M.2 (S80)

InnoOSR 3TO7

Total Solution For Industrial Flash Storage

Customer: _____

Customer Part Number: _____

Innodisk Part Number: _____

Innodisk Model Name: _____

Date: _____

Innodisk Approver	Customer Approver

Table of contents

                                      V1.3   TPS, Dec., 2022

REVISION HISTORY

Revision	Description	Date
V1.0	Official Release	May, 2021
V1.1	Correct Part Number Naming Rule Add InnoOSR Demo Cable Information	July, 2021
V1.2	Remove InnoOSR Demo Cable Information	Aug., 2021
V1.3	Add 112 Layers 3D TLC	Dec., 2022

List of Tables

V1.3

List of Figures

1. Product Overview

1.1 Introduction of Innodisk M.2 (S80) 3TO7

Innodisk 2.5" SATA SSD 3TO7 provides high capacity flash memory Solid State Drive (SSD) that electrically complies with Serial ATA (SATA) standard supporting up to SATA III standard (6.0Gb/s) speed and capable of achieving excellent performance with its 4 channels 4CE Innodisk ID301 controller. Besides outstanding balance of performance, rich form factors, capacity and customization flexibility, the key feature of InnoOSR family is the single-device, Firmware LBA level OS & Data back-up capability which enables on-site recovery of operating system by simple procedure such as GPIO triggering or application commands.

CAUTION **TRIM must be enabled.**

TRIM enables SSD's controller to skip invalid data instead of moving. It can free up significant amount of resources, extends the lifespan of SSD by reducing erase, and write cycles on the SSD. Innodisk's handling of garbage collection along with TRIM command improves write performance on SSDs.

1.2 Product View and Models

Innodisk M.2 (S80) 3TO7 is available in following capacities with 3D TLC flash ICs.

M.2 (S80) 3TO7 64GB

M.2 (S80) 3TO7 128GB

M.2 (S80) 3TO7 256GB

M.2 (S80) 3TO7 512GB
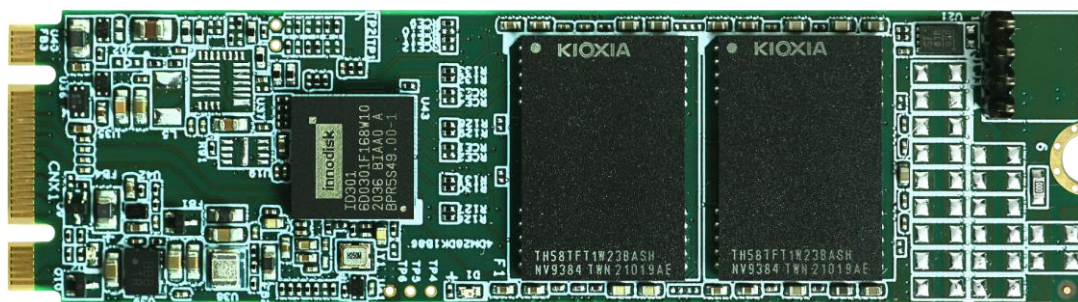
M.2 (S80) 3TO7 1TB

M.2 (S80) 3TO7 2TB

Figure 1: Innodisk M.2 (S80) 3TO7 (type 2280)

1.3 SATA Interface

Innodisk2.5" SATA SSD 3TO7 supports SATA III(6.0Gb/s) interface, and compliant with SATA I (1.5Gb/s) and SATA II(3.0Gb/s).

2. Product Specifications

2.1 Capacity and Device Parameters

M.2 (S80) 3TO7 device parameters are shown in Table 1.

