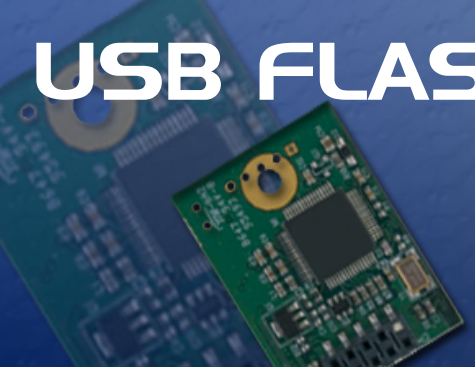
USB FLASH DISK MODULE

128MB to 8GB



QDUFDMxxx(M/G)UU1(I)-y

General Description and Key Features

Quantum Digital's USB Flask Disk Module (UFDM) provides non-volatile, solid-state storage in a compact design, making it perfectly suited for embedded applications. The standard USB 2.0 interface provides designers with a true plug-n-play storage device, allowing for short design cycles and fast time to market.

Quantum Digital selects the highest reliability Single Level Cell (SLC) Flash for its superior endurance. The flash management software that is embedded in the controller emulates a hard disk, enabling read/write operations that are identical to a standard, sector-based hard disk. Sophisticated wear leveling algorithms guarantee 2,000,000 Write/Erase Cycles, while automatic bad block management and a built-in ECC Engine guarantee the highest data reliability. Based on the Reed-Solomon algorithm, the ECC engine can detect up to 5-byte errors and correct up to 4-byte errors per 512 block.

USB Flash Disk Module is available in standart and low profile horizontal type with fixed hole, standard 10 pins 2.54mm pin pitch USB female connector or low profile 10 pins 2.0mm pin pitch USB female connector, specifically suited for designs that have Z-height constraints. High performance, high reliability and low cost per MByte make the USB Flash Disk Module the product of choice in embedded applications, such as Gaming, POS Workstations, Networking Equipment and Industrial PCs.

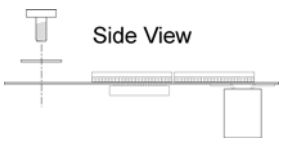
Quantum Digital offers value-added services to OEM customers, such as customized form factors and test solutions, custom firmware, controlled Bill Of Materials, customer-specific labeling and serialization.

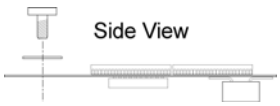
Ordering Information: USB Flash Disk Module

Part Number	PC Card Form Factor	Capacity
QDUFDM128MUU1(I)-y	y=A, B	128 Mbytes
QDUFDM256MUU1(I)-y	y=A, B	256 Mbytes
QDUFDM512MUU1(I)-y	y=A, B	512 Mbytes
QDUFDM1GUU1(I)-y	y=A, B	1 GByte
QDUFDM2GUU1(I)-y	y=A, B	2 GBytes
QDUFDM4GUU1(I)-y	y=A, B	4 GBytes
QDUFDM8GUU1(I)-y	y=A, B	8 GBytes

Legend:

(M/G) = proceeding capacity (xxx) is in Megabytes (M) or Gigabytes (G).
U = RoHS-6 compliant lead-free.
I = Industrial temperature range (-40ºC to +85 ºC).
Part numbers without (I) = Commercial temperature range (0ºC to 70ºC).
(y) = A for Horizontal **(y) =** B for Low Profile





USB Solid - State Flash Disk

Capacity: 128MB -16GB

USB 2.0 and 1.1 backward Compatible

Form Factors:

- Horizontal
- Low Profile

High Reliability:

- Endurance Guarantee of 2,000,000 Write/Erase Cycles
- Dynamic Wear-leveling
- 5-Byte Detection, 4-Byte Correction ECC Engine
- Automatic Bad Block Management
- Single Level Cell (SLC) NAND Flash Memory
- 10 Year Data Retention

Unique Serial Number

Commercial and Industrial Operating Tempreture

RoHS-6 Compliant

Industrial 5-year Warranty

Standard 3-year Warranty

Table of Contents

A Product Specifications

A-1 Mechanical Dimensions

A-1.1 Standard

Table 1 and Figure 2 show the mechanical dimensions of the USB Flash Disk Module–standard form factor.

