



SanDisk SD Card Product Family

OEM Product Manual

Version 2.2

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Revision History

Date	Revision	Description
January 2007	2.0	
February 2007	2.1	
June 2007	2.2	Added Reliability/ Durability table for SD Card to Chapter 2. Added additional capacities and related specs to Tables 3-8; 3-9. Added C_Size 6GB and related specs to Table 3-7. Adjusted Appendix A info. Added CID values to Table 3-4. Added CSD values to Table 3-6. Removed all power requirement tables from Chapter 2, replaced them with reference to Table 2-1.

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Table of Contents

CHAPTER 1	<i>Introduction 1</i> General Description 1 Features 2 Scope 2 SD Card Standard 2 Functional Description 3 Technology Independence 3 Defect and Error Management 3 Content Protection 3 Wear Leveling 4 Automatic Sleep Mode 4 Hot Insertion 4 SD Card Products in SD Bus Mode 4 SPI Mode 6
CHAPTER 2	<i>Product Specifications 1</i> SD Card 1 miniSD Card 3 microSD Card 7
CHAPTER 3	<i>Interface Description 1</i> Pins and Registers 1 Bus Topology 3 Hot Insertion and Power Protection 3 Electrical Interface 4 SD Card Product Family Registers 5
CHAPTER 4	<i>SD Card Protocol Description 1</i> General Description 1 SD Bus Protocol 1 Functional Description 1

APPENDIX A	<i>Ordering Information 1</i>
APPENDIX B	<i>Limited Warranty 1</i>
APPENDIX C	<i>Disclaimer of Liability 1</i>
APPENDIX D	<i>SD Card Application Note 1</i>

1.1 General Description

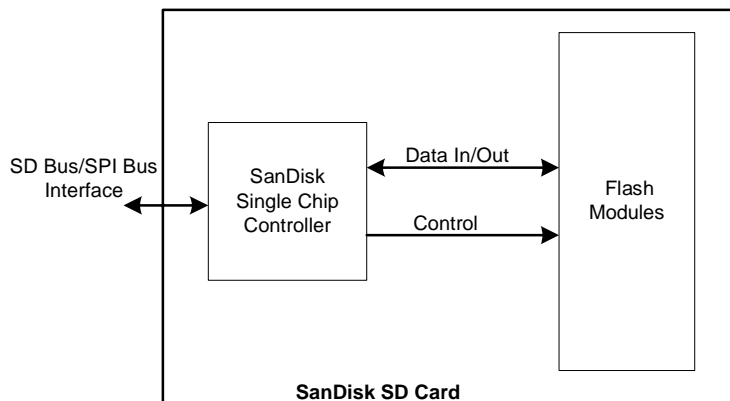
In the SanDisk SD Card Product Family, cards are flash memory specifically designed to meet the security, capacity, performance and environmental requirements inherent in next generation mobile phones and consumer electronic devices. Matsushita Electric Industrial Co. Ltd., SanDisk Corporation and Toshiba Corporation (SD-3C, LLC) originally defined specifications for the SD Card. SD card specifications are now maintained, controlled and assigned by the SD-3C, LLC. The SanDisk miniSD Card and SanDisk microSD Card are both based on the SD Card specification.

The SanDisk SD Card Product Family includes a faster content protection system that complies with the security of the SDMI standard and has a higher memory capacity. In the SanDisk SD Card Product Family, card content is protected from illegal use by mutual authentication and a new cipher algorithm. Unsecured access to the user's own content is also available. With some additions, the physical form factor, pin assignment, and data transfer protocol are forward compatible with future SanDisk SD Card products.

Cards in the SanDisk SD Card Product Family are based on a 9-pin interface designed to operate in a maximum operating frequency of 50 MHz. The interface for SD Card products allows for easy integration into any design, regardless of which type of microprocessor is used. In addition to the interface, SD Card products offer an alternate communication-protocol based on the SPI standard.

Currently, a card in the SanDisk SD Card Product Family provides up to 4 gigabytes (GB) of memory using flash memory chips, which were designed especially for use in mass storage applications. In addition to the mass storage-specific flash memory chip, cards in the SD Card Product Family includes an on-board intelligent controller which manages interface protocols; security algorithms for content protection; data storage and retrieval, as well as Error Correction Code (ECC) algorithms; defect handling; power management; wear leveling and clock control.

Figure 1-1 SanDisk SD Card Block Diagram



1.2 Features

General features of cards in the SanDisk SD Card Product Family include:

- SD-protocol compatible
- Supports SPI Mode
- Targeted for portable and stationary applications for secured (content protected) and unsecured data storage
- Voltage range of 2.7 to 3.6V
- Variable clock rate 0-25 MHz (standard), 0-50 MHz (high performance)
- Up to 25 MB/sec data transfer rate (using four parallel data lines)
- Memory field error correction
- Content protection mechanism that complies with highest security of SDMI standard
- Password protection
- Write-protected using mechanical switch
- Built-in write protection features (permanent and temporary)
- Supports card detection (insertion and removal)
- Application-specific commands

1.3 Scope

This document describes key features and specifications of the SanDisk SD Card, miniSD Card, and microSD Card as well as the information required to interface these products to a host system. Chapter 2 describes the physical and mechanical properties of cards in the SanDisk SD Card Product Family, Chapter 3 contains the pins and register overview, and Chapter 4 gives a general overview of the SD protocol. Information about SPI Protocol can be referenced in Section 7 of the SDA Physical Layer Specification, Version 2.00.

1.4 SD Card Standard

SanDisk SD, miniSD, and microSD cards are fully compatible with the SDA Physical Layer Specification, Version 2.00. This specification is available from the SD Card Association (SDA).

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1.5 Functional Description

The family of SanDisk SD cards contains a high-level, intelligent subsystem as shown in Figure 1-1. This intelligent (microprocessor) subsystem provides many capabilities not found in other types of memory cards. These capabilities include:

- Host independence from details of erasing and programming flash memory
- Sophisticated system for managing defects (analogous to systems found in magnetic disk drives)
- Sophisticated system for error recovery including a powerful ECC
- Power management for low power operation

1.6 Technology Independence

The 512-byte sector size of a card in the SanDisk SD Card Product Family is the same as that in an IDE magnetic disk drive. To write or read a sector (or multiple sectors), the host software simply issues a read or write command to the card. The command contains the address and number of sectors to write or read. The host software then waits for the command to complete.

The host software does not get involved in the details of how the flash memory is erased, programmed or read. This is extremely important because flash devices are expected to get increasingly complex in the future. Because cards in the SanDisk SD Card Product Family use an intelligent on-board controller, host system software will not need to be updated as new flash memory evolves. In other words, systems that support the SD Card Product Family today will be able to access future SanDisk cards built with new flash technology without having to update or change host software.

1.7 Defect and Error Management

The SanDisk SD Card Product Family contains a sophisticated defect and error management system. This system is analogous to the systems found in magnetic disk drives and in many cases offers enhancements. If necessary, SanDisk SD Card Product Family will rewrite data from a defective sector to a good sector. This is completely transparent to the host and does not consume any user data space. The SanDisk SD Card Product Family soft error rate specification is much better than the magnetic disk drive specification. In the extremely rare case that a read error does occur, SanDisk SD Card Product Family has innovative algorithms to recover the data. These defect and error management systems, coupled with the solid state construction, give SanDisk SD Card Product Family unparalleled reliability.

1.8 Content Protection

A detailed description of the content protection mechanism and related security SD commands can be found in the SD Security Specification from the SDA. All SD security-related commands in the SanDisk SD Card Product Family operate in the data transfer mode.

An authentication procedure is done between a card and the connected device, either the LCM (PC for example) or the PD (portable device, such as SD player). After the authentication process passes, the card is ready to accept or give data from/to the connected device. While the card is in the secured mode of operation (after the authentication succeeded) the argument and the associated data that is sent to the card or read from the card are encrypted. At the end of read, write or erase operations, a card automatically gets out of its secured mode.

1.9 Wear Leveling

Wear leveling is an intrinsic part of the erase pooling functionality of cards in the SanDisk SD Card Product Family using NAND memory.

1.10 Automatic Sleep Mode

A unique feature of cards in the SanDisk SD Card Product Family is automatic entrance and exit from sleep mode. Upon completion of an operation, cards enter sleep mode to conserve power if no further commands are received in less than 5 milliseconds (ms). The host does not have to take any action for this to occur. However, in order to achieve the lowest sleep current, the host needs to shut down its clock to the card. In most systems, cards are in sleep mode except when accessed by the host, thus conserving power.

When the host is ready to access a card in sleep mode, any command issued to it will cause it to exit sleep, and respond.

1.11 Hot Insertion

Support for hot insertion will be required on the host but will be supported through the connector. Connector manufacturers will provide connectors that have power pins long enough to be powered before contact is made with the other pins. This approach is similar to that used in PCMCIA and MMCA devices to allow for hot insertion.

1.12 SD Card Products in SD Bus Mode

The following sections provide valuable information on cards in the SanDisk SD Card Product Family in SD Bus mode.