Table 1: Device parameters

Capacity	P/N	OS back-up capacity (GB)	LBA	User Capacity(GB)
64GB	DUM28-64GDK1E*[1]*[2]*[3]F10G	10	96259888	45.9
	DUM28-64GDK1E*[1]*[2]*[3]F20G	20	75288368	35.9
128GB	DUM28-A28DK1%*[1]*[2]*[3]F10G	10	213470128	101.7
	DUM28-A28DK1%*[1]*[2]*[3]F20G	20	192498608	91.7
	DUM28-A28DK1%*[1]*[2]*[3]F30G	30	171527088	81.7
256GB	DUM28-B56DK1E*[1]*[2]*[3]F10G	10	447890608	213.5
	DUM28-B56DK1E*[1]*[2]*[3]F20G	20	426919088	203.5
	DUM28-B56DK1%*[1]*[2]*[3]F30G	30	405947568	193.5
	DUM28-B56DK1K*[1]*[2]*[3]F60G	60	343033008	163.5
	DUM28-B56DK1K*[1]*[2]*[3]F90G	90	280118448	133.5
512GB	DUM28-C12DK1E*[1]*[2]*[3]F10G	10	916731568	437.1
	DUM28-C12DK1E*[1]*[2]*[3]F20G	20	895760048	427.1
	DUM28-C12DK1%*[1]*[2]*[3]F30G	30	874788528	417.1
	DUM28-C12DK1K*[1]*[2]*[3]F60G	60	811873968	387.1
	DUM28-C12DK1K*[1]*[2]*[3]F90G	90	748959408	357.1
1TB	DUM28-01TDK1E*[1]*[2]*[3]F10G	10	1854410928	884.2
	DUM28-01TDK1E*[1]*[2]*[3]F20G	20	1833439408	874.2
	DUM28-01TDK1%*[1]*[2]*[3]F30G	30	1812467888	864.2
	DUM28-01TDK1K*[1]*[2]*[3]F60G	60	1749555888	834.2
	DUM28-01TDK1K*[1]*[2]*[3]F90G	90	1686641328	804.2
2TB	DUM28-02TDK1K*[1]*[2]*[3]F30G	30	3687834288	1758.4
	DUM28-02TDK1K*[1]*[2]*[3]F60G	60	3624919728	1728.4
	DUM28-02TDK1K*[1]*[2]*[3]F90G	90	3562005168	1698.4
Note	%. E: 64 layers 3D TLC; K: 112 layers 3D TLC *[1]: C: standard temperature (0'C to 70'C); W: wide temperature (-40'C to 85'C) *[2]: A: Horizontal pin headers placement；B: Vertical pin headers placement *[3]: S: Single-channel; D: Dual-channels; Q: Quad-Channels			

Note: User capacities vary depend on size of hidden OS back-up area

2.2 Performance

Burst Transfer Rate: 6.0Gbps

Table 2: Performance- 64 Layers 3D TLC

Capacity	Unit	64GB	128GB	256GB	512GB	1TB
Sequential* Read (max.)	MB/s	350	560	560	560	560
Sequential* Write (max.)		70	140	290	330	340
4KB Random** Read (Q32T1)	IOPS	22,000	44,000	76,000	80,000	81,000
4KB Random** Write (Q32T1)		18,300	36,000	67,000	73,500	74,000

Note: * Performance results are based on CrystalDiskMark 5.1.2 with file size 1000MB for reference only.

Table 3: Performance- 112 Layers 3D TLC

Capacity	Unit	128GB	256GB	512GB	1TB	2TB
Sequential* Read (max.)	MB/s	440	550	550	550	550
Sequential* Write (max.)		290	480	500	500	470
4KB Random** Read (Q32T1)	IOPS	43,000	79,000	80,000	80,000	80,000
4KB Random** Write (Q32T1)		21,000	50,000	69,000	70,000	71,000

Note: * Performance results are measured in Room Temperature with Out-of-Box devices and may vary depending on overall system setup.

Note: ** Performance results are based on CrystalDiskMark 6.0.2 with typical tolerances for range from 1% to 10%. Unit of 4KB items is I.O.P.S.

2.3 Electrical Specifications

2.3.1 Power Requirement

Table 4: Innodisk M.2 (S80) 3TO7 Power Requirement

Item	Symbol	Rating	Unit
Input voltage	V_{IN}	+3.3 DC +- 5%	V

2.3.2 Power Consumption

Table 5: Power Consumption

Mode	Power Consumption (W)
Read(RMA)	1.7
Write(RMA)	2.6
Idle(RMA)	1.0
Boot-Up Peak	4.1

* Target: M.2 (S80) 3TO7

2.4 Environmental Specifications

2.4.1 Temperature Ranges

Table 6: Temperature range for M.2 (S80) 3TO7

Temperature	Range
Operating	Standard Grade: 0°C to +70°C
	Industrial Grade:-40°C to +85°C
Storage	-40°C to +85°C

2.4.2 Humidity

Relative Humidity: 10-95%, non-condensing

2.4.3 Shock and Vibration

Table 7: Shock/Vibration Testing for M.2 (S80) 3TO7

Reliability	Test Conditions	Reference Standards
Vibration	7 Hz to 2K Hz, 20G, 3 axes	IEC 68-2-6
Mechanical Shock	Duration: 0.5ms, 1500 G, 3 axes	IEC 68-2-27

2.4.4 Mean Time between Failures (MTBF)

Table 7 summarizes the MTBF prediction results for various M.2 (S80) 3TO7 configurations. The analysis was performed using a RAM Commander™ failure rate prediction.

