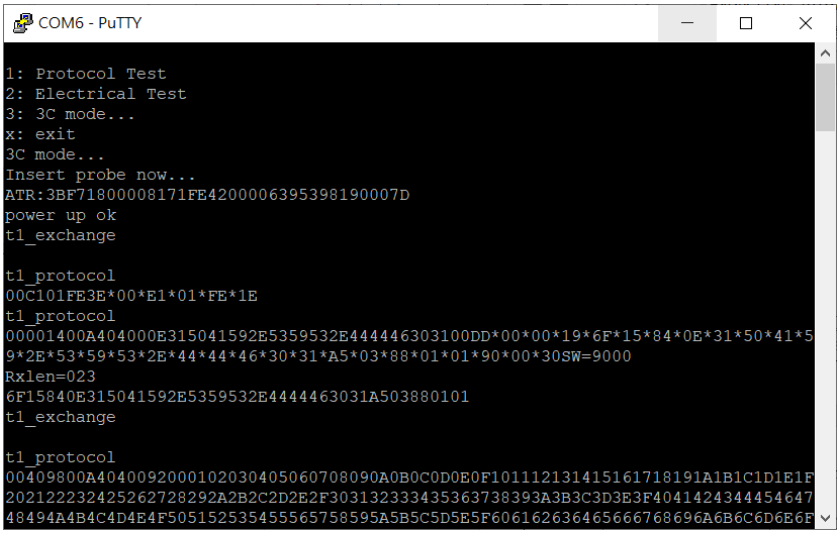
Variable Settings

#define _EMV_ 0

If the _EMV_ variable is set to “0”, the main program will execute the USB CCID Class process. Plugging in the USB will generate a card reader device in the computer.

#define _EMV_ 1

If the _EMV_ variable is set to “1”, the main program will execute the EMV L1 test process. Protocol/electrical test and simple reading card test are supported. Connect the USB COM Bridge(5V) to PB2/PB3 and use the PuTTY or other software to select the test project and obtain the rest results.



#define SHOW_MORE_DEBUGMSG 1

During the development, by setting the SHOW_MORE_DEBUGMSG variable to "1" the transmitted/received data can be displayed for debug. Note that this bit must be set to "0" when some time-related test items fail to pass.

As a large amount of debugging data is transmitted through UART, the program execution speed could be affected. When the development has completed, set the SHOW_MORE_DEBUGMSG bit to "0".

#define _FSYS_ 48 //48MHz

#define _CCLK_ 48 //4.8MHz

These two custom values are used to modify the card clock speed and to calculate the EMV Level 1 time-related test items.

FSYS is used to set the current MCU system frequency.

CCLK is used to define the card clock speed, which currently supports the 48 (4.8MHz), 40 (4.0MHz) and 20 (2.0MHz) settings.

Note that when _CCLK_ is set to 4.8MHz, the system frequency can only be set to 48MHz.

#if PRODUCT_END

#define CRD_VOLTAGE_START CRD_VOLTAGE_18

#define CRD_VOLTAGE_MAX CRD_VOLTAGE_50

#else

#define CRD_VOLTAGE_START CRD_VOLTAGE_30

#define CRD_VOLTAGE_MAX CRD_VOLTAGE_START+1

#endif

The HT32F61141 supports three card voltage levels, 1.8V, 3V and 5V. If designed as a card reader, the device can automatically detect the voltage required by the inserted card. During the EMV Level 1 test process, only a fixed voltage is allowed which can be modified using the above variables.

