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Accessing SDC/MMC card using SPI/SSP on LPC1700

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Abstract	This document describes how to use the LPC1700 SPI/SSP interface to access SDC/MMC (including SDHC) card. A set of easy-to-use SPI and SDC/MMC driver APIs are also provided.

Revision history

Rev	Date	Description
1	20110601	Initial version.

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1. Introduction

This application note describes how to use the SPI/SSP interface on the LPC1700 family MCU to access Secure Digital Card (SDC) or Multi Media Card (MMC). It includes:

- SDC/MMC basic concept and bus protocol at SPI bus mode
- SPI/SSP and SDC/MMC driver APIs description

The sample software is tested on Keil's MCB1700 evaluation board with 2/4/8 GB SanDisk Micro SD (or TF) cards.

The SPI/SSP and SDC/MMC drivers can be easily ported to other NXP ARM MCUs with SPI or SSP interface, requiring little modification.

2. SDC/MMC concept

2.1 Introduction

The **Secure Digital Card** (***SDC***) or **Multi Media Card** (***MMC***) is a flash-based (non-volatile) memory card format specifically designed to meet the security, capacity, performance and environmental requirements inherent in newly emerging audio and video consumer. They are widely used in digital cameras, handheld computers, PDAs, media players, mobile phones, and video game consoles.

The SDC communication is based on an advanced nine-pin interface (clock, command, 4xData and 3xPower lines) designed to operate in a low voltage range. The SDC host interface supports regular MMC operation as well. The main difference between them is the initialization process. There are also reduced size versions, such as RS-MMC, miniSD and microSD, which are functionally identical.

Below is the memory card capacity:

- Standard Capacity SD Card (SDSC): Up to and including 2 GB
- High Capacity SD Card (SDHC): More than 2 GB and up to and including 32 GB
- Extended Capacity SD Card (SDXC): More than 32 GB and up to and including 2 TB
- MMC: up to and including 32 GB

2.2 Interface and topology

The SDC/MMC interface allows for easy integration into any design, regardless of microcontroller used. For compatibility with existing controllers, the SDC/MMC offers, in addition to the SDC/MMC Interface, an alternate communication protocol based on the SPI standard.

Fig 1 shows the SDC/MMC card contact surface.

a. SDC contact surface

b. MMC contact surface

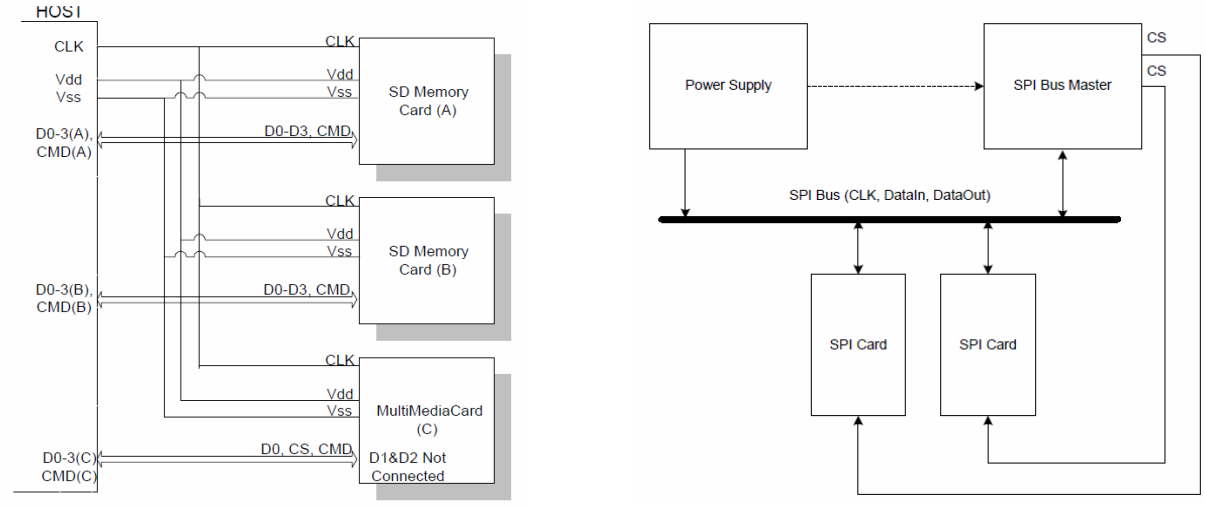
Fig 1. SDC/MMC card contact surface

Table 1 shows the SDC/MMC card pin assignment.