- **Failure Rate**: The total number of failures within an item population, divided by the total number of life units expended by that population, during a particular measurement interval under stated condition.

- **Mean Time between Failures (MTBF)**: A basic measure of reliability for repairable items: The mean number of life units during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions.

Table 8: M.2 (S80) 3TO7 MTBF

Product	Condition	MTBF (Hours)
Innodisk M.2 (S80) 3TO7	Telcordia SR-332 GB, 25°C	>3,000,000

2.5 CE and FCC Compatibility

M.2 (S80) 3TO7 conforms to CE and FCC requirements.

2.6 RoHS Compliance

M.2 (S80) 3TO7 is fully compliant with RoHS directive.

2.7 Reliability

Table 9: M.2 (S80) 3TO7 TBW

Parameter	Value	
Read Cycles	Unlimited Read Cycles	
Flash endurance	3,000 P/E cycles	
Wear-Leveling Algorithm	Support	
Bad Blocks Management	Support	
Error Correct Code	Support	
TBW* (Total Bytes Written) Unit: TB		
Capacity	**Sequential workload**	**Client workload**
64GB	168.6	75
128GB	337.2	150
256GB	674.4	250
512GB	1348.8	500
1TB	2697.6	1000
2TB	5395.2	2000

* Note:

1. Sequential: Mainly sequential write, tested by Vdbench.

2. Client: Follow JESD218 Test method and JESD219A Workload, tested by ULINK. (The capacity lower than 64GB client workload is not specified in JEDEC219A, the values are estimated.)

3. Based on out-of-box performance.

2.8 Transfer Mode

M.2 (S80) 3TO7 support following transfer mode:

Serial ATA III 6.0Gbps

Serial ATA II 3.0Gbps

Serial ATA I 1.5Gbps

2.9 Pin Assignment

Innodisk M.2 (S80) 3TO7 uses a standard SATA pin-out. See Table 10 for M.2 (S80) 3TO7 pin assignment.

Table 10: Innodisk M.2 (S80) 3TO7 Pin Assignment

Signal Name	Pin #	Pin #	Signal Name
		75	GND
3.3V	74	73	GND
3.3V	72	71	GND
3.3V	70	69	GND
NC	68	67	NC
Notch	66	65	Notch
Notch	64	63	Notch
Notch	62	61	Notch
Notch	60	59	Notch
NC	58		
NC	56	57	GND
NC	54	55	NC
NC	52	53	NC
NC	50	51	GND
NC	48	49	RX+
NC	46	47	RX-
NC	44	45	GND
NC	42	43	TX-
NC	40	41	TX+
DEVSLP	38	39	GND
NC	36	37	NC
NC	34	35	NC
NC	32	33	GND
NC	30	31	NC
NC	28	29	NC
NC	26	27	GND
NC	24	25	NC
NC	22	23	NC
Default NC / GPIO Reserve (GPIO 17)	20	21	GND
Notch	18	19	Notch
Notch	16	17	Notch
Notch	14	15	Notch

