



**Industrial 3D TLC
-290S series CFast Card
Product Manual**

December 23, 2024

www.cactus-tech.com

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1.Introduction to Cactus Technologies® Industrial 3D TLC -290S Series CFast Products

Features:

- Solid state design with no moving parts
- Available in industry standard CFast Type 1 form factor
- Capacities from 64GB to 1TB
- Compliant with Serial ATA 3.4 specifications
- ATA-8 ACS2 command set compatible
- Supports Serial ATA Generation I/II transfer rate of 1.5/3.0/6.0 Gbps
- Supports ATA SMART Feature Set
- Supports ATA Security Feature Set
- Supports Data Set Management (TRIM)
- Supports SATA Partial/Slumber/DevSLP
- Advanced LDPC ECC
- Enhanced error correction, < 1 error in 10^{14} bits read
- Voltage support: 3.3V±5%

Cactus Technologies® Industrial 3D TLC CFast card is a high capacity solid-state flash memory product that complies with the Serial ATA 3.4 standard and is functionally compatible with a SATA hard disk drive. Cactus Technologies® Industrial 3D TLC CFast card provides up to 1TB of formatted storage capacity.

Cactus Technologies® Industrial 3D TLC CFast card product uses high quality Industrial Grade 3D TLC NAND flash memory (gTLC) from Kioxia 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. The controller's firmware is upgradeable, thus allowing feature enhancements and firmware updates while keeping the BOM stable.

1.1. Supported Standards

Cactus Technologies® Industrial 3D TLC CFast card is fully compatible with the following specification:

- ATA 8/ACS2 Specification published by ANSI
- Serial ATA 3.4 Specification published by the Serial ATA International Organization

1.2. Product Features

Cactus Technologies® Industrial 3D TLC CFast card contains a high level, intelligent controller. This intelligent controller provides many capabilities including the following:

- Standard ATA register and command set (same as found on most magnetic disk drives).
- Manages details of erasing and programming 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 3D TLC CFast card appears as a standard SATA disk drive to the host system. The drive utilizes a 512-byte sector which is the same as that in an IDE magnetic disk drive. To write or read a sector (or multiple sectors), the host computer software simply issues an ATA Read or Write command to the drive as per the SATA protocol. The host software then waits for the command 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 3D TLC CFast card products today will continue to work with future Cactus Technologies® Industrial 3D TLC CFast cards built with new flash technology without having to update or change host software.

1.2.2. Defect and Error Management

Cactus Technologies® Industrial 3D TLC CFast card 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 3D TLC CFast card 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 3D TLC CFast cards unparalleled reliability.

1.2.3. Power Supply Requirements

Cactus Technologies® Industrial 3D TLC CFast card operates at a voltage range of 3.3 volts $\pm$ 5%.

2.Product Specifications

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 3D TLC CFast card
Temperature	Operating:	0° C to +70° C (Standard) -40° C to +85° C (extended)
Humidity	Operating & Non-Operating:	8% to 95%, non-condensing
Vibration	Operating & Non-Operating:	20G, MIL-STD-883G Method 2005.2, Condition A
Shock	Operating & Non-Operating:	3,000 G, MIL-STD-883G 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 3D TLC CFast card
DC Input Voltage (VCC) 100 mV max. ripple (p-p)		3.3V $\pm$ 5%
(Maximum Average Value) See Notes.	Idle: Reading: Writing:	60 mA 315 mA 305 mA

NOTES: All values quoted are typical at ambient temperature and nominal 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 assume the drive controller is in the default (i.e., fastest) mode.

Table 2-3. Performance

	64GB	128GB	256GB	512GB	1TB
Read Transfer Rate	285MB/s	540MB/s	545MB/s	545MB/s	545MB/s
Write Transfer Rate	230MB/s	465MB/s	510MB/s	510MB/s	500MB/s

2.4. System Reliability

Table 2-4. Reliability

Endurance (estimated TBW):	
64GB	192TB
128GB	384TB
256GB	768TB
512GB	1536TB
1TB	3072TB

Note: estimated TBW assumes workload consisting of mostly large block writes; data-retention effects are not considered.