Cards in the SanDisk SD Card Product Family are fully compliant with the SDA Physical Layer Specification, Version 2.00. Card Specific Data (CSD) Register structures are compliant with CSD Structure 1.0 and 2.0.

This section covers Negotiating Operating Conditions, Card Acquisition and Identification, Card Status, Memory Array Partitioning, Read/Write Operations, Data Transfer Rate, Data Protection in Flash Cards, Write Protection, Copy Bit, and CSD Register.

Additional practical card detection methods can be found in application notes pertaining to the SDA Physical Layer Specification, Version 2.00.

Figure 1-2 Memory Array Partitioning

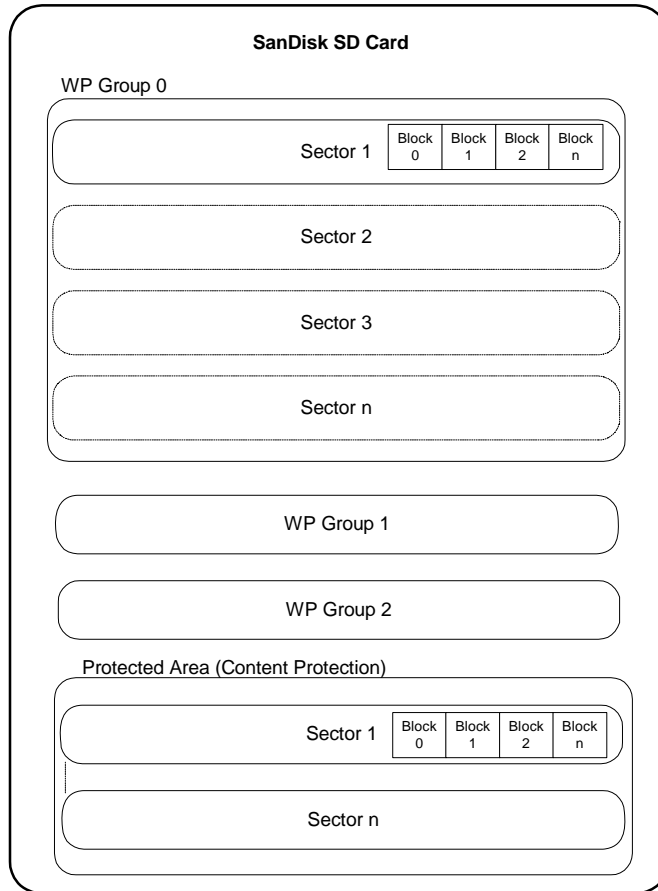


Figure 1-3 illustrates the formatting of a data transfer.

Figure 1-3 Data Transfer Formats

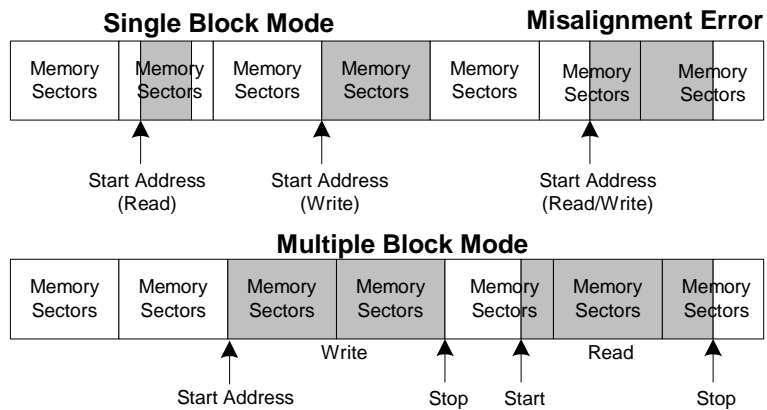


Table 1-1 contains descriptions for each mode.

Table 1-1 Mode Definitions

Mode	Description
Single Block	<p>In this mode the host reads or writes one data block in a pre-specified length. The data block transmission is protected with 16-bit CRC that is generated by the sending unit and checked by the receiving unit.</p> <p>The block length for read operations is limited by the device sector size (512 bytes) but can be as small as a single byte. Misalignment is not allowed. Every data block must be contained in a single physical sector.</p> <p>The block length for write operations must be identical to the sector size and the start address aligned to a sector boundary.</p>
Multiple Block	<p>This mode is similar to the single block mode, except for the host can read/write multiple data blocks (all have the same length) that are stored or retrieved from contiguous memory addresses starting at the address specified in the command. The operation is terminated with a stop transmission command.</p> <p>Misalignment and block length restrictions apply to multiple blocks and are identical to the single block read/write operations.</p>

1.13 SPI Mode

The SPI Mode is a secondary communication protocol for cards in the SanDisk SD Card Product Family. This mode is a subset of the SD Protocol, designed to communicate with an SPI channel, commonly found in Motorola and other vendors' microcontrollers. Detailed information about SPI Mode can be found in Section 7 or the SDA Physical Layer Specification, Version 2.00.

2.1 SD Card

This section provides product specifications for the SanDisk SD Card. For details about the environmental, reliability and durability specifications, refer to Section 8.1 of the SDA Physical Layer Specification, Version 2.00.

2.1.1 Typical Card Power Requirements

The values stated in Table 2-1 represent the SanDisk SD Card power requirements.

Table 2-1 Power Requirements for SanDisk SD Product Family

Mode	Maximum Value
Sleep: ≤ 4GB	250 μ A
6GB, 8GB	300 μ A
Read: Full Speed Mode (25MHz)	100 mA
High Speed Mode (50 Mhz)	200 mA
Write: Full Speed Mode (25 MHz)	100 mA
High Speed Mode (50 MHz)	200 mA

NOTE Current consumption is measured by averaging over one (1) second. Refer to Section 6.6.4 of the SDA Physical Layer Specification, Version 2.00 for more information.

2.1.2 System Performance

All performance values for the SD Card in Table 2-2 were measured under the following conditions:

- Voltage range 2.7 to 3.6V
- Temperature -25° C to 85° C
- Independent of card clock frequency

Table 2-2 System Performance for SanDisk SD Product Family

Timing	Maximum Value
Block Read Access Time	100 ms
Block Write Access Time	250 ms
CMD1 to ready after power-up	500 ms

2.1.3 System Reliability and Maintenance

Reliability and maintenance specifications for the SanDisk SD Card are shown in Table 2-3.

Table 2-3 Reliability and Maintenance Specifications for SanDisk SD Product Family

MTBF	>1,000,000 hours
Preventative Maintenance	None
Data Reliability	<1 non-recoverable error in 10^{14} bits read

2.1.4 Physical Specifications

Reliability and durability specifications are shown in Table 2-4.

Table 2-5 contains the physical dimensions of the SanDisk SD Card.

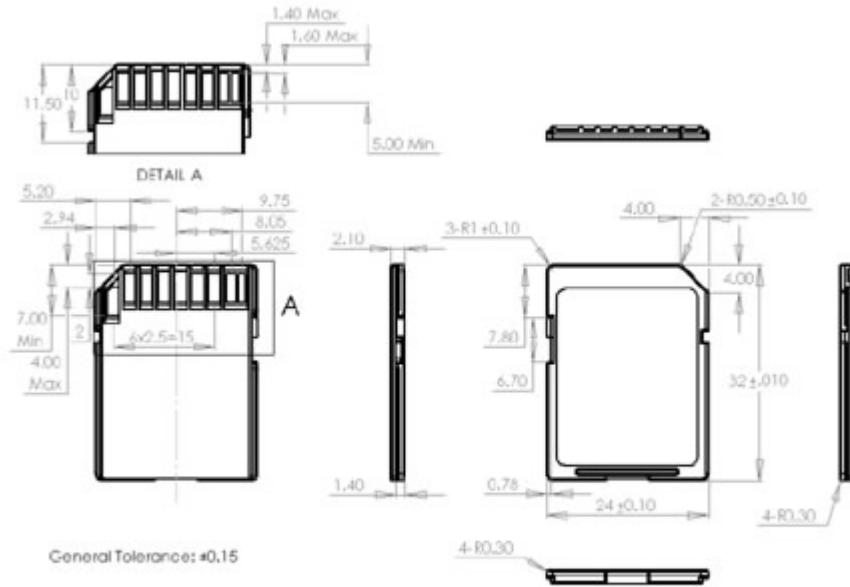
Table 2-4 Reliability and Durability Specifications

Durability	10,000 mating cycles
Bending	10N
Torque	0.15N.m or ± 2.5 deg.
Drop Test	1.5m free fall
UV Light Exposure	UV: 254nm, 15Ws/cm ² according to ISO 7816-1
Visual Inspection/Shape and Form	No warpage; no mold skin; complete form; no cavities; surface smoothness ≤ -0.1 mm/cm ² within contour; no cracks; no pollution (oil, dust, etc)
Minimum Moving Force of WP Switch	40 gf (ensures that the WP switch will not slide when it is inserted in the connector)
WP Switch Cycles	Minimum 1,000 Cycles @ slide force 0.4N to 5N

Table 2-5 SanDisk SD Card Physical Dimensions Summary

Specification	SanDisk SD Card
Weight	2.0 g maximum
Length	32 mm +/- 0.1 mm
Width	24 mm +/- 0.1 mm
Thickness	2.1 mm +/- 0.15 mm

Figure 2-1 SD Card Dimensions



2.2 miniSD Card

This section provides product specifications for the SanDisk miniSD Card. For details about the environmental, reliability and durability specifications, refer to Section 8.1 of the SDA Physical Layer Specification, Version 2.00

2.2.1 Typical Card Power Requirements

The values stated in Table 2-1 represent the SanDisk miniSD Card power requirements.