Table 1. SDC/MMC pin assignment

Pin No.	Name	Type	Description
SDC/MMC Bus Mode (For MMC, only one data line, DAT0, is used)			
1	CD/DAT3	I/O, PP	Card detect/Data line [Bit 3]
2	CMD	I/O, PP	Command/Response
3	Vss1	S	Supply voltage ground
4	Vdd	S	Supply voltage
5	CLK	I	Clock
6	Vss2	S	Supply voltage ground
7	DAT0	I/O, PP	Data line [Bit 0]
8	DAT1	I/O, PP	Data line [Bit 1]
9	DAT2	I/O, PP	Data line [Bit 2]
SPI Bus Mode			
1	CS	I	Chip Select (active low)
2	DataIn	I	Host-to-card Commands and Data
3	Vss1	S	Supply voltage ground
4	Vdd	S	Supply voltage
5	CLK	I	Clock
6	Vss2	S	Supply voltage ground
7	DataOut	O	Card-to-host Data and Status
8	RSV	---	Reserved
9	RSV	---	Reserved

Fig 2 shows the SDC/MMC bus topology.



a. SDC/MMC bus mode

b. SPI bus mode

Fig 2. SDC/MMC system bus topology

3. SDC/MMC bus protocol at SPI mode

Since LPC1700 does not have SD/MMC native host interface, only SPI mode will be described in this section.

3.1 Introduction

The SPI mode is a secondary communication protocol for SDC/MMC. This mode is a subset of the SDC/MMC protocol, designed to communicate with an SPI channel, commonly found in NXP and other vendors' microcontrollers.

The interface is selected during the first reset command after power up (CMD0) and cannot be changed once the part is powered on.

The advantage of the SPI mode is the capability of using an off-the-shelf host, hence reducing the design-in effort to minimum. The disadvantage is the loss of performance of the SPI mode versus SD/MMC mode (e.g. Single data line and hardware CS signal per card).

3.2 SPI bus protocol

The card starts to count SPI bus clock cycle at the assertion of the CS signal. Every command or data token shall be aligned to 8-clock cycle boundary.

Similar to the SDC/MMC protocol, the SPI messages consist of command, response and data block tokens. All communication between host and cards is controlled by the host (master). The host starts every bus transaction by asserting the CS signal low.

In the case of a SDC, a data block can be as big as one card write block and as small as a single byte. Partial block read/write operations are enabled by card options specified in the CSD register.

In the case of SDHC and SDXC cards, block length is fixed to 512 bytes.

3.3 SPI command and response

All the commands are 6 bytes long. The command transmission always starts with the left most bit of the bit string corresponding to the command codeword. All commands are protected by a CRC. The commands and arguments are shown in Fig 3.

Bit position	47	46	[45:40]	[39:8]	[7:1]	0
Width (bits)	1	1	6	32	7	1
Value	'0'	'1'	x	x	x	'1'
Description	start bit	transmission bit	command index	argument	CRC7	end bit

Fig 3. Command format

There are several types of response (R1, R1b, R2, R3, R7), depends on the command index. A byte of response R1 is returned for most commands.

Fig 4 shows the bit field of R1 response.

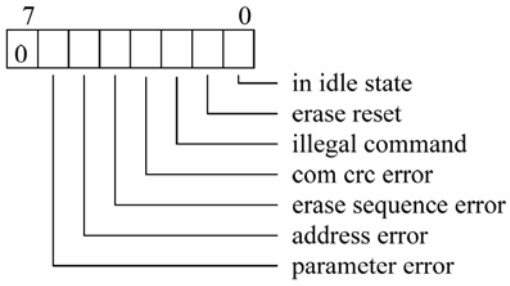


Fig 4. R1 response format

3.4 Mode selection and initialization

The SDC/MMC is powered up in the SD/MMC mode. It will enter SPI mode if the CS signal is asserted (negative) during the reception of the reset command (CMD0). If the card recognizes that the SD/MMC mode is required it will not respond to the command and remain in the SD/MMC mode. If SPI mode is required, the card will switch to SPI and respond with the SPI mode R1 response.

