Industrial Grade
USB Flash Drive (UFD)
-300 Series
Product Manual

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1. Introduction to Cactus Technologies® Industrial Grade UFD300 Products

Features:

- Solid state design with no moving parts

- Plugs into industry standard USB-A receptacles

- Compliant with USB2.0 specifications

- Compliant with USB Mass Storage Class specifications v1.0

- Supports booting from USB device

- Enhanced error correction with 96-bit/1KB BCH ECC

- S.M.A.R.T. feature set supported via ATA Pass Through

Overview:

Cactus Technologies® UFD is a solid-state flash memory product that complies with the USB2.0 standard. Cactus Technologies® UFDs provide up to 32GB of formatted storage capacity and is designed to plug in directly to USB-A receptacles. Cactus Technologies® UFDs are designed to be used in applications which require a solid state disk that is compatible with USB interface.

Cactus Technologies® Industrial Grade UFD products use high quality flash memory from well-known vendors, such as Toshiba Corporation. In addition, it includes an on-drive intelligent controller that manages interface protocols, data storage and retrieval as well as ECC, defect handling and diagnostics, power management, and clock control.

1.1. Supported Standards

Cactus Technologies® UFD is fully electrically compatible with the following specification:

- USB2.0 Specification published by the USB Implementor's Forum

1.2. Product Features

Cactus Technologies® Industrial UFD contains a high level, intelligent controller. This intelligent controller provides many capabilities including the following:

- USB command processing.
- Management of erasing and programming the flash memory independent of the host system
- Sophisticated defect managing capabilities (similar to magnetic disk drives).
- Sophisticated system for error recovery using powerful error correction code (ECC).
- Intelligent power management for low power operation.

1.2.1.   Host and Technology Independence

Cactus Technologies® Industrial UFD appears as a standard USB mass storage device to the host system. The host computer software simply issues USB commands to the drive as per the USB specifications. The host software then waits for the commands to complete. The host system does not get involved in the details of how the flash memory is erased, programmed or read as this is all managed by the built-in controller in the drive. Also, with the intelligent on-board controller, the host system software will not require changing as new flash memory evolves. Thus, systems that support the Cactus Technologies® Industrial UFD products today will continue to work functionally with future Cactus Technologies® Industrial UFDs built with new flash technology without having to update or change host software.

1.2.2.   Defect and Error Management

Cactus Technologies® Industrial UFD contains a sophisticated defect and error management system similar to those found in magnetic disk drives. The defect management is completely transparent to the host and does not consume any user data space.

The soft error rate for Cactus Technologies® Industrial UFDs is much lower than that of magnetic disk drives. In the extremely rare case where a read error does occur, the drive has sophisticated ECC to recover the data.

These defect and error management systems, coupled with the solid-state construction, give Cactus Technologies® Industrial UFDs unparalleled reliability.

1.2.3.   Intelligent Wear Leveling

Cactus Technologies® Industrial UFD employs sophisticated static, dynamic and global wear leveling algorithms and intelligent bad block management to ensure high data reliability and to maximize product life.

2.Power Supply Requirements

Cactus Technologies® Industrial UFD operates off the standard USB bus power supply of 5.00 volts ± 10%.

For all the following specifications, values are defined at ambient temperature and nominal supply voltage unless otherwise stated.

2.1. System Environmental Specifications

Table 2-1. Environmental Specifications

		Cactus Technologies® Industrial UFD
Temperature	Operating:	0° C to +70° C (Standard)
		-45°C to +90°C (Extended)
Humidity	Operating & Non-Operating:	8% to 95%, non-condensing
Acoustic Noise		0 dB
Vibration	Operating & Non-Operating:	20G, MIL-STD883G, Method 2007.3, Condition A
Shock	Operating & Non-Operating:	3000G, MIL-STD883G, Method 2002.4, Condition C
Altitude (relative to sea level)	Operating & Non-Operating:	100,000 feet maximum

2.2. System Power Requirements

Table 2-2. Power Requirements

		Cactus Technologies® Industrial UFD
DC Input Voltage (VCC) 100 mV max. ripple (p-p)		5V ±10%
(Maximum Average Value) See Notes.	Standby: Reading: Writing:	60mA 60mA 120mA

NOTES: All values quoted are worst case at low temperature and high supply voltage unless otherwise stated.