Table 1: Mechanical dimensions - standard form factor

Parameter	Value
Length	37.80 ± 0.15 mm (1.488 ±. 0.006 in)
Width	26.65 ± 0.15 mm (1.049 ± 0.006 in)
Height (128MB-4GB)	10.27 mm (0.404 in) max
Height (8GB)	11.16 mm (0.439 in) max

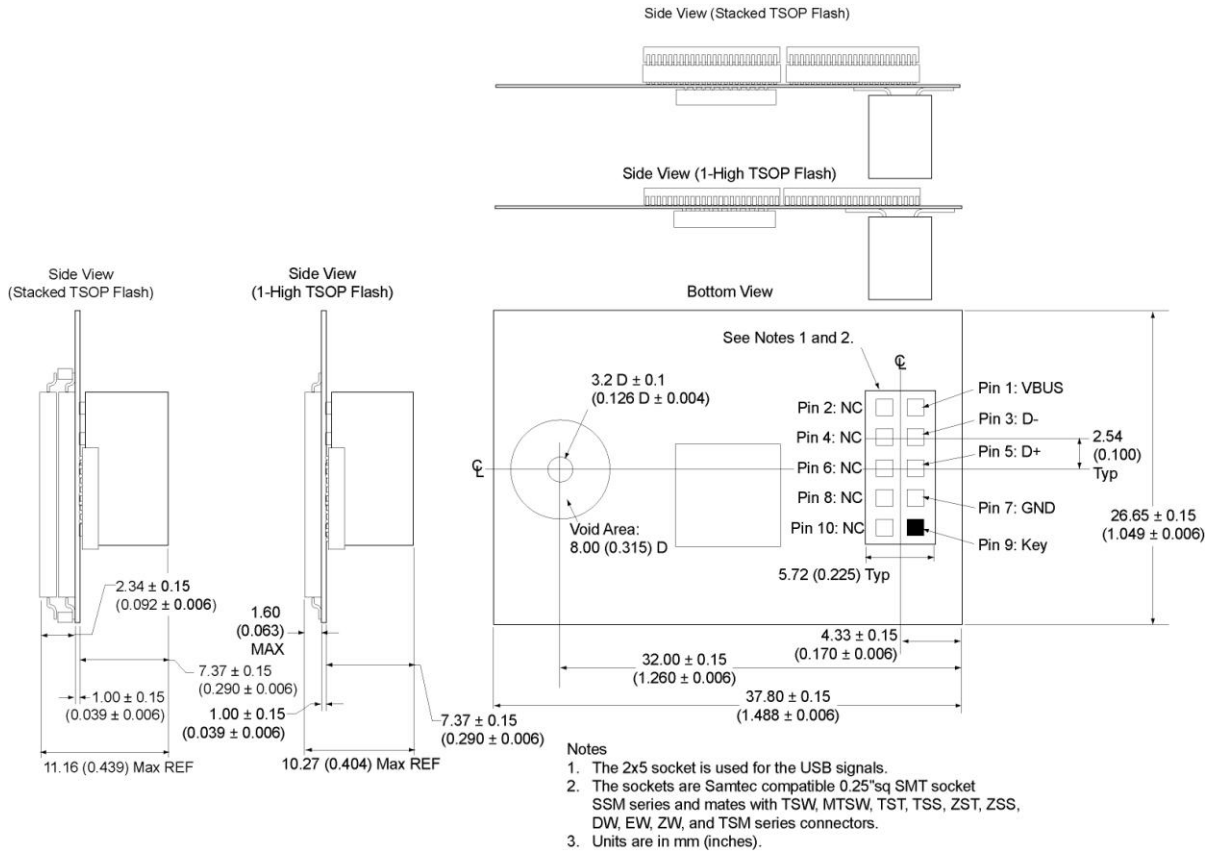


Figure 2: Mechanical dimensions-standard form factor

A-1.2 Low Profile

Table 2 and Figure 3 show the mechanical dimensions of the USB Flash Disk Module–low profile form factor.