Fig 5 shows the initialization sequence of SPI mode.

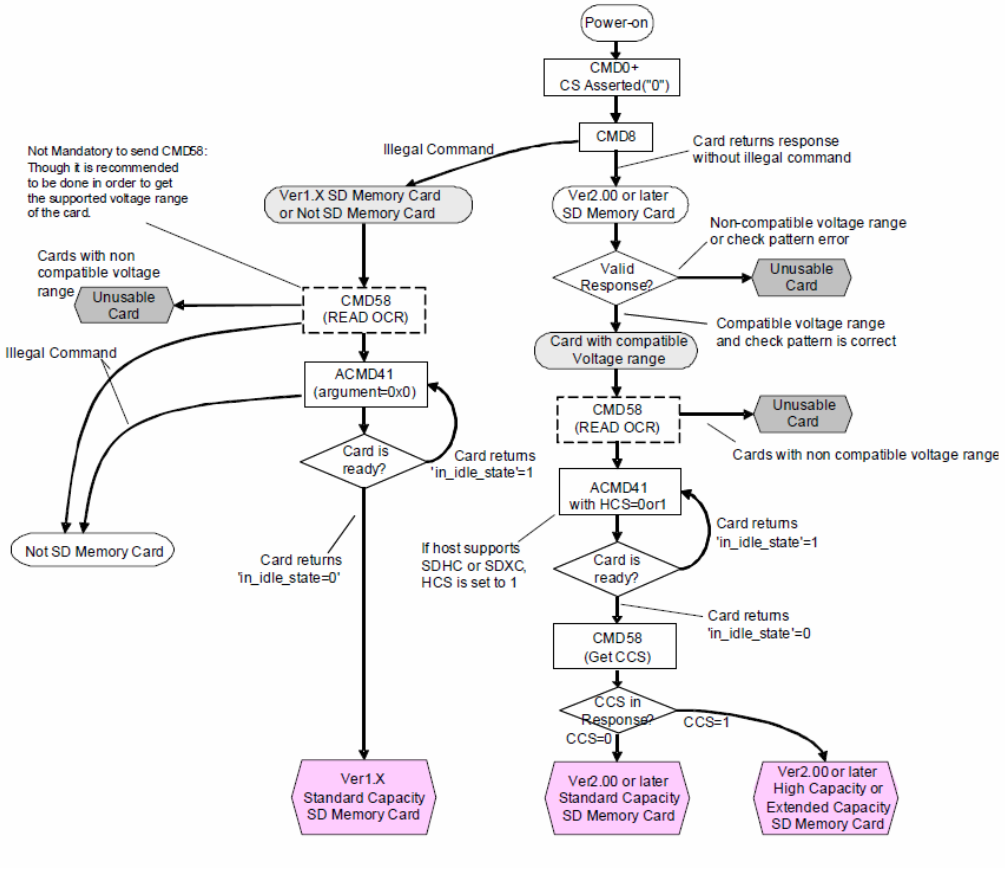


Fig 5. SPI mode initialization flow

Note: Fig 5 is the standard initialization flow for SDC described in SD specifications. The actual initialization flow implemented in the sample software is based on the flow chart from ChaN: http://elm-chan.org/docs/mmc/sdinit.png