Sleep mode is specified under the condition that all drive inputs are static CMOS levels and in a "Not Busy" operating state.

2.3. System Performance

All performance timings are typical values under normal operating conditions and assuming the drive controller is in the default (i.e., fastest) mode.

Table 2-3. Performance

Read Transfer Rate		up to 30MBytes/s
Write Transfer Rate		up to 25MBytes/s

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2.4. System Reliability

Table 2-4. Reliability

MTTF (@ 25°C)	> 4,000,000 hours
Data Reliability	< 1 non-recoverable error in 10^{14} bits READ
Endurance (avg. TBW): 512M 1G 2G 4G 8G 16G 32G	 30 60 120 240 480 960 1920

Note: TBW values are dependent on work load; values presented in this table represents average values for workloads consisting mostly of large block writes.

2.5. Physical Specifications

The following sections provide the physical specifications for Cactus Technologies® Industrial UFD products.

2.5.1.   UFD Physical Specifications
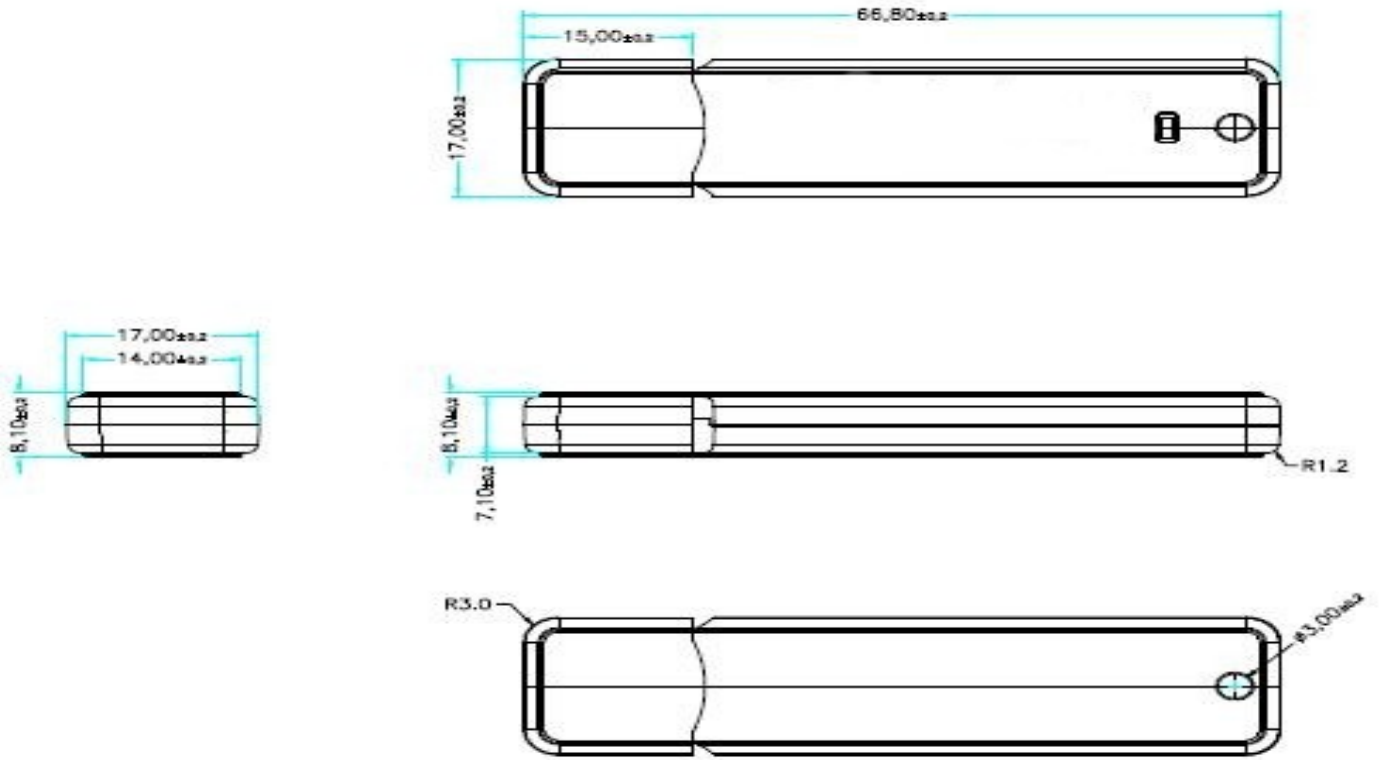
2.6. Capacity Specifications

Cactus Technologies® UFD product is offered in capacities of 512MByte, 1GByte, 2GByte, 4GByte, 8 Gbyte, 16GByte or 32GByte.

3.Interface Description

The following sections provide detailed information on the Cactus Technologies® Industrial UFD interface.

3.1. Electrical Specification

The following table defines all D.C. Characteristics for the UFD. Unless otherwise stated, conditions are:

Vcc = 5V ± 10%
Ta = -45°C to 90°C

3.1.1. Absolute Maximum Ratings

Parameter	Symbol	MIN	MAX	Units
Storage Temperature	Ts	-55	125	°C
Operating Temperature	T_{A-}	-45	90	°C
Vcc with respect to GND	Vcc	-0.3	6.5	V

3.1.2. DC Characteristics

Parameter	Symbol	MIN	MAX	Units