2.2.2 System Performance

See Section 2.1.2.

2.2.3 System Reliability and Maintenance

See Section 2.1.3.

2.2.4 Physical Specifications

Table 2-6 contains the physical dimensions of the SanDisk miniSD Card.

Table 2-6 SanDisk miniSD Card Physical Specification Summary

Specification	miniSD Card
Weight	1.0 g maximum
Length	21.5 mm +/- 0.1 mm
Width	20 mm +/- 0.1 mm
Thickness	1.4 mm +/- 0.15 mm

Figure 2-3 miniSD Card Dimensions (Bottom View)

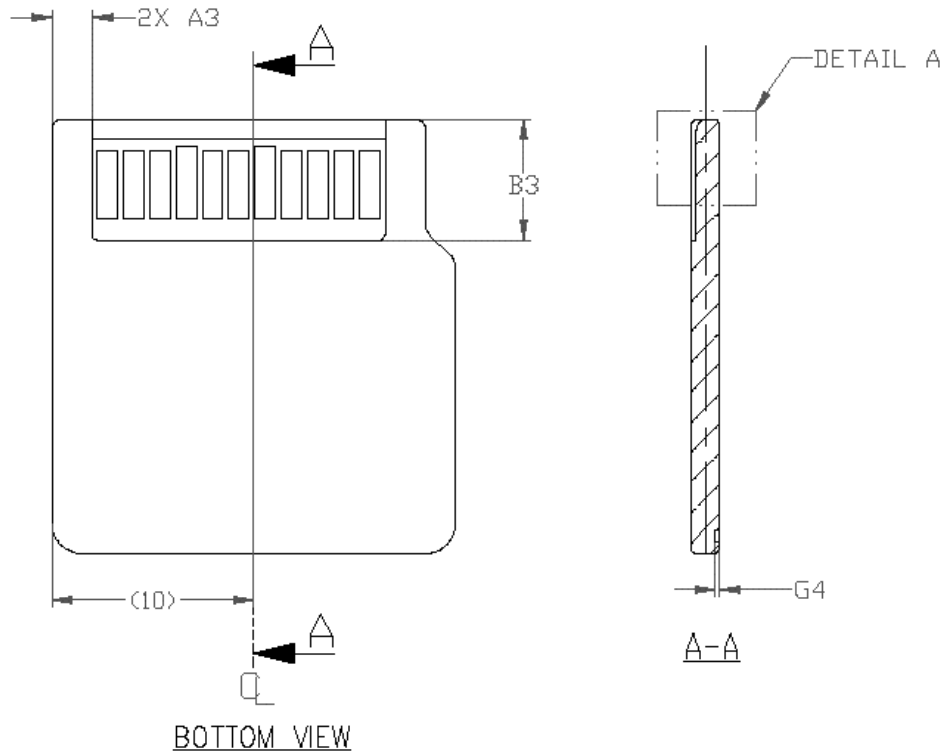


Figure 2-4 miniSD Card Dimensions (Detail)

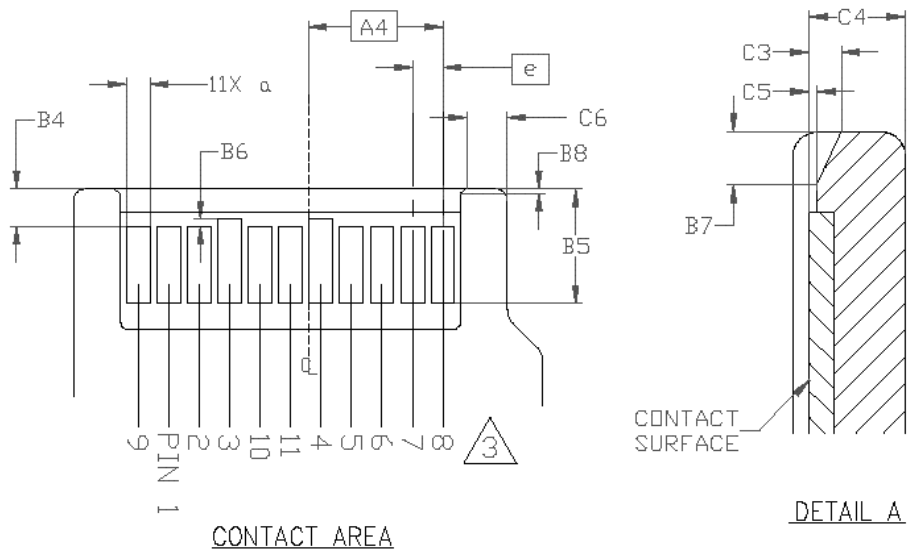


Figure 2-5 miniSD Card Package Dimensions

SYMBOL	COMMON DIMENSIONS			NOTE
	MIN	NOM	MAX	
A	19.90	20.00	20.10	
A1	18.40	18.50	18.60	
A2	0.50	0.60	0.70	
A3	1.45	-	2.05	
A4	-	5.75	-	BASIC
B	21.40	21.50	21.60	
B1	7.60	7.70	7.80	
B2	5.40	5.50	5.60	
B3	5.85	6.00	6.15	
B4	1.45	1.60	1.75	
B5	5.20	-	-	
B6	0.20	0.30	0.40	
B7	0.55	0.65	0.75	
B8	0.20	-	-	5
B9	0.00	0.20	0.40	
C	1.30	1.40	1.50	6
C1	0.80	0.90	1.00	
C2	0.55	0.70	0.85	
C3	0.30	0.40	0.50	
C4	1.10	1.20	1.30	
C5	0.00	-	0.20	
C6	-	-	1.85	
C7	0.00	-	0.20	
G1	0.75	0.90	1.05	
G2	0.60	-	-	
G3	10.00	-	-	
G4	0.20	-	-	
J2	0.90	1.00	1.10	
J3	1.00	1.20	1.40	
a	0.85	1.00	1.15	
e	-	1.30	-	BASIC
R1	0.15	0.30	0.45	
R2	0.10	0.20	0.30	
R3	0.35	0.50	0.65	
R4	0.05	0.10	0.15	
R5	0.00	0.20	0.40	
R6	-	-	1.10	
R7	0.15	0.30	0.45	
R9	-	-	0.20	
D1	17.50	-	-	
D2	3.40	-	-	
D3	1.65	-	-	
D4	1.50	-	-	
D5	0.80	-	-	
D6	12.00	-	-	
D7	6.00	-	-	
H	-	-	2.50	
aaa	-	-	0.20	

VARIATION	AA			AB		
	SYMBOL	MIN	NOM	MAX	MIN	NOM
R8	0.10	0.20	0.30	-	-	-
Z	-	-	-	0.60	-	-
R10	-	-	-	0.10	0.20	0.30
NOTE						

NOTES:

1 DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.

2 DIMENSIONS ARE IN MILLIMETERS.

3 THE FOLLOWING PIN ASSIGNMENT IS PER SDA SPECIFICATION.

4 RECESSED ARROW 0.025MM DEEP MAX.

5 NOT REQUIRED IF A3 IS LESS THAN OR EQUAL TO 1.85MM.

6 SUBSTRATE AREA IS HATCHED AREA OF FIGURE 6.

PIN NO. PIN NAME (SD MODE)

- 1 CD/DAT3
- 2 CMD
- 3 VSS1
- 4 VDD
- 5 CLK
- 6 VSS2
- 7 DAT0
- 8 DAT1
- 9 DAT2
- 10 NC (FOR FUTURE USE)
- 11 NC (FOR FUTURE USE)

2.3 microSD Card

This section provides product specifications for the SanDisk microSD Card. For details about the environmental, reliability and durability specifications, refer to Section 8.1 of the SDA Physical Layer Specification, Version 2.00.

2.3.1 Typical Card Power Requirements

The values stated in Table 2-1 represent the SanDisk microSD Card power requirements.

2.3.2 System Performance

See Section 2.1.2.

2.3.3 System Reliability and Maintenance

See Section 2.1.3.

2.3.4 Physical Specifications

Table 2-7 contains the physical dimensions of the SanDisk microSD Card.

Table 2-7 SanDisk microSD Card Physical Specification Summary

Specification	microSD Card
Weight	.29 g
Length	15 mm +/- 0.1 mm
Width	11 mm +/- 0.1 mm
Thickness	0.95 mm ^a

- a. Maximum thickness calculated as follows:
0.8mm (max. thickness in Inter-connect Area) + 0.15mm (max. thickness of mask label) = 0.95mm
See Figure 2-8 for more information.