Table 2: Mechanical dimensions – low profile form factor

Parameter	Value
Length	37.80 ± 0.15 mm (1.488 ±. 0.006 in)
Width	26.65 ± 0.15 mm (1.049 ± 0.006 in)
Height (128MB-4GB)	6.46 mm (0.254 in) max
Height (8GB)	7.35 mm (0.289 in) max

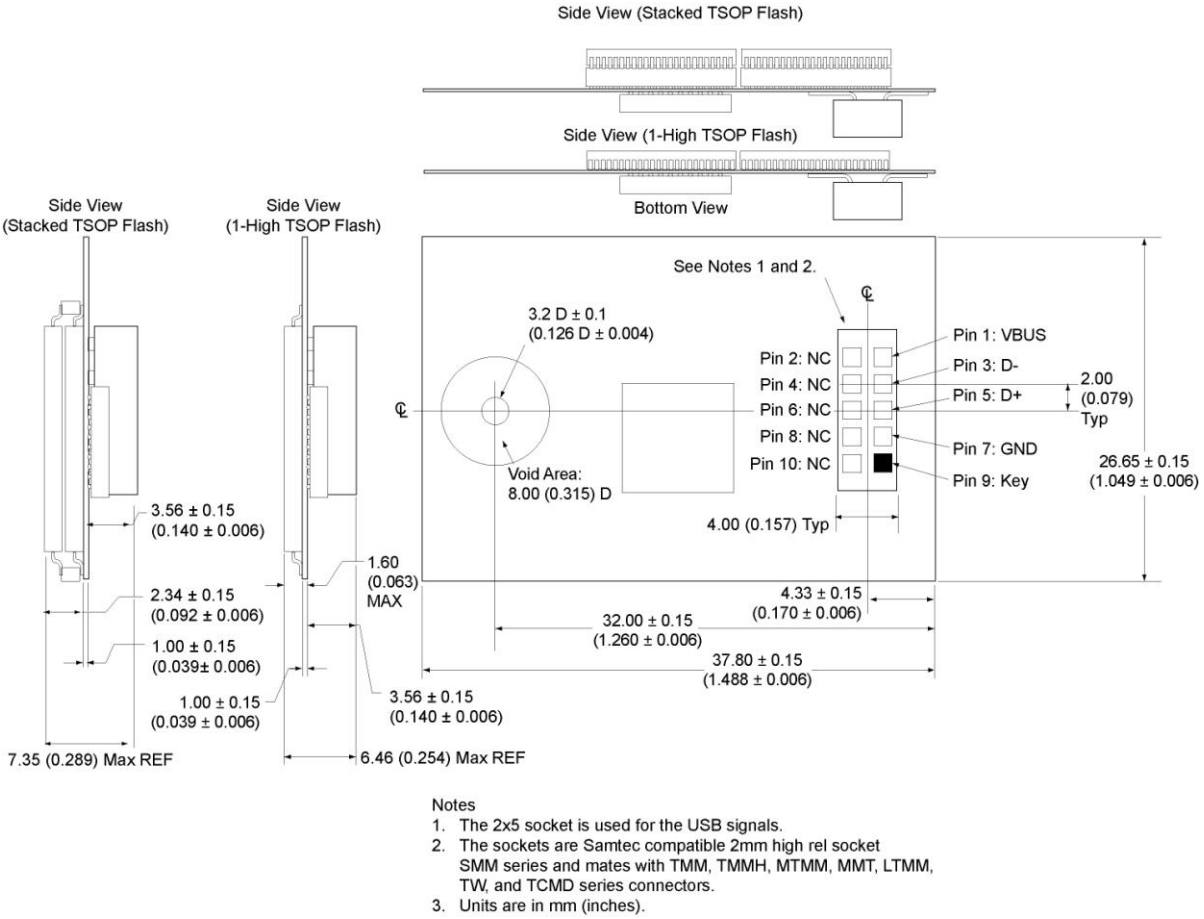


Figure 3: Mechanical dimensions–low profile form factor

A-2 Pin Assignment

Table 3: Pin Assignment

Pin Number	Signal Name	Pin Type	Pin Number	Signal Name	Pin Type
1	VBUS	Power	6	NC	I/O
2	NC	—	7	GND	Ground
3	D-	I/O	8	NC	—
4	NC	—	9	Key	Blocked Pin
5	D+	I/O	10	NC	—

A-3 Signal Description

Table 4: Signal Description

Signal Name	Type	Pin Number	Description
VBUS	Power	1	Bus voltage supply from source
D-	I/O	3	Data line –
D+	I/O	5	Data line +
GND	Ground	7	Ground
NC	Open	2, 4, 6, 8, 10	No Connect
Key	Open	9	Alignment pin

A-4 Performance

Table 5: Read/Write Performance

Parameter	Value
Sustained Read	up to 14 MB/sec
Sustained Write	up to 12 MB/sec

B Theory of Operation

B-1 Block Diagram

Quantum Digital's USB Flask Disk Module provides non-volatile, solid-state storage in a compact design, making it perfectly suited for embedded applications. The standard USB 2.0 interface provides designers with a true plug-n-play storage