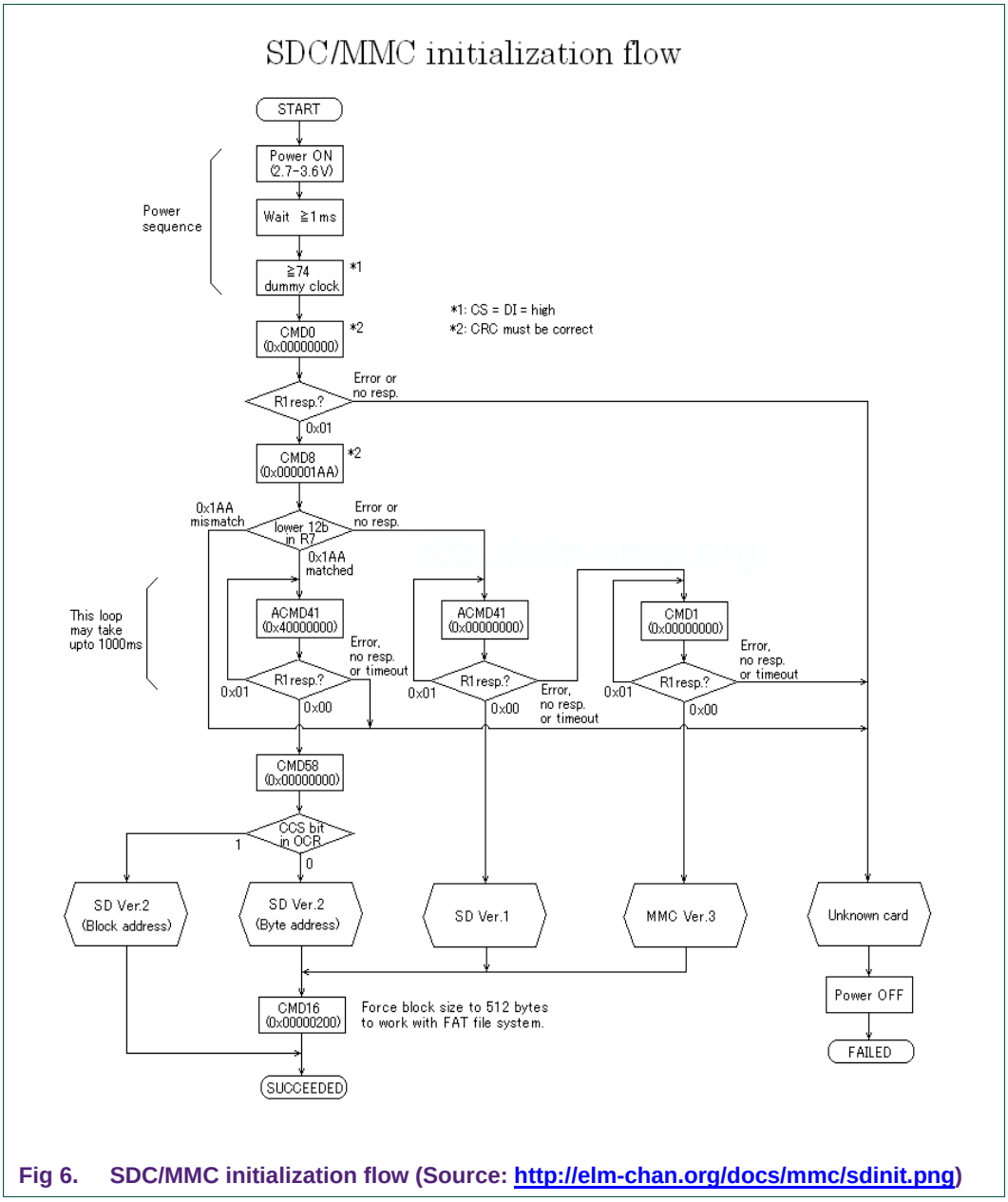


Fig 6. SDC/MMC initialization flow (Source: http://elm-chan.org/docs/mmc/sdinit.png)

3.5 Block read and write

The SPI mode supports single and multiple block(s) read/write operations.

The complete read and write operation process can be found in the *SanDisk Secure Digital Card Product Manual, version 2.2* by SanDisk Corporation and *The MultiMediaCard System Specification version 3.1* by MMC Association Technical Committee.

4. SPI and SDC/MMC driver APIs

4.1 SPI interface on LPC1700

There is one SPI controller with synchronous, serial, full duplex communication and programmable data length on LPC1700 devices. In addition, there are two SSP interfaces (SSP0 and SSP1) on the LPC1700 devices which are capable of operation on a SPI, 4-wire SSI or Microwire bus.