Figure 2-6 microSD Card (Bottom View)

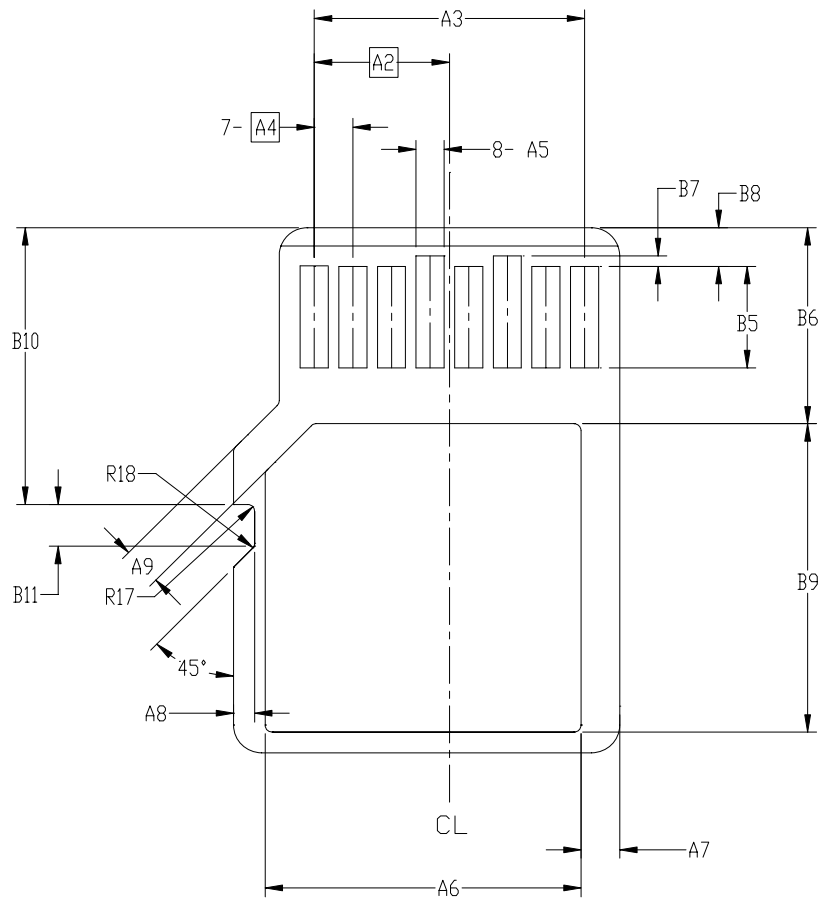


Figure 2-7 microSD Card (Keep Out Area)

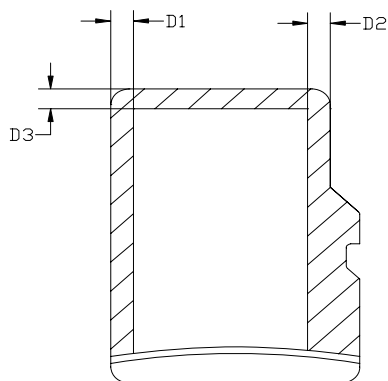



Figure 2-8 microSD Card Package Dimensions

SYMBOL	COMMON DIMENSIONS			NOTE
	MIN	NOM	MAX	
A	10.90	11.00	11.10	
A1	9.60	9.70	9.80	
A2	-	3.85	-	BASIC
A3	7.60	7.70	7.80	
A4	-	1.10	-	BASIC
A5	0.75	0.80	0.85	
A6	-	-	8.50	
A7	0.90	-	-	
A8	0.60	0.70	0.80	
A9	0.80	-	-	
B	14.90	15.00	15.10	
B1	6.30	6.40	6.50	
B2	1.64	1.84	2.04	
B3	1.30	1.50	1.70	
B4	0.42	0.52	0.62	
B5	2.80	2.90	3.00	
B6	5.50	-	-	
B7	0.20	0.30	0.40	
B8	1.00	1.10	1.20	
B9	-	-	9.00	
B10	7.80	7.90	8.00	
B11	1.10	1.20	1.30	
C	0.90	1.00	1.10	
C1	0.60	0.70	0.80	
C2	0.20	0.30	0.40	
C3	0.00	-	0.15	
D1	1.00	-	-	
D2	1.00	-	-	
D3	1.00	-	-	
R1	0.20	0.40	0.60	
R2	0.20	0.40	0.60	
R3	0.70	0.80	0.90	
R4	0.70	0.80	0.90	
R5	0.70	0.80	0.90	
R6	0.70	0.80	0.90	
R7	29.50	30.00	30.50	
R10	-	0.20	-	
R11	-	0.20	-	
R17	0.10	0.20	0.30	
R18	0.20	0.40	0.60	
R19	0.05	-	0.20	

Notes:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3.  COPLANARITY IS ADDITIVE TO C1 MAX THICKNESS.

3.1 Pins and Registers

The SanDisk SD Card Product Family have exposed contacts on one side. The host uses a dedicated 9-pin connector to connect to SD cards.

In Table 3-1, pin assignments for the SanDisk SD Card, miniSD Card, and microSD Card are for SD Bus Mode. Table 3-2 contains pin assignments for SPI Mode.

NOTE Pin assignments are provided by the SDA Physical Layer Specification, Version 2.00 and associated addendums (microSD and miniSD). For more details, refer to Section 4.7 of the SDA Physical Layer Specification, Version 2.00.

Table 3-1 SD Bus Mode Pin Assignment

Pin No.	Name	Type ^a	Description
SD Card			
1	CD/DAT3 ^b	I/O ^c /PP	Card Detect/Data Line [bit 3]
2	CMD	PP	Command/Response
3	V _{SS1}	S	Supply Voltage Ground
4	V _{DD}	S	Supply Voltage
5	CLK	I	Clock
6	V _{SS2}	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]
miniSD Card			
1	CD/DAT3	I/O/PP	Card Detect/Data Line [bit 3]
2	CMD	I/O/PP	Command/Response
3	V _{SS1}	S	Supply Voltage Ground
4	V _{DD}	S	Supply Voltage
5	CLK	I	Clock
6	V _{SS2}	S	Supply Voltage Ground
7	DAT 0	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]
10	NC	I/O/PP	For future use
11	NC	I/O/PP	For future use
microSD Card			
1	DAT2	I/O/PP	Data Line [bit 2]
2	CD/DAT3	I/O/PP	Card Detect/Data Line [bit 3]

Table 3-1 SD Bus Mode Pin Assignment

Pin No.	Name	Type ^a	Description
3	CMD	PP	Command/Response
4	V _{DD}	S	Supply Voltage
5	CLK	I	Clock
6	V _{SS}	S	Supply Voltage Ground
7	DAT0	I/O/PP	Data Line [bit 1]
8	DAT1	I/O/PP	Data Line [bit 2]

- Type Key: S=power supply; I=input; O=output using push-pull drivers; PP=I/O using push-pull drivers.
- The extended DAT lines (DAT1-DAT3) are input on power up. They start to operate as DAT lines after the SET_BUS_WIDTH command. It is the responsibility of the host designer to connect external pullup resistors to all data lines even if only DAT0 is to be used. Otherwise, non-expected high current consumption may occur due to the floating inputs of DAT1 & DAT2 (in case they are not used).
- At power up this line has a 50KOhm pullup enabled in the card. This resistor serves two functions: Card detection and Mode Selection. For Mode Selection, the host can drive the line high or let it be pulled high to select SD mode. If the host wants to select SPI mode it should drive the line low. For Card detection, the host detects that the line is pulled high. This pull-up should be disconnected by the user, during regular data transfer, with SET_CLR_CARD_DETECT (ACMD42) command.

The SanDisk SD Card, miniSD Card, and microSD Card pin assignments in Table 3-2 below are for SPI Mode.

Table 3-2 SPI Mode Pin Assignment

Pin No.	Name	Type	Description
SD Card			
1	CS	I	Chip Select (active low)
2	DataIn	I	Host-to-Card Commands and Data
3	V _{SS1}	S	Supply Voltage Ground
4	V _{DD}	S	Supply Voltage
5	SCLK	I	Clock
6	V _{SS2}	S	Supply Voltage Ground
7	DataOut	O/PP	Card-to-Host Data and Status
8	RSV	—	Reserved
9	RSV	—	Reserved
miniSD Card			
1	CS	I	Chip Select (active low)
2	DataIn	I	Host-to-Card Commands and Data
3	V _{SS1}	S	Supply Voltage Ground
4	V _{DD}	S	Supply Voltage
5	SCLK	I	Clock
6	V _{SS2}	S	Supply Voltage Ground
7	DataOut	O/PP	Card-to-Host Data and Status
8	RSV	—	Reserved
9	RSV	—	Reserved
10	NC	—	For future use

Table 3-2 SPI Mode Pin Assignment

Pin No.	Name	Type	Description
11	NC	—	For future use
microSD Card			
1	RSV	—	Reserved
2	CS	I	Chip Select (active low)
3	DataIn	I	Data in
4	V _{DD}	S	Supply Voltage
5	SCLK	I	Clock
6	V _{SS}	S	Supply Voltage Ground
7	DataOut	O/PP	Data out
8	RSV	—	Reserved

Each card has a set of information registers. Register descriptions and SDA references are provided in Section 5.0 of the SDA Physical Layer Specification, Version 2.00.