device, allowing for short design cycles and fast time to market. The controller's firmware supports the latest NAND flash technology from multiple vendors, and is optimized for the highest performance and reliability.

The USB Flash Disk Module controller consists of the functional blocks shown in

Figure 4 and described below.

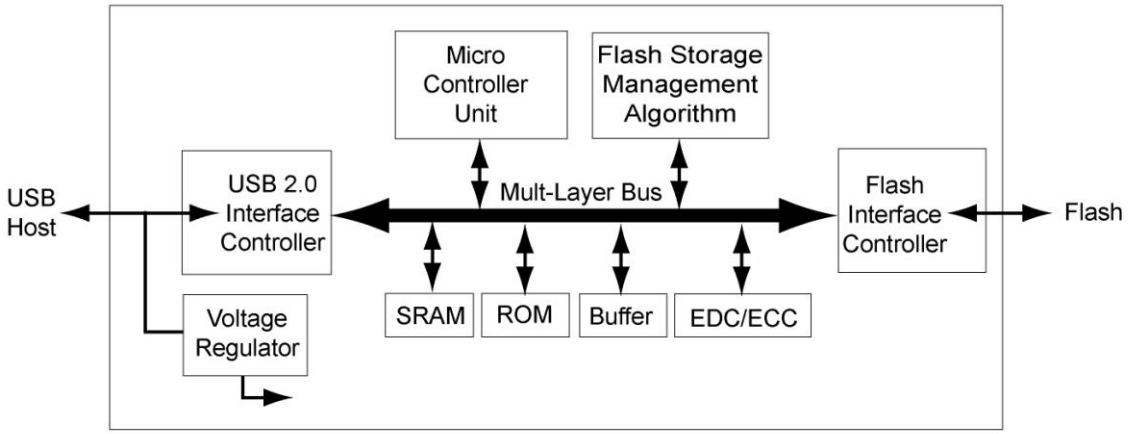


Figure 4: Controller block diagram

B-1.1 Controller Internal Components

- *Microcontroller* which serves as the hardware backbone for the flash controller algorithm.
- *USB 2.0 Interface Controller* with high speed (480 Mbps) device function. This block interfaces with the host system via the USB interface.
- *Flash Interface Controller* that serves as the interface to the NAND flash components. It supports all the major NAND flash memory manufacturers.
- *Flash Storage Management Algorithm Block* is responsible for the flash management, including wear leveling, bad block management, and Error Detection and Correction.
- *EDC/ECC block* is responsible for on-the-fly error detection and correction.
- *Sector Buffer* for optimized performance.
- *SRAM* for running controller firmware fast and efficient.
- *ROM* for storing controllers boot code.