Input Levels USB D+,D-, Full Speed Mode Low High	V_{IL} V_{IH}	- 2.0	0.8 -	V
Output Levels USB D+, D-, Full Speed Mode Low High	V_{OL} V_{OH}	0 2.8	0.3 3.6	V
Output Signal Crossover Voltage USB D+, D-, Full Speed Mode	V_{CRS}	1.3	2	V

Parameter	Symbol	MIN	MAX	Units
Input Levels USB D+, High Speed Mode 　　Low 　　High	V_{IL} VIH	 -10 360	 10 440	mV
Input Levels USB D-, High Speed Mode 　　Low 　　High	V_{IL} VIH	 360 -10	 440 10	mV
Output Levels USB D+, D-, High Speed Mode 　　Low 　　High	V_{OL} V_{OH}	-10 360	10 440	mV
Operating Current 　　Suspend 　　Active	I_{CC}		 2.5 200	mA

4. S.M.A.R.T Feature Set

Cactus Technologies® -300 series USB products support S.M.A.R.T. reporting through the use of SCSI ATA Passthrough mechanism in the USB protocol.   The supported SMART commands are determined by the value loaded into the Feature Register:

Value	Command
D0h	SMART read data
D1h	SMART read attribute thresholds
D8h	SMART enable operations
D9h	SMART disable operations
DAh	SMART return status

The following sections describes these commands in detail.

4.1. SMART Enable Operations

This command enables access to the SMART features of the Cactus Technologies® -300 series Industrial USB devices. For this command to take effect, the following signature bytes must be loaded:

Cylinder Low – 4Fh

Cylinder High - C2h

 The state of SMART (enabled/disabled) is preserved across power cycles.

4.2. SMART Disable Operations

This command disables access to the SMART features of the Cactus Technologies® -300 series Industrial USB devices. For this command to take effect, the following signature bytes must be loaded:

Cylinder Low – 4Fh

Cylinder High – C2h

 The state of SMART (enabled/disabled) is preserved across power cycles.