2.5. Physical Specifications

The following sections provide the physical specifications for Cactus Technologies® Industrial 3D TLC CFast card products.

2.5.1. 290S CFast card Physical Specifications

Table 1: Type I CFast Card Physical Specifications

Length:	36.4 ± 0.15 mm (1.433 ± .006 in.)
Width:	42.80 ± 0.10 mm (1.685 ± .004 in.)
Thickness Including Label Area:	3.6 mm maximum (.1418 in maximum).

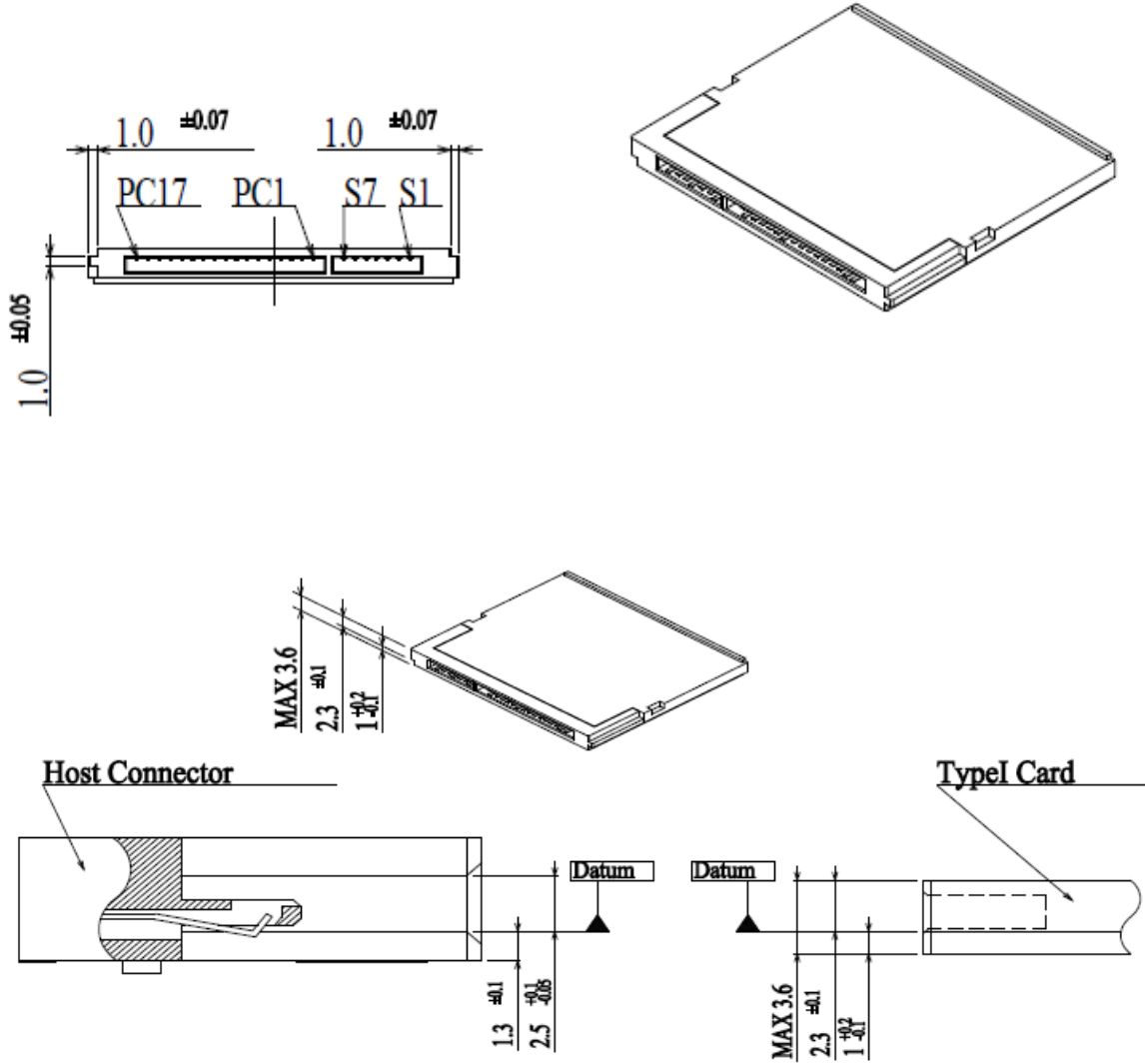


Table 3-5. CFast card Pin Assignments and Pin Type

Number	Segment	Name	Type	Description	Mating Sequence
S1	SATA	SGND	Signal GND	Ground for signal integrity	1 st
S2	SATA	A+	SATA Differential	Signal Pair A	2 nd
S3	SATA	A-	SATA Differential		2 nd
S4	SATA	SGND	Signal GND	Ground for signal integrity	1 st
S5	SATA	B-	SATA Differential	Signal Pair B	2 nd
S6	SATA	B+	SATA Differential		2 nd
S7	SATA	SGND	Signal GND	Ground for signal integrity	1 st
	Key				
	Key				
PC1	PWR/CTL	CDI	Input	Card Detect In	3 rd
PC2	PWR/CTL	PGND	Device GND		1 st
PC3	PWR/CTL	DEVSLP	DEVSLP Card Input	DevSleep Power State Enable	2 nd
PC4	PWR/CTL			Reserved ¹	2 nd
PC5	PWR/CTL			Reserved ¹	2 nd
PC6	PWR/CTL			Reserved ¹	2 nd
PC7	PWR/CTL	PGND	Device GND		1 st
PC8	PWR/CTL	LED1	LED Output	LED Output ¹	2 nd
PC9	PWR/CTL	LED2	LED Output	LED Output ¹	2 nd
PC10	PWR/CTL			Reserved ¹	2 nd
PC11	PWR/CTL			Reserved	2 nd
PC12	PWR/CTL	IFDet	GND	Card output, connect to PGND on card ²	2 nd
PC13	PWR/CTL	PWR	3.3V	Device Power (3.3V)	2 nd
PC14	PWR/CTL	PWR	3.3V	Device Power (3.3V)	2 nd