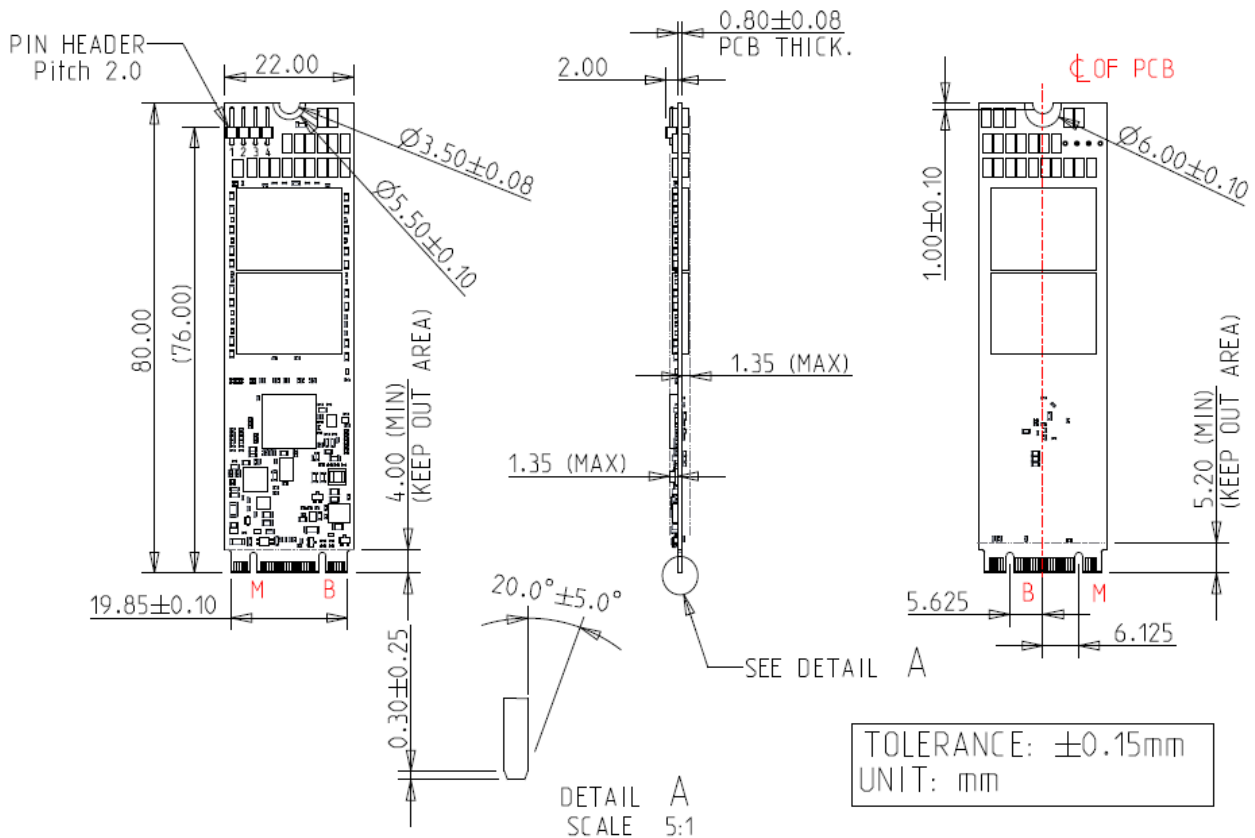| Notch	12	13	Notch
DAS/DSS	10	11	NC
Default NC / InnoOSR LED Signaling Pin (GPIO 8)	8	9	NC
Default NC / InnoOSR Recovery/Back-up Pin (GPIO 13) Option #1	6	7	NC
3.3V	4	5	NC
3.3V	2	3	Default NC / InnoOSR Recovery/Back-up Pin (GPIO 13) Option #2
		1	GND