4.3. SMART Read Data

For this command to take effect, the following signature bytes must be loaded:

Cylinder Low – 4Fh

Cylinder High – C2h

This command returns one sector of SMART data. The format of the returned data is as follows:

Offset	Value	Description
0 – 1	0010h	SMART structure version
2 – 361		Attribute entries 1 to 30 (12 bytes each)
362	00h	Offline data collection status (no offline data collection)
363	00h	Selftest execution status (selftest completed)
364 – 365	0000h	Total time to complete offline data collection
366	00h	----
367	00h	Offline data collection capability (none)
368 369	0003h	SMART capabilities
370	00h	Error logging capability (none)
371	00h	----
372	00h	Short selftest routine recommended polling time
373	00h	Extended selftest routine recommended polling time
374 – 385	00h	Reserved
386 – 387	0004h	SMART structure version
388 – 391		Firmware commit counter
392 – 395		Firmware wear level threshold
396		Global wear leveling status: '0' – not active, '1' - active
397		Global bad block management status: '0' – not active, '1' - active
398 – 401		Average flash block erase count
402 – 405		Number of flash blocks involved into wear leveling
406 – 409		Number of total ECC errors during firmware initialization
410 – 413		Number of correctable ECC errors during firmware initialization

Offset	Value	Description
414 – 510	00h	----
511		Data structure checksum

There are 12 attributes defined for the -300 series products. The following sections describe in detail what these attributes are.

4.3.1.   Spare Block Count Attribute

This attribute gives information about the amount of available spare blocks. The data structure of this attribute is as follows:

Offset	Value	Description
0	196	Attribute ID
1 – 2	0003h	Flags – Pre-fail type, attribute is updated during normal operation
3		Attribute value – the value returned here is the percentage of spare blocks remaining summed over all flash chips
4		Attribute value – worse value
5 – 7		Sum of initial number of spare blocks over all flash chips
8 – 10		Sum of current number of spare blocks over all flash chips
11	00h	Reserved

This attribute is used for the SMART Return Status command. If the attribute value is less than a preset threshold determined during at factory low level format process, the SMART Return Status will indicate a threshold exceeded condition.

4.3.2.   Spare Block Count Worse Chip Attribute

This attribute gives information about the spare blocks in the flash chip with the lowest current number of spare blocks. The data structure of this attribute is as follows:

Offset	Value	Description
0	213	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – this value is fixed at 100
4	64h	Attribute value – this value is fixed at 100
5 – 7		Initial number of spare blocks in the flash chip with the lowest current number of spare blocks
8 – 10		Current number of spare blocks in the flash chip with the lowest current number of spare blocks
11	00h	Reserved

4.3.3.   Erase Count Attribute

This attribute gives information about the number of flash block erases performed. The data structure of this attribute is as follows:

Offset	Value	Description
0	229	Attribute ID
1 – 2	000Xh	Flags – Pre-fail or Advisory type, attribute is updated during normal operation
3		Attribute value – the value returned here is an estimation of the percentage of card life remaining based on the number of flash block erases that have occurred and the target number of erases per flash block.
4		Attribute value – worse value
5 – 10		Estimated total number of block erases
11	00h	Reserved

This attribute is used for the SMART Return Status command. If the attribute value is less than a preset threshold determined during at factory low level format process, the SMART Return Status will indicate a threshold exceeded condition.

The target number of erases is set during factory low level format time. The attribute flag – Pre-fail or Advisory, is also set at that time.