PC15	PWR/CTL	PGND	Device GND	Device Ground	1 st
PC16	PWR/CTL	PGND	Device GND	Device Ground	1 st
PC17	PWR/CTL	CDO	Output	Card Detect Out	3 rd 3

Notes:

¹ The functionality of these pins is deprecated, and is included to provide backwards compatibility with CFast V1.1. The CFA plans to use these pins differently in the future. These pins should not be used by devices that are compliant with the CFast specification V2.0.

² IFDet shall be connected to PGND on all CFast V2.0 compliant devices.

³ The connection of any pin is not reliable until CDO signals that the card is fully inserted.

3.2. Electrical Specifications

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

$$V_{cc} = 3.3V \pm 5\%$$

$$T_a = -40^{\circ}\text{C to } 85^{\circ}\text{C}$$

3.2.1. Absolute Maximum Ratings

Parameter	Symbol	MIN	MAX	Units
Storage Temperature	T _s	-55	+100	°C
Operating Temperature	T _A	-40	+85	°C
V _{cc} with respect to GND	V _{cc}	-0.3	3.6	V

3.2.2. DC Characteristics

Parameter	Symbol	MIN	MAX	Units
Input Voltage	V _{in}	-0.5	V _{cc} + 0.5	V
Output Voltage	V _{out}	-0.3	V _{cc} + 0.3	V
Input Leakage Current	I _{Li}	-10	10	uA
Output Leakage Current	I _{Lo}	-10	10	uA
Input/Output Capacitance	C _i /C _o		10	pF
Operating Current	I _{cc}			mA
Idle			60	
Active			315	

3.2.3. AC Characteristics

Cactus Technologies® CFast card products conforms to all AC timing requirements as specified in the CFA specifications. Please refer to that document for details of AC timing for all operation modes of the device.