B-1.2 Controller external components

In addition to the functional blocks shown in

Figure 4, the USB Flash Disk Module has the following external components:

- *SLC NAND Flash* for the most reliable data storage.
- *Crystal Oscillator 12Mhz*, as the main clock source.

B-2 Flash Management

Since the USB Flash Disk Module provides a standard USB interface to the host, no software integration is required, providing the shortest time-to-market for design engineers.

The firmware of the embedded USB 2.0 controller contains Quantum Digital's advanced flash memory management algorithms to ensure the most optimum device performance, reliability and endurance. It was designed to maximize the benefits of flash memory, while at the same time overcoming inherent NAND flash limitations. Implemented in firmware are the below features:

- Flash file system management
- Bad-block management
- Wear-leveling
- Power failure management
- Performance optimization

B-2.1 Bad Block Management

Inherent to NAND flash technology are areas (blocks) on the media that cannot be used for storage because of their high error rate. These so-called "bad blocks" are already identified by the flash vendor during manufacturing, but can also be accumulated over time during device operation.

The USB 2.0 controller contains a table that lists all the bad blocks on the device (Bad Block Table), and automatically maps out these blocks upon system initialization. During device operation it ensures that newly accumulated bad blocks are also mapped out and added to the Bad Block Table.

Bad block management is 100% transparent to the host application, which will not be aware of the location or existence of bad blocks on the media.

B-2.2 Wear Leveling

The SLC NAND flash devices that are being used in the USB Flash Disk Module are guaranteed for 100,000 Write/Erase cycles per block. This means that after approximately 100,000 erase cycles, the erase block has a higher probability for errors than the error rate that is typical to the flash. While 100,000 write/erase cycles may be good for consumer data storage, such as digital cameras, MP3 players, etc., it is not sufficient for industrial and embedded applications where data is constantly written to the device and long product life is required.

For example, operating systems that use a file system, will update the File Allocation Table (FAT) every time a write is done to the device. Without any wear leveling in place, the area on the flash where the FAT table is located would wear out faster than other areas, reducing the lifetime of the entire flash device.

To overcome this limitation, the flash management algorithm needs to make sure that each block in the device ages, i.e. is “worn out”, at the same rate. The built-in wear leveling scheme makes sure that with every write to the flash, the youngest block is used. This ensures that the full flash media is used uniformly, so that one area of the flash will not reach the endurance limits prematurely before other areas. The implemented wear leveling algorithm ensures a minimum of 2 million write/erase cycles for the entire flash media.

B-2.3 Error Correction/Detection

The USB 2.0 controller implements an advanced Error Correction/Detection scheme, based on the Reed-Solomon algorithm. The ECC engine can detect up to 5 bytes and correct up to 4 bytes per 512 bytes (symbol based). To ensure the fastest performance, both detection and correction are done on-the-fly, in hardware only.

Each time the host application writes a sector of 512 bytes to the USB Flash Disk Module, a unique ECC signature is created by the ECC engine and written together with the data to the flash. When the data is read back by the host, the ECC engine creates again a unique ECC signature. It will then compare the original written signature with the newly created signature, and sets an error flag if the two signatures are not the same. Correction of the data is done on-the-fly when the error flag is set, and the data presented to the host will be the same as the original written data. This powerful Error Correction/Detection scheme results in an overall error rate of less than 1 in 10^{14} bits, read.