4.3.4.   Total ECC Error Attribute

This attribute gives information about the total number of ECC errors on flash read commands. The data structure of this attribute is as follows:

Offset	Value	Description
0	203	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 8		Total number of ECC errors, correctable and uncorrectable
9 – 10		--
11	00h	Reserved

4.3.5.   Correctable ECC Error Attribute

This attribute gives information about the total number of correctable ECC errors on flash read commands. The data structure of this attribute is as follows:

Offset	Value	Description
0	204	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 8		Total number of correctable ECC errors
9 – 10		--
11	00h	Reserved

4.3.6. UDMA CRC Error Attribute

This attribute gives information about the total number of UDMA CRC errors on flash read commands. The data structure of this attribute is as follows:

Offset	Value	Description
0	199	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 8		Total number of UDMA CRC errors
9 – 10		--
11	00h	Reserved

4.3.7. Total Number of Reads Attribute

This attribute gives information about the total number of flash read commands. The data structure of this attribute is as follows:

Offset	Value	Description
0	232	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 10		Total number of flash read commands
11	00h	Reserved

4.3.8. Power On Count Attribute

This attribute gives information about the total number of power on cycles. The data structure of this attribute is as follows:

Offset	Value	Description
0	12	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 8		Total number of power on cycles
9 – 10		--
11	00h	Reserved

4.3.9. Total LBAs Written Attribute

This attribute gives information about the total amount of data written in units of 32MB. The data structure of this attribute is as follows:

Offset	Value	Description
0	241	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 10		Total number of LBAs written, divided by 32768
11	00h	Reserved

4.3.10. Total LBAs Read Attribute

This attribute gives information about the total amount of LBAs read in units of 32MB. The data structure of this attribute is as follows:

Offset	Value	Description
0	242	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 10		Total number of LBAs read, divided by 32768
11	00h	Reserved

4.3.11. Anchor Block Status Attribute

This attribute gives information about the total number time the Anchor block has been re-written, either by a repair operation or by firmware updates. The data structure of this attribute is as follows:

Offset	Value	Description
0	214	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3	64h	Attribute value – fixed at 100
4	64h	Attribute value – fixed at 100
5 – 8		Anchor block write count
9 – 10		--
11	00h	Reserved

4.3.12.   TRIM Status Attribute

This attribute gives information about the percentage of card capacity that is in trimmed state. The range is from 0 to 99. The data structure of this attribute is as follows:

Offset	Value	Description
0	215	Attribute ID
1 – 2	0002h	Flags – Advisory type, attribute is updated during normal operation
3		Attribute value
4	01h	Attribute value – fixed at 01h
5 – 10		--
11	00h	Reserved

4.4. SMART Read Attribute Threshold

For this command to take effect, the following signature bytes must be loaded:

Cylinder Low – 4Fh

Cylinder High – C2h

This command returns one sector of SMART attribute thresholds information. The format of the returned data is as follows:

Offset	Value	Description
0 – 1	0010h	SMART structure version
2 – 361		Attribute entries 1 to 30 (12 bytes each)
362 - 379	00h	Reserved
380 - 510	00h	--
511		Data structure checksum

The SMART attribute threshold entries are as follows:

4.4.1.   Spare Block Count Attribute Threshold

Offset	Value	Description
0	196	Attribute ID
1		Spare block count attribute threshold defined during low level format
2 - 11	00h	Reserved

4.4.2.   Spare Block Count Worst Chip Attribute Threshold

Offset	Value	Description
0	213	Attribute ID

Offset	Value	Description
1	00h	None defined
2 - 11	00h	Reserved

4.4.3.   Erase Count Attribute Threshold

Offset	Value	Description
0	229	Attribute ID
1		Erase count attribute threshold defined during low level format
2 - 11	00h	Reserved

4.4.4.   Total ECC Errors Attribute Threshold

Offset	Value	Description
0	203	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.5.   Correctable ECC Errors Attribute Threshold

Offset	Value	Description
0	204	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.6.   UDMA CRC Errors Attribute Threshold

Offset	Value	Description
0	199	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.7.   Total Number of Reads Attribute Threshold

Offset	Value	Description
0	232	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.8. Power On Count Attribute Threshold

Offset	Value	Description
0	12	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.9. Total LBA Written Attribute Threshold

Offset	Value	Description
0	241	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.10. Total LBA Read Attribute Threshold