4.ATA Drive Register Set Definition and Protocol

The communication to or from the CFast card is done using FIS. Legacy ATA protocol is supported by using the legacy mode defined in the SATA specifications. In this mode, the FIS has defined fields which provide all the necessary ATA task file registers for control and status information. The Serial ATA interface does not support Primary/Secondary or Master/Slave configurations. Each SATA channel supports only one SATA device, with the register selection as defined by the ATA standard.

4.1. ATA Task File Definitions

The following sections describes the usage of the ATA task file registers. Note that the Alternate Status Register of legacy ATA is not defined for SATA drives.

4.1.1. Data Register

The Data Register is a 16-bit register, and it is used to transfer data blocks between the CFast card data buffer and the Host.

4.1.2. Error Register

This register contains additional information about the source of an error when an error is indicated in bit 0 of the Status register. The bits are defined as follows:

D7	D6	D5	D4	D3	D2	D1	D0
BBK	UNC	0	IDNF	0	ABRT	0	AMNF

- Bit 7 (BBK)** This bit is set when a Bad Block is detected.
- Bit 6 (UNC)** This bit is set when an Uncorrectable Error is encountered.
- Bit 5** This bit is 0.
- Bit 4 (IDNF)** The requested sector ID is in error or cannot be found.
- Bit 3** This bit is 0.
- Bit 2 (Abort)** This bit is set if the command has been aborted because of a status condition: (Not Ready, Write Fault, etc.) or when an invalid command has been issued.
- Bit 1** This bit is 0.
- Bit 0 (AMNF)** This bit is set in case of a general error.

4.1.3. Feature Register

This register provides information regarding features of the CFast card that the host can utilize.

4.1.4. Sector Count Register

This register contains the number of sectors of data requested to be transferred on a read or write operation between the host and the CFast card. If the value in this register is zero, a count of 256 sectors is specified. If the command was successful, this register is zero at command completion. If not successfully completed, the register contains the number of sectors that need to be transferred in order to complete the request.

4.1.5. Sector Number (LBA 7-0) Register

This register contains the starting sector number or bits 7-0 of the Logical Block Address (LBA) for any CFast card data access for the subsequent command.

4.1.6. Cylinder Low (LBA 15-8) Register

This register contains the low order 8 bits of the starting cylinder address or bits 15-8 of the Logical Block Address.

4.1.7. Cylinder High (LBA 23-16) Register

This register contains the high order bits of the starting cylinder address or bits 23-16 of the Logical Block Address.

4.1.8. Drive/Head (LBA 27-24) Register

The Drive/Head register is used to select the drive and head. It is also used to select LBA addressing instead of cylinder/head/sector addressing. The bits are defined as follows:

D7	D6	D5	D4	D3	D2	D1	D0
1	LBA	1	DRV	HS3	HS2	HS1	HS0

Bit 7 This bit is set to 1.

Bit 6 LBA is a flag to select either Cylinder/Head/Sector (CHS) or Logical Block Address Mode (LBA). When LBA=0, Cylinder/Head/Sector mode is selected. When LBA=1, Logical Block Address is selected. In Logical Block Mode, the Logical Block Address is interpreted as follows:
 LBA07-LBA00: Sector Number Register D7-D0.
 LBA15-LBA08: Cylinder Low Register D7-D0.
 LBA23-LBA16: Cylinder High Register D7-D0.
 LBA27-LBA24: Drive/Head Register bits HS3-HS0.

Bit 5 This bit is set to 1.

Bit 4 (DRV) DRV is the drive number. This should always be set to 0.

Bit 3 (HS3) When operating in the Cylinder, Head, Sector mode, this is bit 3 of the head number. It is Bit 27 in the Logical Block Address mode.

Bit 2 (HS2) When operating in the Cylinder, Head, Sector mode, this is bit 2 of the head number. It is Bit 26 in the Logical Block Address mode.

Bit 1 (HS1) When operating in the Cylinder, Head, Sector mode, this is bit 1 of the head number. It is Bit 25 in the Logical Block Address mode.