B-2.4 Power Failure Management

The embedded flash management software uses algorithms that ensure data integrity, even during power failures. After each write, a verify write flag is set in the extra area of the flash page, while a dismount flag is set for the whole device during regular power-down. When a power failure occurs, both the verify write and the dismount flag will not be set, indicating a power failure during a write or erase operation. Upon the next power-up, the mapping tables will be reconstructed from the information stored in the flash memory, and the last version of the sector with a correct verify write flag will be used.

This mechanism ensures complete data integrity. When writing, copying, or erasing the flash device, the data format remains valid at all intermediate stages. Old data is never erased until the verify write flag of the new sector has been set. Therefore, a data sector cannot exist in a partially written state. The operation is either successfully completed (verify write flag is set) and the new data is valid, or the operation has not yet been completed or has failed, in which case the old sector contents remain valid.

B-3 OS and Boot Support

USB Flash Disk Module can be used as the OS boot and main storage device for most Microsoft Operating Systems, as well as most embedded Operating Systems, as listed in Table 6 In both modes the USB Flash Disk Module is recognized as fixed hard drive in the system.

Table 6: Supported Operating Systems

Operating System	Secondary Storage	Boot	Version
Windows XP Pro/Vista	√	√	
Windows XP Embedded	√	√	Service Pack 2007
Windows CE	√	√	4.2 and 5.0
Windows for POS (WEPOS)	√	-	
VxWorks	√	√	6.1 and up
Linux	√	√	Kernel 2.4 and up

Note: When using the USB Flash Disk Module as the OS boot device, it should be verified that the system BIOS supports booting from a USB device. Please contact your BIOS vendor to verify this.

B-3.1 Using USB Flash Disk Module with XP Embedded

When using USB Flash Disk Module with Windows XP Embedded, it is recommended that the Enhanced Write Filter (EWF) feature is implemented. The EWF intercepts calls at the sector level, and thereby eliminates many file system updates/writes to the flash. Windows XP Embedded Service Pack 2 Feature Pack 2007 introduced an additional write protect feature, called File Based Write Filter (FBWF). The new FBWF function write-protects embedded devices at the file level, in contrast to the EWF, which has been protecting devices at the sector level.

FBWF and EWF, combined with the built-in wear leveling algorithm, ensure that the maximum life span of the flash device is achieved.

C Environmental Specifications

C-1 Recommended Operating Conditions

Table 8: Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Commercial Operating Temperature	T_{A1}	0	25	70	°C
Industrial Operating Temperature	T_{A2}	-40	-	85	°C
Bus Voltage	V_{BUS}	4.5	-	5.5	V

C-2 Reliability

Table 9: Endurance & Data Reliability

Parameter	Value
Endurance	2,000,000 Write/Erase Cycles
Data reliability	1 in 10^{14} bits, read
Data retention	10 years

C-3 Shock, Vibration, and Humidity

Table 10: Shock, Vibration & Humidity

Parameter	Value
Shock	1500G Peak, 0.5m pulse duration, 5 pulses, 6 axes (per JESD22-B110)
Vibration	20G Peak, 20-2000 Hz, 4 cycles per direction (X, Y and Z) (per JESD22-B103)
Humidity	85°C, 85% RH, Vmax for 500 hrs (per JESD22-A101)

C-4 Electrostatic Discharge (ESD)

USB Flash Disk Module has been tested and approved for immunity from ESD under the conditions described in Table 11 below.

Table 11: ESD Rating for USB Flash Disk Module

ESD Type	Value (KV)
Air	2, 4, 8
Contact	2, 4

C-5 Mean Time Between Failure (MTBF)

Quantum Digital estimates Mean Time Between Failure (MTBF), using a prediction methodology based on reliability data for the individual components in the USB Flash Disk Module Table 12 below summarizes the prediction results for the USB Flash Disk Module, based on the following two methodologies:

- Telcordia Special Report SR-332, Reliability Prediction Procedure for Electronic Equipment.
- MIL-HNBK-217

The analysis was performed using Relex Software.