Table 3-3 SD Card Product Family Register Overview

Register Abbreviation	Width (in bits)	Register Name
CID	128	Card Identification Number
RCA	16	Relative Card Address
CSD	128	Card Specific Data
SCR	64	SD Configuration Register
OCR	32	Operation Condition Register
SSR	512	SD Status Register
CSR	32	Card Status Register

3.2 Bus Topology

The family of SanDisk SD products supports two communication protocols: SD and SPI. For more details, refer to Section 3.5 of the SDA Physical Layer Specification, Version 2.00. Section 6 of the specification contains a bus circuitry diagram for reference.

3.2.1 SD Bus

For more details, refer to Section 3.5.1 of the SDA Physical Layer Specification, Version 2.00.

3.2.2 SPI Bus

For more details, refer to Section 3.5.2 of the SDA Physical Layer Specification, Version 2.00.

3.3 Hot Insertion and Power Protection

Refer to Section 6.1 and Section 6.2 of the SDA Physical Layer Specification, Version 2.00.

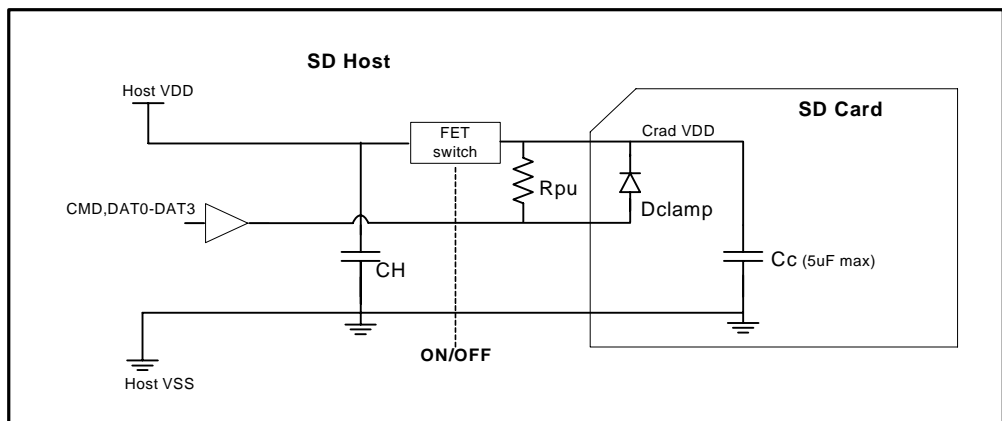
3.4 Electrical Interface

The power scheme of SanDisk SD products is handled locally in each card and in the bus master. Refer to Section 6.4 of the SDA Physical Layer Specification, Version 2.00.

3.4.1 Power Up

Power must be applied to the V_{DD} pin before any I/O pin is set to logic HIGH. In other words, CMD, CLK, and DAT0-3 must be at zero (0) volts when power is applied to the V_{DD} pin. For more information, refer to Section 6.4.1 of the SDA Physical Layer Specification, Version 2.00.

Figure 3-1 Recommended Power Control Scheme



The recommended power control scheme for SanDisk SD, miniSD, and microSD cards is illustrated in Figure 3-1. Most card connectors have a card detect switch that signals the SD host when the card is inserted. After the host is aware of the card insertion, it turns on the FET switch to apply power to card's V_{DD} pin.

Once the card is inserted and all card pins are making contact, there is a delay before the FET switch is turned on.

IMPORTANT Because there are clamping diodes on the CMD, CLK, and DAT0-3 pins, it is crucial to ensure that CLK, CMD, and DAT0-3 are at zero (0) volts during the delay, and before FET switch is turned on. If any I/O pin, (CMD, CLK, or DAT0-3) goes above zero volts during the delay and before power reaches the card V_{DD} pin, it will forward bias the clamping diodes and can cause the card to go into an unknown state.

It is the host's responsibility to make sure power gets to V_{DD} before CMD, CLK, or DAT0-3 go above zero volts.

3.4.2 Bus Operating Conditions

SPI Mode bus operating conditions are identical to SD Card Bus Mode operating conditions. For details, see Section 6.6 of the SDA Physical Layer Specification, Version 2.00.

3.4.3 Bus Timing (Standard Mode)

See Section 6.7 of the SDA Physical Layer Specification, Version 2.00.

3.4.4 Bus Timing (High Performance Mode)

See Section 6.8 of the SDA Physical Layer Specification, Version 2.00.

3.5 SD Card Product Family Registers

There is a set of eight registers within the card interface. However, the DSR Register is optional and is not used in the SanDisk SD Card Product Family. For specific information about all registers, refer to Section 5 of the SDA Physical Layer Specification, Version 2.00.

3.5.1 Operation Conditions Register

The Operation Conditions Register (OCR) stores a card's V_{DD} voltage profile. Refer to Section 5.1 of the SDA Physical Layer Specification, Version 2.00 for more information.

3.5.2 Card Identification Register

The Card Identification (CID) Register is 16 bytes long and contains the unique card identification number. It is programmed during card manufacturing and cannot be changed by card hosts. See Table 3-4.

Table 3-4 CID Register Definitions

Name	Type	Width	CID Value	Comments																														
Manufacturer ID (MID)	Binary	8	0x03	Manufacturer IDs are controlled and assigned by the SD-3C, LLC.																														
OEM/Application ID (OID)	ASCII	16	SD ASCII Code 0x53, 0x44	Identifies the card OEM and/or the card contents. The OID is controlled and assigned by the SD-3C, LLC.																														
Product Name (PNM)	ASCII	40	<table border="0"> <tr> <td>SD</td> <td>miniSD</td> <td>microSD</td> </tr> <tr> <td>SD16G</td> <td>SD04G</td> <td>SD08G</td> </tr> <tr> <td>SD08G</td> <td>SD02G</td> <td>SD06G</td> </tr> <tr> <td>SD04G</td> <td>SD01G</td> <td>SD04G</td> </tr> <tr> <td>SD02G</td> <td>SD512</td> <td>SD02G</td> </tr> <tr> <td>SD01G</td> <td>SD256</td> <td>SD01G</td> </tr> <tr> <td>SD512</td> <td>SD128</td> <td>SD512</td> </tr> <tr> <td>SD256</td> <td>SD064</td> <td>SD256</td> </tr> <tr> <td>SD128</td> <td></td> <td>SD128</td> </tr> <tr> <td>SD064</td> <td></td> <td>SD064</td> </tr> </table>	SD	miniSD	microSD	SD16G	SD04G	SD08G	SD08G	SD02G	SD06G	SD04G	SD01G	SD04G	SD02G	SD512	SD02G	SD01G	SD256	SD01G	SD512	SD128	SD512	SD256	SD064	SD256	SD128		SD128	SD064		SD064	Five-character ASCII string.
SD	miniSD	microSD																																
SD16G	SD04G	SD08G																																
SD08G	SD02G	SD06G																																
SD04G	SD01G	SD04G																																
SD02G	SD512	SD02G																																
SD01G	SD256	SD01G																																
SD512	SD128	SD512																																
SD256	SD064	SD256																																
SD128		SD128																																
SD064		SD064																																
Product Revision (PRV)	BCD	8	Product Revision xx	See Section 5.2 in the SDA Physical Layer Specification, Version 2.00.																														

Table 3-4 CID Register Definitions

Name	Type	Width	CID Value	Comments
Serial Number (PSN)	Binary	32	Product Serial Number	32-bit unsigned integer
Reserved	—	4	—	—
Manufacture Date Code (MDT)	BCD	12	Manufacture date (for example, April 2001=0x014)	Manufacturing date-ymm (offset from 2000)
CRC7 Checksum (CRC)	Binary	7	CRC7	Calculated
No use, always 0	—	1	—	—

3.5.3 Card Specific Data Register

The Card Specific Data (CSD) Register configuration information is required to access card data. The CSD defines the data format, error correction type, maximum data access time, etc. The field structures of the CSD Register vary depending on the physical specifications and card capacity. The CSD_STRUCTURE field in the CSD Register indicates which structure version is used. Table 3-5 shows the version number as it relates to the CSD structure. Refer to Section 5.3.1 of the SDA Physical Layer Specification, Version 2.00 for more information.

Table 3-5 CSD Register Structure

CSD_STRUCTURE	CSD Structure Version	Valid for SD Card Physical Specification Version / Card Capacity
0	CSD Version 1.0	Version 1.01 to 1.10 Version 2.00/Standard Capacity
1	CSD Version 2.0	Version 2.00/High Capacity
2-3	Reserved	—

Table 3-6 provides an overview of the CSD Register. More field-specific information can be found in Section 5.3.2 of the SDA Physical Layer Specification, Version 2.00.