2.10 Mechanical Dimensions

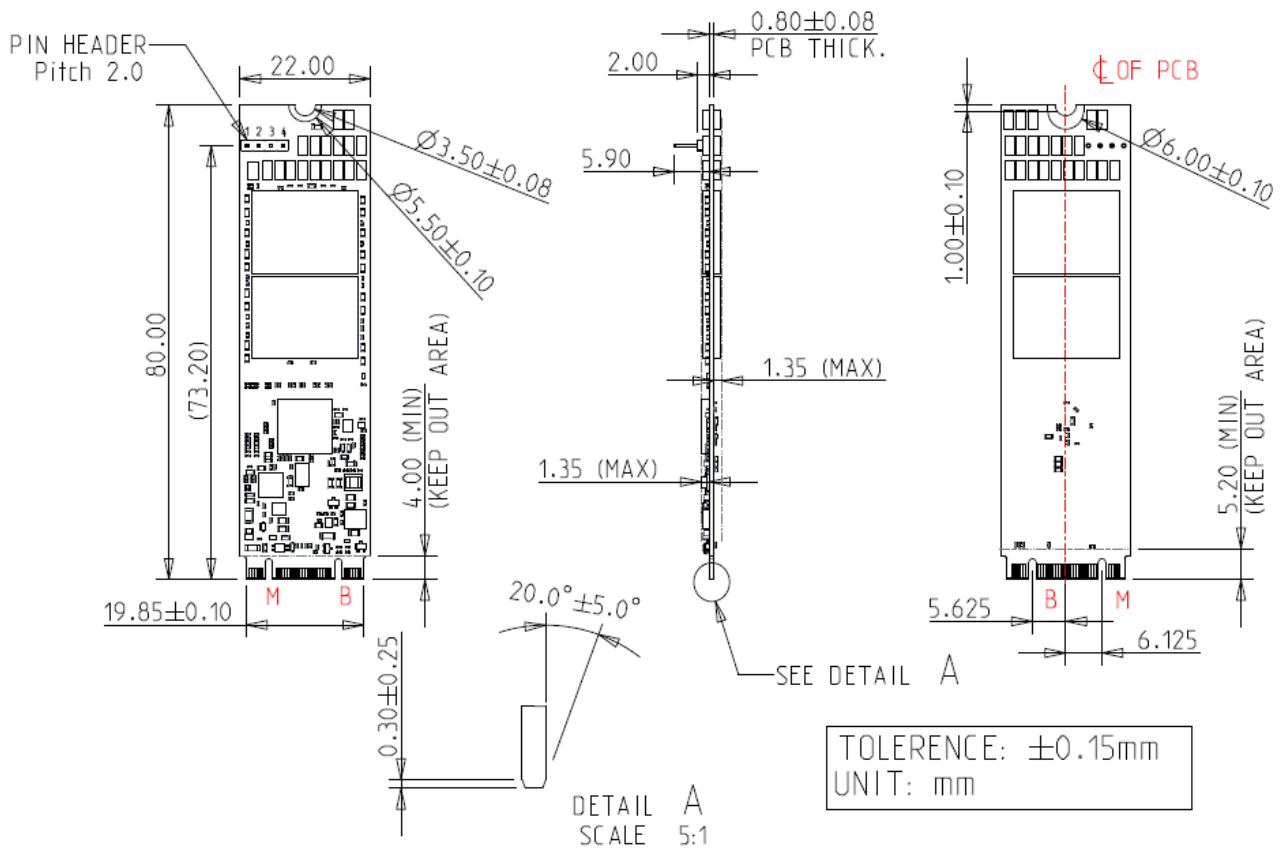**Figure 2: Innodisk M.2 (S80) 3TO7 diagram with Horizontal Pin Headers**

Figure 3: Innodisk M.2 (S80) 3TO7 diagram with Vertical Pin Headers

2.11 Assembly Weight

An Innodisk M.2 (S80) 3TO7 within flash ICs, 64GB's weight is 8 grams approximately.

2.12 Seek Time

Innodisk M.2 (S80) 3TO7 is not a magnetic rotating design. There is no seek or rotational latency required.

2.13 Hot Plug

The SSD support hot plug function and can be removed or plugged-in during operation. User has to avoid hot plugging the SSD which is configured as boot device and installed operation system.

Surprise hot plug   : The insertion of a SATA device into a backplane (combine signal and power) that has power present. The device powers up and initiates an OOB sequence.

Surprise hot removal: The removal of a SATA device from a powered backplane, without first being placed in a quiescent state.

2.14 NAND Flash Memory

Innodisk M.2 (S80) 3TO7 uses 3D Triple Level Cell (TLC) NAND flash memory, which is non-volatility, high reliability and high speed memory storage.