Software Flowchart

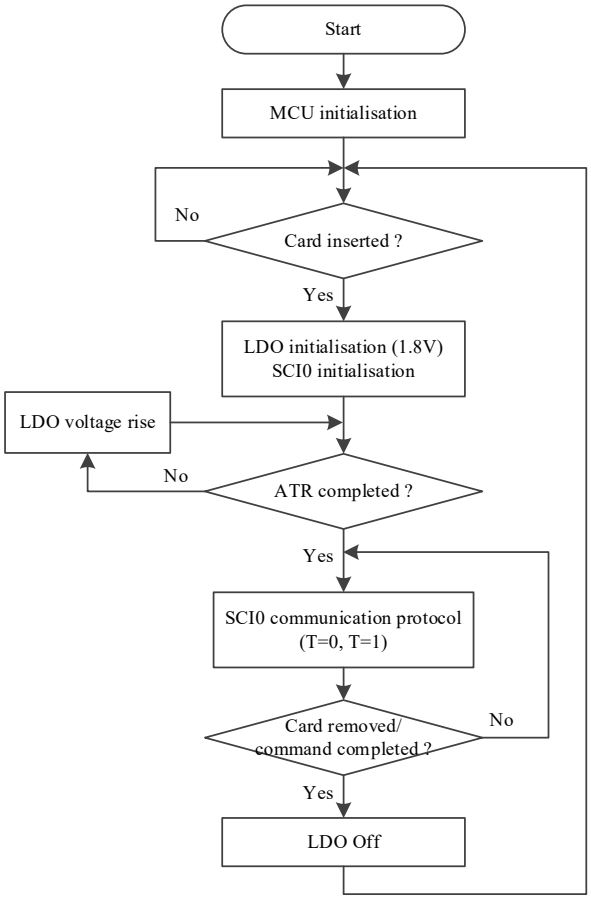


Figure 6. HT-SCR200 Smart Card Reader Software Main Flowchart

1. Initialisation: clear RAM, initialise pin functions and set WDT.
2. USB: set the USB control registers and declare the USB CCID class device.
3. Card detection: detect whether a card has been inserted or not.
4. LDO: configure its initial value to 1.8V.
5. SCI0: set smart card related specifications such as clock source, ETU parameter, etc.
6. ATR: determine whether the acknowledge has completed or not. If no, increase the LDO output voltage sequentially to 3V or 5V.
7. If the ATR acknowledge is successful, go on to implement the T=0 and T=1 communication protocols.
8. Detect whether the card has been removed or not. If the card has been removed, turn off the LDO to avoid additional sleep current consumption.
9. Return to step 3 to wait for the next card insertion.

ISO 7816-1 ~ ISO 7816-13 and ISO 7816-15 have defined various smart card specifications. The specifications above ISO 7816-4 can be viewed on the ISO official website, which mainly define the Contact Level 2 specifications on smart card transmission applications such as encrypted transmission, file data management and other protocols.

Demo Board Operating Description

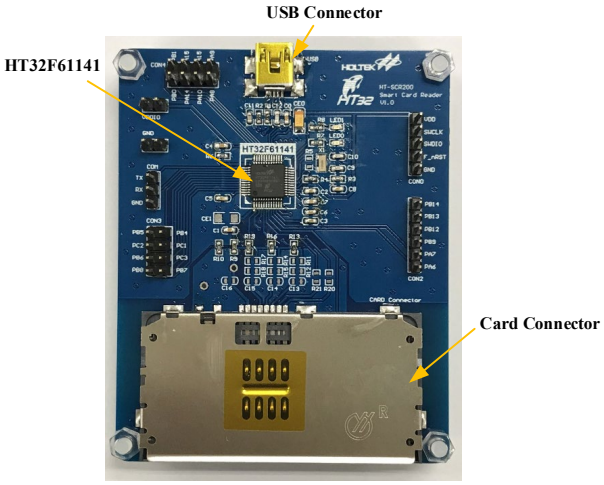


Figure 7. HT-SCR200 Smart Card Reader Demo Board

1. USB: plug the Mini-USB cable into the USB connector and also connect it to a computer or mobile phone for communication and power supply.
2. Smart Card: once a smart card is inserted to the card connector, it will be immediately displayed on the computer.
3. VDDIO: if an external power supply is required, remove the USB cable and connect to the external power supply using the VDDIO jumper.
4. If the SCI1 interface needs to operate simultaneously, remove the R6 resistor to avoid voltage conflict with V_{DD}. When an external power is supplied to the VDDIO jumper, all V_{DDIO} power domain GPIO pins will be powered by this external power supply.

Test Data

The following figure shows the Contact Level-1 test results at Taipei FIME Laboratory. The test instrument used a power supply to provide a 5V input power and the smart card voltage $V_{OREGCRD}$ was set to 3V. The detailed test report can be downloaded from the Holtek official website.

Test	Verdict
Mechanical Test	PASS
Electrical Tests	PASS
Card Session Tests	PASS
Protocol T=0 Tests	PASS
Protocol T=1 Tests	PASS

Figure 8. ISO 7816-3 Contact Level-1 Test Results

Conclusions

This text has provided an introduction to the smart card reader, SCI operating principle and the software control processes. If developers have a demand for the ISO 7816-3 example program authorisation, contact the Holtek business unit.

Reference Material

Reference files: HT32F61141 Datasheet and User Manual.

For more details, refer to the Holtek official website www.holtek.com.

Versions and Modification Information

Date	Author	Issue	Modification Description
2022.12.29	黃啟德	V1.00	First version

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