Table 3-6 CSD Register (CSD Version 1.0)

Field	CSD Value	Description
CSD_STRUCTURE	1.0	CSD structure
—	—	Reserved
TAAC	1.5 msec	Data read access-time-1
NSAC	0	Data read access-time-2 in CLK cycles (NSAC*100)
TRANS_SPEED	Standard Mode 25MHz High Performance Mode 50MHz	Maximum data transfer rate
CCC	All (inc. WP, lock/unlock)	Card command classes
READ_BL_LEN	2G = 0xA Up to 1G = 0x9	Maximum read data block length
READ_BL_PARTIAL	Yes	Partial blocks for read allowed
WRITE_BLK_MISALIGN	No	Write block misalignment
READ_BLK_MISALIGN	No	Read block misalignment

Table 3-6 CSD Register (CSD Version 1.0)

Field	CSD Value		Description
DSR_IMP	No		DSR implemented
—	—		Reserved
C_SIZE	Non Secured	Secured	Device Size
64 MB	0xF4E	0xEDF	
128 MB	0xF4E	0xF03	
256 MB	0xF4E	0xF13	
512 MB	0xF4E	0xF1E	
1 GB	0xF4E	0xF22	
2 GB	0xF4E	0xF24	
VDD_R_CURR_MIN	100 mA		Maximum read current @V _{DD} min
VDD_R_CURR_MAX	80 mA		Maximum read current @V _{DD} max
VDD_W_CURR_MIN	100 mA		Maximum write current @V _{DD} min
VDD_W_CURR_MAX	80 mA		Maximum write current @V _{DD} max
C_SIZE_MULT	8G=8192 6G=6144 4G=4096 2G=2048 1G=1024 512=512 256=256 128=128 64=64		Device size multiplier
ERASE_BLK_EN	Yes		Erase single block enable
SECTOR_SIZE	31 blocks		Erase sector size
WP_GRP_SIZE	127 sectors		Write protect group size
WP_GRP_ENABLE	Yes		Write protect group enable
Reserved	—		Reserved for MMC compatibility
R2W_FACTOR	x16		Write speed factor
WRITE_BL_LEN	2G Up to 1G		Maximum write data block length
WRITE_BL_PARTIAL	No		Partial blocks for write allowed
—	—		Reserved
FILE_FORMAT_GRP	0		File format group
COPY	Has been copied		Copy flag (OTP)
PERM_WRITE_PROTECT	Not protected		Permanent write protection
TMP_WRITE_PROTECT	No protected		Temporary write protection
FILE_FORMAT	HD w/partition		File format
Reserved	—		Reserved
CRC	CRC7		CRC
—	—		Not used, always “1”

Refer to Section 5.3.3, Table 5-16 of the SDA Physical Layer Specification, Version 2.00 for more detailed information..

Table 3-7 CSD Register (CSD Version 2.0)

Field	CSD Value		Description
CSD_STRUCTURE	2.0		CSD structure
—	—		Reserved
TAAC	1.5 msec		Data read access-time
NSAC	0		Data read access-time in CLK cycles (NSAC*100)
TRANS_SPEED	Standard Mode 25MHz High Performance Mode 50MHz		Maximum data transfer rate
CCC	All (inc. WP, lock/unlock)		Card command classes
READ_BL_LEN	9		Maximum read data block length
READ_BL_PARTIAL	Yes		Partial blocks for read allowed
WRITE_BLK_MISALIGN	No		Write block misalignment
READ_BLK_MISALIGN	No		Read block misalignment
DSR_IMP	No		DSR implemented
—	0		Reserved
C_SIZE	Non Secured	Secured	Device Size
4 GB	0x1E9E	0x1E5C	
6 GB	0x2DEE	0x2D8C	
8 GB	0x3D3E	0x3CDC	
12 GB	0x5BDE	0x5B6C	
16 GB	0x7A7E	0x79FC	
32 GB	0xF4FE	0xF45C	
—	0		Reserved
ERASE_BLK_EN	1		Erase single block enable
SECTOR_SIZE	31 blocks		Erase sector size
WP_GRP_SIZE	127 sectors		Write protect group size
WP_GRP_ENABLE	Yes		Write protect group enable
Reserved	—		Reserved for MMC compatibility
R2W_FACTOR	x16		Write speed factor
WRITE_BL_LEN			Maximum write data block length
WRITE_BL_PARTIAL	No		Partial blocks for write allowed
—	—		Reserved
FILE_FORMAT_GRP	0		File format group
COPY	Has been copied		Copy flag (OTP)
PERM_WRITE_PROTECT	Not protected		Permanent write protection
TMP_WRITE_PROTECT	No protected		Temporary write protection
FILE_FORMAT	HD w/partition		File format
Reserved	—		Reserved
CRC	CRC7		CRC
—	—		Not used, always “1”

3.5.4 Card Status Register

The Card Status Register (CSR) transmits the card's status information (which may be stored in a local status register) to the host. The CSR is defined in Section 4.10.1 in the SDA Physical Layer Specification, Version 2.00.

3.5.5 SD Status Register

The SD Status Register (SSR) contains status bits that are related to the SD Card proprietary features and may be used for future applications. The SD Status structure is described in Section 4.10.2 in the SDA Physical Layer Specification, Version 2.00.

3.5.6 Relative Card Address Register

The 16-bit Relative Card Address (RCA) Register carries the card address published by the card during the card identification. Refer to Section 5.4 in the SDA Physical Layer Specification, Version 2.00 for more information.

3.5.7 SD Card Configuration Register

The SD Card Configuration Register (SCR) is in addition to the CSD Register. The SCR provides information about special features in the SanDisk SD Card products. For more information, refer to Section 5.6 in the SDA Physical Layer Specification, Version 2.00.

3.5.8 SD Card Product Family Registers in SPI Mode

All card registers are accessible in SPI Mode. Their format is identical to the format in the SD Bus Mode, however a few fields are irrelevant in SPI Mode. In SPI Mode, the Card Status Register has a different, shorter, format as well. Refer to Section 7.4 in the SDA Physical Layer Specification, Version 2.00. for more details. Data Interchange Format and Card Sizes

In general, a file system provides structure for data in SanDisk SD Card products. The SD Card File System Specification, published by the SDA, describes the file format system that is implemented in the SanDisk SD Card products. In general, each card is divided into two separate DOS-formatted partitions as follows:

- **User Area**—used for secured and non-secured data storage and can be accessed by the user with regular read/write commands.
- **Security Protected Area**—used by content protection applications to save security related data and can be accessed by the host using the secured read/write command after doing authentication as defined in the SD Security Specification. The security protected area size is defined by SanDisk as approximately one percent of the total size of the card.

Tables 3-8 and 3-9 describe the user and protected areas for all SanDisk SD Card Family products.

Table 3-8 User Area DOS Image Parameters

Capacity	Total LBAs	No. of Partition System Area Sectors	Total Partition Sectors	User Data Sectors	User Data Bytes
16GB	31,978,496	8192	31,970,304	31,962,112	16,364,601,344
8GB	15,954,944	8192	15,946,752	15,938,560	8,160,542,720
6GB	11,940,864	8192	11,932,672	11,924,480	6,105,333,760
4 GB	7,959,552	8192	7,951,360	7,943,168	4,066,902,016
2 GB	3,970,048	519	3,967,239	3,966,720	2,030,960,640
1 GB	1,984,000	519	1,983,495	1,982,976	1,015,283,712
512 MB	990,976	275	990,627	990,352	507,052,032
256 MB	494,080	155	493,979	493,824	252,837,888
128 MB	246,016	95	245,919	245,824	125,861,888
64 MB	121,856	57	121,817	121,760	62,341,120

Table 3-9 Protected Area DOS Image Parameters

Capacity	Total LBAs	No. of Partition System Area Sectors	Total Partition Sectors	User Data Sectors	User Data Bytes
16GB	131,072	65	131,009	130,944	67,043,328
8GB	98,304	51	98,259	98,208	50,282,496
6GB	98,304	51	98,259	98,208	50,282,496
4 GB	65,536	45	65,485	65,440	33,505,280
2 GB	40,960	41	40,905	40,864	20,922,368
1 GB	20,480	37	20,421	20,384	10,436,608
512 MB	10,240	37	10,213	10,176	5,210,112
256 MB	5,376	37	5,365	5,328	2,727,936
128 MB	2,624	35	2,611	2,576	1,318,912
64 MB	1,376	37	1,373	1,336	684,032

4.1 General Description

SD Protocol information for cards in the SanDisk SD Card Product Family is contained in this chapter; information includes SD bus protocol, card identification, and a functional description.

4.2 SD Bus Protocol

Communication over the SD bus is based on command and data-bit streams initiated by a start bit and terminated by a stop bit. See Section 3.6.1 of the SDA Physical Layer Specification, Version 2.00 for details.