3. Theory of Operation

3.1 Overview

Figure 4 shows the operation of Innodisk M.2 (S80) 3TO7 from the system level, including the major hardware blocks.
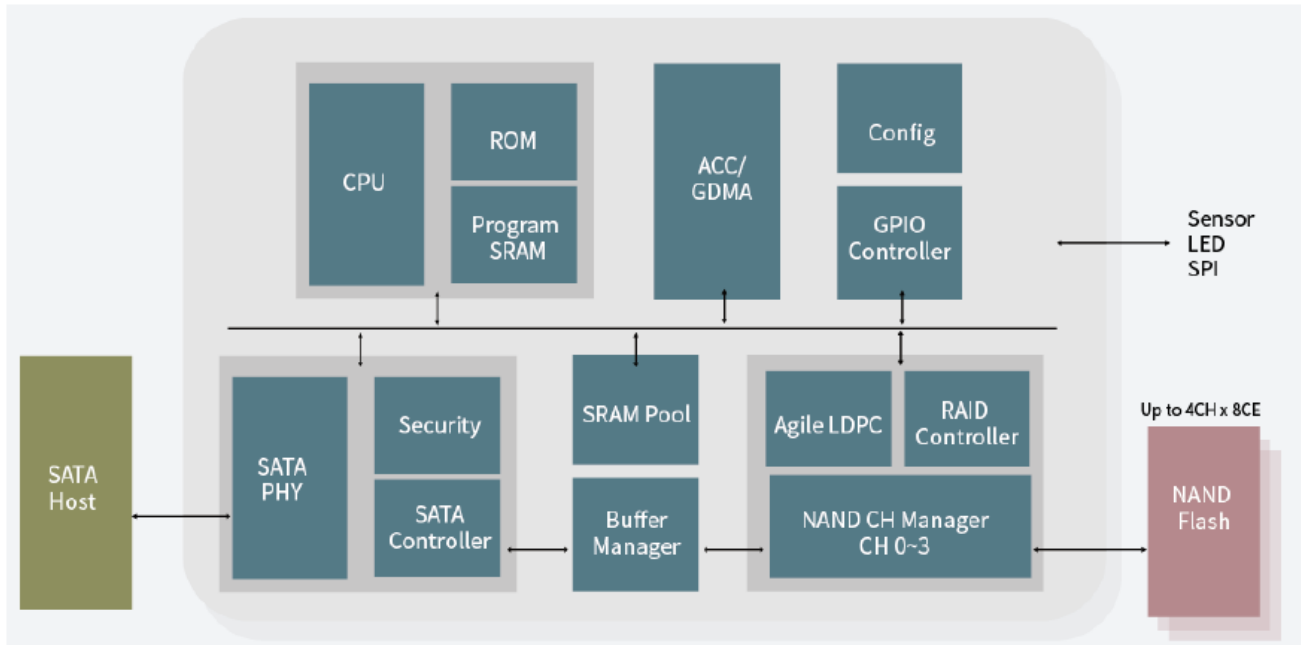

Figure 4: Innodisk M.2 (S80) 3TO7 Block Diagram

Innodisk M.2 (S80) 3TO7 integrates a SATA III controller and NAND flash memories. Communication with the host occurs through the host interface, using the standard ATA protocol. Communication with the flash device(s) occurs through the flash interface.

3.2 SATA III Controller

Innodisk M.2 (S80) 3TO7 is designed with SATA III 6.0Gbps (Gen. 3) Controller, a SATA III 6.0Gbps (Gen. 3) controller. The Serial ATA physical, link and transport layers are compliant with Serial ATA Gen 1, Gen 2 and Gen 3 specification (Gen 3 supports 1.5Gbps/3.0Gbps/6.0Gbps data rate). The controller has 2 channels for flash interface.

3.3 Error Detection and Correction

Innodisk 2.5"SATA SSD 3TO7 is designed with hardware LDPC ECC engine with hard-decision and soft-decision decoding. Low-density parity-check (LDPC) codes have excellent error correcting performance close to the Shannon limit when decoded with the belief-propagation (BP) algorithm using soft-decision information.

3.4 Wear-Leveling

Flash memory can be erased within a limited number of times. This number is called the ***erase cycle limit*** or ***write endurance limit*** and is defined by the flash array vendor. The erase cycle limit applies to each individual erase block in the flash device.

Innodisk M.2 (S80) 3TO7 uses a static wear-leveling algorithm to ensure that consecutive writes of a specific sector are not written physically to the same page/block in the flash. This spreads flash media usage evenly across all pages, thereby extending flash lifetime.

3.5 Bad Blocks Management

Bad Blocks are blocks that contain one or more invalid bits whose reliability are not guaranteed. The Bad Blocks may be presented while the SSD is shipped, or may develop during the life time of the SSD. When the Bad Blocks is detected, it will be flagged, and not be used anymore. The SSD implement Bad Blocks management, Bad Blocks replacement, Error Correct Code to avoid data error occurred. The functions will be enabled automatically to transfer data from Bad Blocks to spare blocks, and correct error bit.