The SSP can produce a faster data bit rate than SPI. The maximum SPI data bit rate is one eighth of the input clock rate, and the maximum SSP speed (in master mode) is pclk/2. In Slave mode, the SSP clock rate provided by the master must not exceed 1/12 of the SSP peripheral clock (selected in peripheral clock selection register).

For example, if the PCLK is set to 100 MHz, the maximum SPI rate will be 12.5 Mbit/sec (100 MHz/8). The maximum SSP speed in master mode will be 50 Mbit/sec (100 MHz/2) and in slave mode 8 Mbit/sec (100 MHz/12).

The pin connection between LPC1700 SSP0 and external Micro SD card slot on Keil's MCB1700 board is shown below:

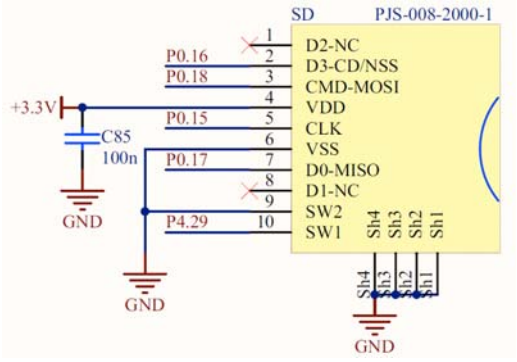


Fig 7. Schematic of SDC/MMC on Keil MCB1700 board

Note: the pin assignment of SDC and Micro SD card is slightly different. Refer to Table 2.

Table 2. Micro SD card pin assignment

Pin No.	Name	Type	Description
SDC Bus Mode			
1	DAT2	I/O, PP	Data line [Bit 2]
2	CD/DAT3	I/O, PP	Card detect/Data line [Bit 3]
3	CMD	I/O, PP	Command/Response
4	Vdd	S	Supply voltage (2.7 V / 3.6 V)
5	CLK	I	Clock
6	Vss	S	Supply voltage ground
7	DAT0	I/O, PP	Data line [Bit 0]

Pin No.	Name	Type	Description
8	DAT1	I/O, PP	Data line [Bit 1]
SPI Bus Mode			
1	RSV	---	Reserved
2	CS	I	Chip Select (active low)
3	DataIn	I	Host-to-card Commands and Data
4	Vdd	S	Supply voltage
5	CLK	I	Clock
6	Vss	S	Supply voltage ground
7	DataOut	O	Card-to-host Data and Status
8	RSV	---	Reserved

4.2 SPI drivers APIs

A total of six API functions are provided for the SPI communication (refer to the source file lpc17xx_spi.c):

- **void SPI_Init (void)**;

  This API is used to initialize SPI interface on LPC1700 through configuring SSP0 PCONP, GPIO, control registers.

- **void SPI_CS_Low (void)**;

  This API is used to assert the CS (low).

  The host starts every bus transaction by asserting the CS signal, low and the CS signal must be asserted during a transaction. If the CS signal goes high any time during a data transfer, the transfer is considered to be aborted. This signal is not directly driven by the master. It could be driven by a simple general purpose I/O under software control.

- **void SPI_CS_High (void)**;

  This API is used to de-assert the CS (high) to release the SPI bus.

- **void SPI_ConfigClockRate (uint32_t SPI_CLOCKRATE)**;

  This API is used to configure the SPI data bit rate.

  SPI_CLOCKRATE can be SPI_CLOCKRATE_LOW (set to 400 KHz during initialization phase) or SPI_CLOCKRATE_HIGH (set to 25 MHz during data transfer phase).

  Note: The highest SPI clock rate is 20 MHz for MMC and 25 MHz for SDC

- **void SPI_SendByte (uint8_t data)**;

  This API is used to send one byte of data through SPI bus.

- **uint8_t SPI_RecvByte (void)**;

  This API is used to receive one byte of data through SPI bus.

4.3 SDC/MMC drivers APIs

A total of four API functions are provided for read/write operation of SDC/MMC (refer to the source file sd.c):

- **SD_BOOL SD_Init (void)**;

  This API is used to initialize the SDC/MMC.