Offset	Value	Description
0	242	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.11. Anchor Block Status Attribute Threshold

Offset	Value	Description
0	214	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.4.12. TRIM Status Attribute Threshold

Offset	Value	Description
0	215	Attribute ID
1	00h	None defined
2 - 11	00h	Reserved

4.5. SMART Return Status

For this command to take effect, the following signature bytes must be loaded:

Cylinder Low – 4Fh

Cylinder High – C2h

This commands checks the health of the device. If either the Spare Block Count or the Erase Count attribute exceeded the factory preset threshold, signature values will be returned in the Cylinder Low/High registers as follows:

Cylinder Low – F4h

Cylinder High – 2Ch

If the thresholds are not exceeded, the Cylinder Low/High registers retains the initially loaded 4Fh/C2h values.

Appendix A. Ordering Information

A.1. UFD

Model KU**XRY**-300

> Where **X** is drive capacities:
> 512M ---------------- 512MB
>   1G ---------------- 1GB
>   2G ---------------- 2GB
>   4G ---------------- 4GB
>   8G ---------------- 8GB
> 16G -------------- 16GB
> 32G -------------- 32GB
>
> Where **Y** is temperature grade:
> Blank -------------- standard temp.
> I --------------------- extended temp.
>
> Example:
>
> (1) 2GB standard grade UFD --------------------------------- KU2GR-300
> (2) 1GB extended grade UFD -------------------------------- KU1GRI-300

Appendix B.Technical Support Services

B.1.Direct Cactus Technical Support

Cactus Technologies Limited

Suite C, 15/F, Capital Trade Center

62 Tsun Yip Street, Kwun Tong

Kowloon, Hong Kong

Tel: +852-27972261

Fax: +852-27973777

Email: tech@cactus-tech.com

Appendix C.Cactus Worldwide Sales Offices

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Suite C, 15/F, Capital Trade Center

62 Tsun Yip Street, Kwun Tong

Kowloon, Hong Kong

Tel: +852-27972277

Fax: +852-27973777

Email: sales@cactus-tech.com

US Office:

Cactus USA

3112 Windsor Road , Suite A356

Austin, Texas 78703

Tel: (512) 775 0746

Email: americas@cactus-tech.com

Appendix D.Limited Warranty

I. WARRANTY STATEMENT

Cactus Technologies® warrants its Industrial Grade products only to be free of any defects in materials or workmanship that would prevent them from functioning properly for five years from the date of purchase or when rated TBW is exceeded, whichever occurs sooner. This express warranty is extended by Cactus Technologies® Limited

II. GENERAL PROVISIONS

This warranty sets forth the full extent of Cactus Technologies®' responsibilities regarding the Cactus Technologies® Industrial Grade CompactFlash Card. In satisfaction of its obligations hereunder, Cactus Technologies®, at its sole option, will either 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.

Cactus Technologies®' 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, Cactus Technologies® will have the option of repairing or replacing the defective product, if the following conditions are met:

> A. The defective product is returned to Cactus Technologies® for failure analysis as soon as possible after the failure occurs.
>
> B. An incident drive filled out by the user, explaining the conditions of usage and the nature of the failure, accompanies each returned defective product.
>
> C. 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 Cactus Technologies® 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.

Cactus Technologies® 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.

Cactus Technologies® 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, Cactus Technologies® 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 Cactus Technologies®' warranty procedure, defective product should be returned only with prior authorization from Cactus Technologies® Limited. Please contact Cactus Technologies® Customer Service department with the following information: product model number and description, nature of defect, conditions of use, proof of purchase and purchase date. If approved, Cactus Technologies® will issue a Return Material Authorization or Product Repair Authorization number. Ship the defective product to:

Cactus Technologies Limited

Suite C, 15/F, Capital Trade Center

62 Tsun Yip Street, Kwun Tong

Kowloon, Hong Kong