Bit 0 (HS0) When operating in the Cylinder, Head, Sector mode, this is bit 0 of the head number. It is Bit 24 in the Logical Block Address mode.

4.1.9. Status Registers

These registers return the status when read by the host. Reading the Status register does clear a pending interrupt while reading the Auxiliary Status register does not. The meaning of the status bits are described as follows:

D7	D6	D5	D4	D3	D2	D1	D0
BUSY	RDY	DWF	DSC	DRQ	CORR	0	ERR

- Bit 7 (BUSY)** The busy bit is set when the device has access to the command buffer and registers and the host is locked out from accessing the command register and buffer. No other bits in this register are valid when this bit is set to a 1.
- Bit 6 (RDY)** RDY indicates whether the device is capable of performing operations requested by the host. This bit is cleared at power up and remains cleared until the device is ready to accept a command.
- Bit 5 (DWF)** This bit, if set, indicates a write fault has occurred.
- Bit 4 (DSC)** This bit is set when the device is ready.
- Bit 3 (DRQ)** The Data Request is set when the device requires that information be transferred either to or from the host through the Data register.
- Bit 2 (CORR)** This bit is set when a Correctable data error has been encountered and the data has been corrected. This condition does not terminate a multi-sector read operation.
- Bit 1 (IDX)** This bit is always set to 0.
- Bit 0 (ERR)** This bit is set when the previous command has ended in some type of error. The bits in the Error register contain additional information describing the error.

4.1.10. Device Control Register

This register is used to control the drive interrupt request and to issue an ATA soft reset to the drive. The bits are defined as follows:

D7	D6	D5	D4	D3	D2	D1	D0
HOB	X	X	X	1	SW Rst	-IEn	0

- Bit 7** This bit is used in 48-bit addressing mode. When cleared, the host can read the most recently written values of the Sector Count, Drive/Head and LBA registers. When set, the host will read the previous written values of these registers. A write to any Command block register will clear this bit.
- Bit 6** This bit is an X (Do not care).
- Bit 5** This bit is an X (Do not care).
- Bit 4** This bit is an X (Do not care).
- Bit 3** This bit is ignored by the drive.
- Bit 2 (SW Rst)** This bit is set to 1 in order to force the drive to perform an AT Disk controller Soft Reset operation. The drive remains in Reset until this bit is reset to '0'.
- Bit 1 (-IEn)** The Interrupt Enable bit enables interrupts when the bit is 0. When the bit is 1, interrupts from the drive are disabled. This bit is set to 0 at power on and Reset.
- Bit 0** This bit is ignored by the drive.

4.1.11. Drive Address Register

This register is provided for compatibility with the AT disk drive interface. It is recommended that this register not be mapped into the host's I/O space because of potential conflicts on Bit 7. The bits are defined as follows:

D7	D6	D5	D4	D3	D2	D1	D0
X	-WTG	-HS3	-HS2	-HS1	-HS0	-nDS1	-nDS0

Bit 7 This bit is unknown.

Implementation Note:

Conflicts may occur on the host data bus when this bit is provided by a Floppy Disk Controller operating at the same addresses as the CFast card. Following are some possible solutions to this problem:

1. Locate the CFast card at a non-conflicting address (i.e., Secondary address (377) when a Floppy Disk Controller is located at the Primary addresses).
2. Do not install a Floppy and a CFast card in the system at the same time.
3. Implement a socket adapter that can be programmed to (conditionally) tri-state D7 of I/O address 3F7/377 when a CFast card product is installed and conversely to tri-state D6-D0 of I/O address 3F7/377 when a floppy controller is installed.
4. Do not use the CFast card's Drive Address register. This may be accomplished by either a) If possible, program the host adapter to enable only I/O addresses 1F0-1F7, 3F6 (or 170-177, 176) to the CFast card or b) if provided use an additional Primary/Secondary configuration in the CFast card that does not respond to accesses to I/O locations 3F7 and 377. With either of these implementations, the host software must not attempt to use information in the Drive Address Register.