- **SD_BOOL SD_ReadConfiguration ()**;

  This API is used to read card configuration and fill structure CardConfig which contains some card information: sector size, sector total count, erase block size (in unit of sector), OCR, CID and CSD.

- **SD_BOOL SD_ReadSector (uint32_t sect, uint8_t *buf, uint32_t cnt)**;

  This API is used to read single or multiple sector(s) from memory card.

  Note: sector size is fixed to 512 bytes.

- **SD_BOOL SD_WriteSector (uint32_t sect, const uint8_t *buf, uint32_t cnt)**;

  This API is used to write single or multiple sectors to SD/MMC.

5. Demo

The complete KEIL MDK project is included in the sample software.

The demo will read the information of the inserted memory card, read/write single (multiple) sector(s) and test the read/write speed.

The sample software is tested on the KEIL MCB1700 evaluation board with 2/4/8 GB SanDisk Micro SD (TF) cards.

For more information about MCB1700, please refer to: http://www.keil.com/mcb1700/.

Tera Term (or a similar tool) is used for serial communication between PC terminal and MCB1700 (UART1) and configured at 115200 baud, 8-bits, no parity, 1 stop bit, XON/XOFF.

Fig 8 to Fig 10 shows the card information for different capacity of cards.

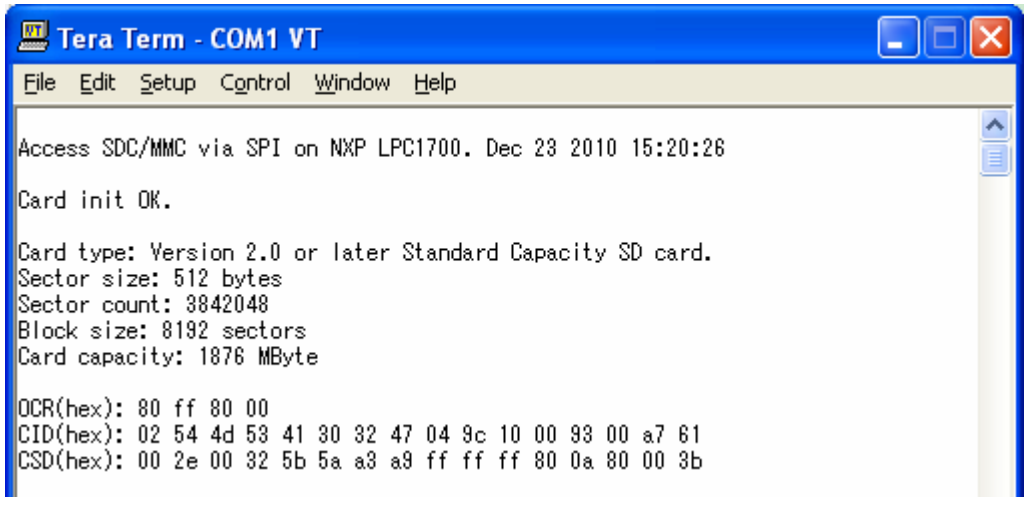


Fig 8. Card information of 2 GB Micro SD card

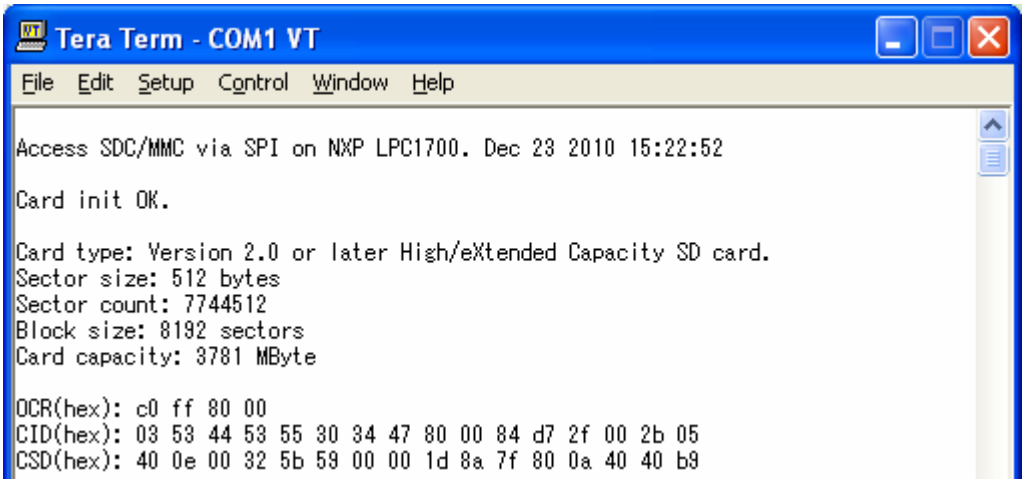


Fig 9. Card information of 4 GB Micro SD card

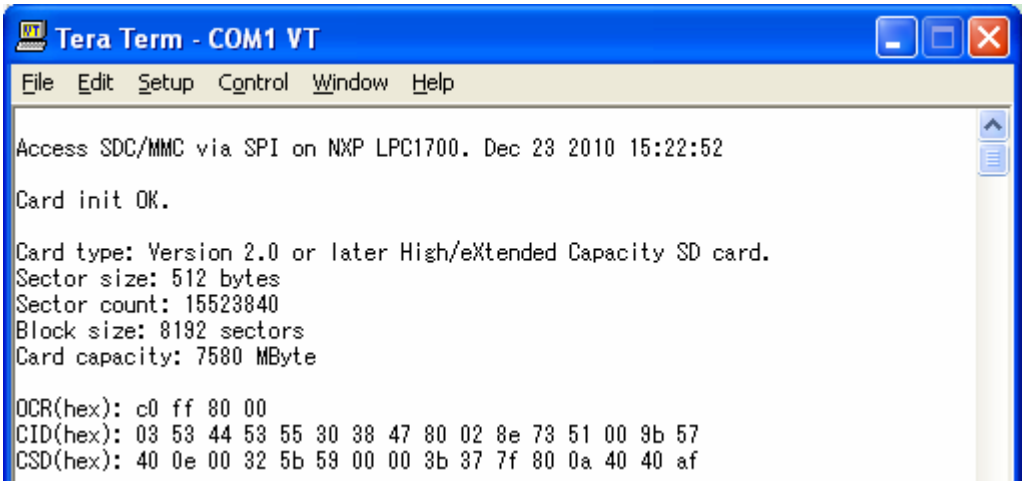


Fig 10. Card information of 8 GB Micro SD card

Fig 11 shows the single/multiple sector(s) read/write test and read/write speed test. Only the test result of the 4 GB Micro SD card is shown since the result is almost the same with the other two cards.