4.3 Functional Description

In the SanDisk SD Card Product Family, the host controls all communication between itself and the cards. To demonstrate how this communication works, this section provides a general overview of the card identification and data transfer modes; commands; card dependencies; various card operation modes and restrictions for controlling the clock signal. All SD Card commands, together with corresponding responses, state transitions, error conditions, and timings are also provided. For detailed information, refer to Section 4 of the SDA Physical Layer Specification, Version 2.00.

4.3.1 Card Identification Mode

In Card Identification Mode, the host resets all cards, validates operation voltage range, identifies and requests cards to publish a relative card address. For more information see Section 4.2 in the SDA Physical Layer Specification, Version 2.00.

4.3.2 Data Transfer Mode

In Data Transfer Mode, the host may operate SanDisk SD Card Product Family cards in the f_{pp} frequency range. In the SDA Physical Specification, this section includes information about data read and write, erase, write-protect management, card lock/unlock operations, application-specific commands, switch function command, high-speed mode, command system, and the Send Interface Condition command (CMD8). CMD8 is part of identification mode and command functional differences in high capacity SD cards. For more detailed information, refer to Section 4.3 of the SDA Physical Layer Specification, Version 2.00.

4.3.3 Clock Control

The host can use the bus clock signal in SanDisk SD cards to switch them to energy saving mode or to control data flow on the bus. See Section 4.4 of the SDA Physical Layer Specification, Version 2.00.

4.3.4 Cyclic Redundancy Codes

The Cyclic Redundancy Check (CRC) protects against transmission errors that may occur on the bus in SanDisk SD Card Product Family cards. Detailed information and examples for CRC7 and CRC16 are provided in Section 4.5 of the SDA Physical Layer Specification, Version 2.00.

4.3.5 Error Conditions

See Section 4.6 of the SDA Physical Layer Specification, Version 2.00.

4.3.6 Commands

See Section 4.7 of the SDA Physical Layer Specification, Version 2.00 for detailed information about card commands in the SanDisk SD Card Product Family.

4.3.7 Card State Transition

In SD cards, the state transition is dependent on the received command. The transition is defined in Section 4.8 of the SDA Physical Layer Specification, Version 2.00 along with responses sent on the command line.

4.3.8 Timing Diagrams and Values

See Section 4.12 of the SDA Physical Layer Specification, Version 2.00.

4.3.9 Speed Class Specification

The speed class specification classifies card performance by speed class number and offers the method to calculate performance. For more information, refer to Section 4.13 of the SDA Physical Layer Specification, Version 2.00.

4.3.10 Erase Timeout Calculation

See Section 4.14 of the SDA Physical Layer Specification, Version 2.00.

Ordering Information

To order SanDisk products¹ directly from SanDisk, call (408) 801-1000.

Part Number	Block Size
SD Card	
SDSDJ-64	64 MB
SDSDJ-128	128 MB
SDSDJ-256	256 MB
SDSDH-256	256MB
SDSDJ-512	512 MB
SDSDH-512	512 MB
SDSDJ-1024	1024 MB
SDSDH-1024	1024 MB
SDSDX3-1024	1024 MB
SDSDJ-2048	2048 MB
SDSDH-2048	2048 MB
SDSDJ-4096	4096 MB
SDSDH-4096	4096 MB
SDSDX3-4096	4096 MB
SDSDJ-008G	8192 MB
SDSDH-008G	8192 MB
SDSDX3-008G	8192 MB
miniSD Card	
SDSDM-64	64 MB
SDSDM-128	128 MB
SDSDM-256	256 MB
SDSDM-512	512 MB
SDSDM-1024	1024 MB
SDSDM-2048	2048 MB
SDSDM-4096	4096 MB

1. 1 megabyte (MB) = 1 million bytes; 1 gigabyte (GB) = 1 billion bytes. Some of the listed capacity is used for formatting and other functions, and thus is not available for data storage.

Part Number	Block Size
microSD Card	
SDSDQ-64	64 MB
SDSDQ-128	128 MB
SDSDQ-256	256 MB
SDSDQ-512	512 MB
SDSDQ-1024	1024 MB
SDSDQ-2048	2048 MB
SDSDQ-4096	4096 MB
SDSDQ-006G	6144 MB
SDSDQ-008G	8192 MB

I. WARRANTY STATEMENT

SanDisk warrants its products to be free of any defects in materials or workmanship that would prevent them from functioning properly for one year from the date of purchase. This express warranty is extended by SanDisk Corporation.

II. GENERAL PROVISIONS

This warranty sets forth the full extent of SanDisk's responsibilities regarding the SanDisk SD Card, miniSD Card, and microSD Card . In satisfaction of its obligations hereunder, SanDisk, at its sole option, will repair, replace or refund the purchase price of the product.

NOTWITHSTANDING ANYTHING ELSE IN THIS LIMITED WARRANTY OR OTHERWISE, THE EXPRESS WARRANTIES AND OBLIGATIONS OF SELLER AS SET FORTH IN THIS LIMITED WARRANTY, ARE IN LIEU OF, AND BUYER EXPRESSLY WAIVES ALL OTHER OBLIGATIONS, GUARANTIES AND WARRANTIES OF ANY KIND, WHETHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR INFRINGEMENT, TOGETHER WITH ANY LIABILITY OF SELLER UNDER ANY CONTRACT, NEGLIGENCE, STRICT LIABILITY OR OTHER LEGAL OR EQUITABLE THEORY FOR LOSS OF USE, REVENUE, OR PROFIT OR OTHER INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION PHYSICAL INJURY OR DEATH, PROPERTY DAMAGE, LOST DATA, OR COSTS OF PROCUREMENT OF SUBSTITUTE GOODS, TECHNOLOGY OR SERVICES. IN NO EVENT SHALL THE SELLER BE LIABLE FOR DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE PRODUCT, ARISING OUT OF THE USE OR INABILITY TO USE SUCH PRODUCT, TO THE FULL EXTENT SUCH MAY BE DISCLAIMED BY LAW.

SanDisk's products are not warranted to operate without failure. Accordingly, in any use of products in life support systems or other applications where failure could cause injury or loss of life, the products should only be incorporated in systems designed with appropriate redundancy, fault tolerant or back-up features.

III. WHAT THIS WARRANTY COVERS

For products found to be defective within one year of purchase, SanDisk will have the option of repairing or replacing the defective product, if the following conditions are met:

- A. A warranty registration card for each defective product was submitted and is on file at SanDisk. If not, a warranty registration card must accompany each returned defective product. This card is included in each product's original retail package.
- B. The defective product is returned to SanDisk for failure analysis as soon as possible after the failure occurs.
- C. An incident card filled out by the user, explaining the conditions of usage and the nature of the failure, accompanies each returned defective product.
- D. No evidence is found of abuse or operation of products not in accordance with the published specifications, or of exceeding storage or maximum ratings or operating conditions.

All failing products returned to SanDisk under the provisions of this limited warranty shall be tested to the product's functional and performance specifications. Upon confirmation of failure, each product will be analyzed, by whatever means necessary, to determine the root cause of failure. If the root cause of failure is found to be not covered by the above provisions, then the product will be returned to the customer with a report indicating why the failure was not covered under the warranty.

This warranty does not cover defects, malfunctions, performance failures or damages to the unit resulting from use in other than its normal and customary manner, misuse, accident or neglect; or improper alterations or repairs.

SanDisk reserves the right to repair or replace, at its discretion, any product returned by its customers, even if such product is not covered under warranty, but is under no obligation to do so.

SanDisk may, at its discretion, ship repaired or rebuilt products identified in the same way as new products, provided such cards meet or exceed the same published specifications as new products. Concurrently, SanDisk also reserves the right to market any products, whether new, repaired, or rebuilt, under different specifications and product designations if such products do not meet the original product's specifications.

IV. RECEIVING WARRANTY SERVICE

According to SanDisk's warranty procedure, defective product should be returned only with prior authorization from SanDisk Corporation. Please contact SanDisk's OEM Support Department at 866-436-6073 with the following information: product model number and description, serial number(s), nature of defect, conditions of use, proof of purchase and purchase date. If approved, SanDisk will issue a Return Material Authorization or Product Repair Authorization number and provide a shipping address where the defective product can be returned.

V. STATE LAW RIGHTS

SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR LIMITATION ON HOW LONG AN IMPLIED WARRANTY LASTS, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU. This warranty gives you specific rights and you may also have other rights that vary from state to state.

C.1 SanDisk Corporation Policy

SanDisk Corporation general policy does not recommend the use of its products in life support applications wherein a failure or malfunction of the product may directly threaten life or injury. Accordingly, in any use of products in life support systems or other applications where failure could cause damage, injury or loss of life, the products should only be incorporated in systems designed with appropriate redundancy, fault tolerant or back-up features.

SanDisk shall not be liable for any loss, injury or damage caused by use of the Products in any of the following applications:

- Special applications such as military related equipment, nuclear reactor control, and aerospace
- Control devices for automotive vehicles, train, ship and traffic equipment
- Safety system for disaster prevention and crime prevention
- Medical-related equipment including medical measurement device

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D.1 Host Design Considerations

Host design considerations for products in the SanDisk SD Card Family are described in the application note that follows.