Bit 6 (-WTG) This bit is 0 when a write operation is in progress, otherwise, it is 1.

Bit 5 (-HS3) This bit is the negation of bit 3 in the Drive/Head register.

Bit 4 (-HS2) This bit is the negation of bit 2 in the Drive/Head register.

Bit 3 (-HS1) This bit is the negation of bit 1 in the Drive/Head register.

Bit 2 (-HS0) This bit is the negation of bit 0 in the Drive/Head register.

Bit 1 (-nDS1) This bit is 0 when drive 1 is active and selected.

Bit 0 (-nDS0) This bit is 0 when the drive 0 is active and selected.

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

Cactus Technologies® -290S Series CFast cards supports S.M.A.R.T. attribute reporting. The reported attributes are listed below.

5.1. S.M.A.R.T Attributes

The following table lists the attributes returned in bytes 2-361 of the 512-byte SMART data. Each attribute occupies 12 byte of data. Byte 0 is Attribute ID, bytes 1-2 are status flags, bytes 3-4 are reserved bytes; the table below shows the definitions of bytes 5-11:

Attribute ID	Attribute Name
01h	Raw Data Error rate
05h	Reallocated sectors count
09h	Power on hours

Attribute ID	Attribute Name
0Ch	Power cycle count
A1h	GDN
A2h	Total Erase Count
A3h	Max. P/E cycle
A4h	Average erase count
A6h	Total bad block count
A7h	CFast card protect mode
A8h	SATA PHY error count
A9h	Health (%)
ABh	Program fail count
ACh	Erase fail count
A Eh	Unexpected power loss count
AFh	ECC fail count
B5h	Unaligned access count
BBh	Uncorrectable error count
C2h	Drive temperature (°C)
C3h	Cumulative corrected ECC
C4h	Reallocation event count
C7h	UltraDMA CRC error count
CEh	Min. erase count
CFh	Max. erase count
E8h	Available reserved space
F1h	Total LBAs written (in units of GB)
F2h	Total LBAs read (in units of GB)
F9h	Total GB written to NAND (TLC)
FAh	Total GB written to NAND (SLC)

Appendix A. Ordering Information

Model KCXFI-290S

Where: X is drive capacities:

64G -----	64GB
128G -----	128GB
256G -----	256GB
512G -----	512GB
1T -----	1TB

Where: I is temperature grade

blank -----	standard
I -----	extended

Example:

- (1) 128GB CFast card ----- KC128GF-290S
- (2) 128GB CFast card extended temp. ----- KC128GFI-290S
- (3) 1TB CFast card ----- KC1TF-290S

Appendix B. Technical Support Services

B.1. Direct Cactus Technologies® Technical Support

Email: tech@cactus-tech.com

Appendix C.Cactus Technologies® Worldwide Sales Offices

Email: sales@cactus-tech.com

Email: americas@cactus-tech.com

Appendix D.Limited Warranty

I. WARRANTY STATEMENT

Cactus Technologies® warrants its Industrial 3D TLC products only to be free of any defects in materials or workmanship that would prevent them from functioning properly for two years from the date of purchase or when rated TBW is exceeded, whichever occurs first. This express warranty is extended by Cactus Technologies® Limited to customers of our products.

II. GENERAL PROVISIONS

This warranty sets forth the full extent of Cactus Technologies® responsibilities regarding the Cactus Technologies® Industrial 3D TLC Flash Storage Products. Cactus Technologies®, at its sole option, will repair, replace or refund the purchase price of the defective product. Cactus Technologies® guarantees our products meet all specifications detailed in our product manuals. Although Cactus Technologies® products are designed to withstand harsh environments and have the highest specifications in the industry, they are not warranted to never have failure and Cactus Technologies® does not warranty against incidental or consequential damages. 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 backup features.

III. WHAT THIS WARRANTY COVERS

For products found to be defective, Cactus Technologies® will have the option of repairing, replacing or refunding the purchase price 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 card 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 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® Limited may 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.

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 (tech@cactus-tech.com) 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 with shipping instructions.