```
>Single sector read/write test ...

Read sector #103:
(Only display the first 32 bytes to avoid too many content in terminal).
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
Fill sector #103 with 0xaa.
Read sector #103
(Only display the first 32 bytes to avoid too many content in terminal).
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa

>Multiple sector read/write test ...

Read 2 sectors from #203:
(Only display the first 32 bytes to avoid too many content in terminal).
55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55
55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55
Fill 2 sectors from #203 with 0x55.
Read 2 sectors from #203:
Only display the first 32 bytes to avoid too many content in terminal.
55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55
55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55

>Read speed test ...

Reading 16 sectors (8192 bytes) ... at speed of 910 kB/sec.
Reading 32 sectors (16384 bytes) ... at speed of 963 kB/sec.

>Write speed test ...

Writing 16 sectors (8192 bytes) ... at speed of 682 kB/sec.
Writing 32 sectors (16384 bytes) ... at speed of 910 kB/sec.

Test complete successfully.
```

Fig 11. Single/multiple sector(s) read/write test and read/write speed test

6. References

[1] NXP LPC17xx User Manual UM10360 (Rev.0.2), NXP Semiconductors, Aug 19, 2010

[2] SanDisk SD Card Product Manual (Version 2.2), SanDisk Corporation. Nov, 2004

[3] SD Specifications, Version 3.01, SD Group, 2010

[4] The MultiMediaCard System Specification, Version 3.1, MMC Association Technical Committee, June 2001.

[5] How to use SDC/MMC, ChaN, http://elm-chan.org/docs/mmc/mmc_e.html

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