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APPLICATION NOTE

HOST DESIGN CONSIDERATIONS FOR NAND MMC AND SD PRODUCTS

MAY 2005

INTRODUCTION

SanDisk's MultiMediaCard (MMC) and Secure Digital (SD) Card have been designed into a wide variety of consumer electronic products: MP3 players, cell phones, PDAs, digital still and video cameras, data loggers, and more. However, there are many options to consider before designing a card slot into a product: end-product time-out delays, bus type selection, block mode selection, and more. These options can have a major impact on the performance and compatibility of the product. This application note provides a review of options and recommendations on the optimum way to manage them.

TIMING

There are important timing issues design engineers must consider when integrating the MultiMediaCard or SD Card into a new product: timing specifications, read access and program times.

Timing Specifications

A product design must meet the rise, fall, setup, hold, and other SD Card and MultiMediaCard bus timing specifications. To support MultiMediaCards, the clock speed should be controllable by a host, because of the MultiMediaCard's open-drain mode. MultiMediaCards power up in the open-drain mode and cannot handle a clock faster than 400 kHz. After MultiMediaCards complete initialization, they switch to push-pull mode. In push-pull mode, MultiMediaCards can run at maximum clock speed.

Refer to the MultiMediaCard Association at www.mmca.org or the SD Card Association at www.sdcard.org for published timing specifications.

Read Access and Program Times

Read access and program times are also extremely critical to ensure proper operation of a product design. If time-out values for read access and program times are not met, data read from- and written to- the card may be incorrect or invalid. Designers must also ensure that a product time-out value is not set below the maximum specification set by MultiMediaCard and SD Card manufacturers.

The maximum read and write time-out values for the MultiMediaCard and SD Card are shown in Table 1.

Table 1. MMC and SD Card Read/Write Time-Out Values

Product	Time-Out Values	
	Typical	Maximum
MultiMediaCard		
Read	(TAAC + NSAC)	10 * (TAAC + NSAC)
Write	(TAAC + NSAC) * R2W_FACTOR	(TAAC + NSAC) * R2W_FACTOR * 10
SD Card		
Read	(TAAC + NSAC)	100 ms
Write	(TAAC + NSAC) * R2W_FACTOR	250 ms

The factors used in calculating the values in Table 1-TAAC, NSAC, and R2W_FACTOR-can be read directly from the CSD Register of the MultiMediaCard and SD Card.

The TAAC factor's unit is time, and the NSAC factor has units of 100 clocks. TAAC units can be converted to clock cycles by multiplying the clock frequency and calculating the time-outs in units of clock cycles. Alternatively, given the frequency of the clock, the NSAC units can be converted to time, and calculate the time-outs in units of time.

The R2W_FACTOR is a read-to-write factor and contains no units. Designers can make the design compatible with all MultiMediaCards and SD cards by using the time-out values derived from the CSD Register, regardless of manufacturer.

INTERFACE

The MultiMediaCard and SD Card support multiple busses. Both cards support the 1-bit SPI bus that includes bus pins DATin, DATout, CLK, and CS. The SPI bus is generally found on Motorola and other major MCU manufactured products.

The SD Card also supports a 4-bit and a 1-bit SD bi-directional bus mode. SD bus pins are CLK, CMD, and DAT in 1-bit mode and CLK, CMD, and DAT [0:3] in 4-bit mode. The MultiMediaCard also supports the 1-bit bi-directional MMC bus mode and uses CLK, CMD, and DAT bus pins. The CMD and DAT pins are bi-directional on the SD Card 1-bit, SD Card 4-bit, and MultiMediaCard 1-bit.

The maximum burst rate achievable with an SD Card and MultiMediaCard depends on the clock speed and bus mode. The burst rate is the data transfer rate between the card's buffer and host as shown in Table 2.

Table 2. MMC and SD Card Clock Speed and Burst Rate

Product	Maximum clock Speed and Burst Rate	
	Clock Speed	Burst Rate
MultiMediaCard		
SPI Mode	20 MHz	2.5 MB/s
MMC 1-bit Mode	20 MHz	2.5 MB/s
SD Card		
SPI Mode	25 MHz	3.125 MB/s
SD 1-bit Mode	25 MHz	3.125 MB/s
SD 4-bit Mode	25 MHz	12.5 MB/s
SD High-speed Mode	50 MHz	25 MB/s

Write and read throughput rates of the SD Card and MultiMediaCard are slower than the burst rate, because each card includes the busy time to write data from the card's buffers to its internal Flash RAM and busy time to read data from the internal Flash RAM to the card's buffer. Because most designs use this write and read busy time to complete other processes, choosing a 1- or 4-bit bus mode can have a quadruple speed effect on the time spent servicing the SD Card.

The example in Table 3 shows the difference between moving 512 bytes of data to and from a MultiMediaCard or SD Card internal buffer using different bus modes.

Table 3. MMC and SD Card Clock Speed and Transfer Time

Product	Maximum clock Speed and Burst Rate	
	Clock Speed	Time
MultiMediaCard		
SPI Mode	20 MHz	204.8 us
MMC 1-bit Mode	20 MHz	204.8 us
SD Card		
SPI Mode	25 MHz	163.8 us
SD 1-bit Mode	25 MHz	163.8 us
SD 4-bit Mode	25 MHz	41 us
SD High-speed Mode	50 MHz	25 MB/s

READ/WRITE MODE SELECTION

Another important design consideration for MultiMediaCards and SD Cards is the use of single block or multiple block command modes. Single block mode reads and writes data one block at a time; multiple-block mode reads and writes multiple blocks until a stop command is received.

Multiple-block mode takes advantage of the multiple internal block buffers present in all MultiMediaCards or SD Cards. In this mode, one block buffer fills during a write operation, and the card gives the host access to other empty block buffers to fill while programming the first block. The card does not enter a busy state until all block buffers are full.

In single block mode, a card enters a busy state by forcing the DAT line low when the first block buffer is full and remains busy until the write process is complete. During the busy state, the host cannot send any additional data to the card because the card forces the DAT line low.

If speed is critical in a design, multiple-block mode is faster and the recommended method. Design engineers should ensure that enough system RAM will be available to support the multiple-block capability; the performance gain will outweigh the cost of extra RAM. However, if speed is not critical, single block mode is more than adequate. For example-data-logger designs that record only 512 bytes of data per minute.

POWER AND CLOCK CONTROL

Power control should be considered when creating designs that will use MultiMediaCards or SD cards. Power controlled by software creates more flexible and robust design capabilities. Independent of card insertion or removal, hosts can turn power on or off to the card, which helps card initialization when contact bounce occurs during card insertion. The host will wait for a specified amount of time after the card is inserted before powering up and starting the initialization process.

Also, if a card goes into an unknown state, the host can cycle the power and start the initialization process again. Overall power consumption can be reduced when the host is allowed to power-down the bus when card access is unnecessary.

Clock control is another option that should be considered in MultiMediaCard or SD Card designs. As mentioned in the Timing section, if the design needs to support a MultiMediaCard, the clock should be lowered to 400 kHz or less during initialization. The host can raise the clock speed to the card's maximum when the initialization process is complete.

INITIALIZATION ALGORITHM

The initialization algorithm should be considered for products designed to support MultiMediaCards and SD Cards or SD cards only. SD Card sockets are physically thicker which allows both types of cards to be inserted. Therefore, the host needs to be able to detect which type of card is inserted into the socket.

When the SD Card's initialization command is used first, it causes the MultiMediaCard to return an error that provides the host with card identification. If the host is supporting both MultiMediaCards and SD cards, it can use MMC commands to continue with initialization commands. If the host does not support both MMC and SD cards, it issues an error message instructing the user to insert an SD Card.

If the design uses MultiMediaCard sockets, the host can start the initialization with the MMC command. The host does not need to detect which type of card is inserted because the SD Card will not physically fit into an MMC socket.

FILE SYSTEM SUPPORT

If a design needs to support a file system, such as SanDisk's Host Developers Tool Kit (HDTK), additional considerations are necessary.

Reading and writing to MultiMediaCards and SD cards is generally done in 512-byte blocks, however, erasing often occurs in much larger blocks. The NAND architecture used by SanDisk and other card vendors currently has erase block sizes of (32) or (64) 512-byte blocks, depending on card capacity. In order to re-write a single 512-byte block, all other blocks that belong to the same erase block will be simultaneously erased and need to be re-written.

For example-writing a file to a design using a FAT file system takes three writes/updates of the system area of FAT and one write/update of the data area to complete the file write. First, the directory has to be updated with the new file name. Second, the actual file is written to the data area. Third, the FAT table is updated with the file data location. Finally, the directory is updated with the start location, length, date and time the file was modified. Therefore, when selecting the file size to write into a design, it should be as large as possible and a multiple of the erase block size: doing so takes advantage of the architecture.

Some designs update the FAT table for every cluster of the data file written. This can slow the write performance, because the FAT table is constantly being erased and re-written. The best approach is to write all the file clusters then update the FAT table once to avoid the performance hit of erasing and re-writing all the blocks within the erase-block multiple times.



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