Table 12: USB Flash Disk Module MTBF

Product	Condition	MTBF (hours)
QDUFDM128MUU1-A	Telcordia SR-332, GB, 25°C, MIL-HNBK-217	>8,000,000
QDUFDM4GUU1-A	Telcordia SR-332, GB, 25°C, MIL-HNBK-217	>8,000,000
QDUFDM8GUU1-A	Telcordia SR-332, GB, 25°C, MIL-HNBK-217	>7,000,000

C-6 Standards Compliance

USB Flash Disk Module complies with the following standards:

- CE - EN 55022/55024
- FCC - Class B for Information Technology
- UL 60950
- RoHS-6
- USB 2.0 – Mass Storage Class

D Electrical Specifications

D-1 Absolute Maximum Ratings

Table 13: Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Power Supply Voltage Relative to Ground	V_{BUS}	-0.5 to 6	V
Voltage on D+ and D- Relative to Ground	V_{DATA}	-0.5 to 3.6	V
Storage Temperature	T_{STG}	-65 to +150	°C
Ambient Operating Temperature (Commercial)	T_{A1}	0 to +70	°C
Ambient Operating Temperature (Industrial)	T_{A2}	-40 to +85	°C

D-2 DC Characteristics

Measurements at Recommended Operating Conditions, unless otherwise specified.

Table 14: DC Characteristics for Full-Speed Operation (T_A=25ºC, Vdd=3.3V, Vss=0V)

Parameter	Symbol	Test conditions	Min	Typ	Max	Unit
Supply Voltage	V_{BUS}		4.75	5	5.25	V
Operating current	I_{cc}	V_{BUS}=5.0V	60	-	90	mA
Suspend current	I_{ccs}	V_{BUS}=5.0V	320	-	500	μA
Input LOW Voltage	V_{IL}		-	-	0.8	V
Input HIGH Voltage	V_{IH}		2.0	-	-	V
Output LOW Voltage	V_{OL}	R_L of 1.5kΩ to 3.6V	-	-	0.3	V
Output HIGH Voltage	V_{OH}	R_L of 15kΩ to GND	2.8	-	3.6	V
Output Signal Crossover Voltage	V_{CRS}		1.3	-	2.0	V

Table 15: DC Characteristics for High-Speed Operation (T_A=25ºC, Vdd=3.3V, Vss=0V)

Parameter	Symbol	Test conditions	Min	Typ	Max	Unit
Supply Voltage	V_{BUS}		4.75	5	5.25	V
Operating current	I_{cc}	V_{BUS}=5.0V	120	-	150	mA
Suspend current	I_{ccs}	V_{BUS}=5.0V	320	-	500	μA
High Speed Idle Level	VHSOI		-10	-	10	mV
High Speed Data Signaling High	VHSOH		360	-	440	mV
High Speed Data Signaling Low	VHSOL		-10	-	10	mV
Chirp J Level (differential Voltage)	VCHIRPJ		0.7	-	1.1	V
Chirp K Level (differential Voltage)	VCHIRPK		-0.9	-	-0.5	mV

D-3 AC Characteristics

Measurements at Recommended Operating Conditions, unless otherwise specified.

Table 16: AC Characteristics Full Speed

Parameter	Symbol	Min	Typ	Max	Unit
Rise Time	T_{FR}	4	-	20	ns
Fall Time	T_{FF}	4	-	20	ns
Differential Rise and Fall Time Matching	T_{FRFM}	90		111.11	%
Driver Output Resistance	Z_{DRV}	28	-	44	Ω

Table 17: AC Characteristics High Speed

Parameter	Symbol	Min	Typ	Max	Unit
Rise Time (10%~90%)	T_{HSR}	500	-	-	ps
Fall Time (10%~90%)	T_{HSF}	500	-	-	ps
Driver Output Resistance	Z_{HSDRV}	40.5	-	49.5	Ω