3.6 iData Guard

Innodisk's iData Guard is a comprehensive data protection mechanism that functions before and after a sudden power outage to SSD. Low-power detection terminates data writing before an abnormal power-off, while table-remapping after power-on deletes corrupt data and maintains data integrity. Innodisk's iData Guard provides effective power cycling management, preventing data stored in flash from degrading with use.

3.7 Garbage Collection

Garbage collection is used to maintain data consistency and perform continual data cleansing on SSDs. It runs as a background process, freeing up valuable controller resources while sorting good data into available blocks, and deleting bad blocks. It also significantly reduces write operations to the drive, thereby increasing the SSD's speed and lifespan.

3.8 Trim

The Trim command is designed to enable the operating system to notify the SSD which pages no longer contain valid data due to erases either by the user or operating system itself. During a delete operation, the OS will mark the sectors as free for new data and send a Trim command to the SSD to mark them as not containing valid data. After that the SSD knows not to preserve the contents of the block when writing a page, resulting in less write amplification with fewer writes to the flash, higher write speed, and increased drive life.
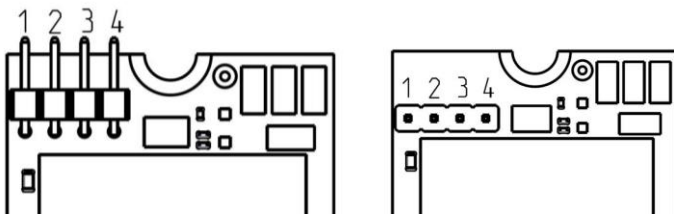
3.9 iPower Guard

iPower Guard technology is a set of preventive measures that protect the SSD in an unstable power supply environment. This comprehensive package comprises safeguards for startup and shutdown to maintain device performance and ensure data integrity.
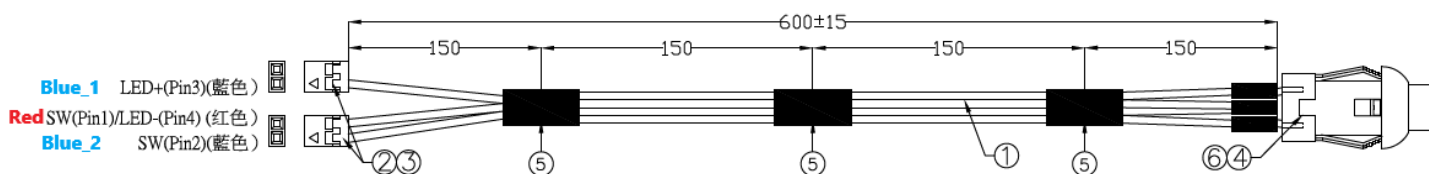
3.10 Die RAID

Die RAID is a controller function which leveraged user capacity to back up the data in NAND flash. Die RAID supported can ensure the user data in the NAND Flash more consistent in certain scenario. Innodisk M.2 (S80) 3TO7 series is default enable the Die RAID function for the industrial application.

3.11 InnoOSR Back-up/Recovery

Pin Header Number	Pin Define	Installation for Innodisk Demo Cable (PN: 7W3000000920)	Rating
1	Power	NA	3.3V ± 5%
2	GPIO Pin8, Output for InnoOSR LED indication	Blue cable_1	3.3V ± 5%
3	GND	Red	NA
4	GPIO Pin13, Input for InnoOSR Recovery Trigger, Low active	Blue cable_2	3.3V ± 5%

3.11.1 InnoOSR Back-up Implementation Process

Process of InnoOSR Back-up / Recovery can be found in Independent "Innodisk InnoOSR Implementation Process" document.

3.11.2 InnoOSR Recovery Triggering Methods

There are two methods to trigger OS recovery process listed as follows:

Button triggering: With Pin3 & 4 of the 1 x 4 pin headers located on the end of M.2 PCB shorted for more than 5 seconds, the recovery process will start. Back-up image of which this process leads to can be established by our InnoOSR software tool.

Software triggering: Our InnoOSR software tool can also trigger the recovery process. However, due to the recovery process itself essentially means covering your operating OS up, you may experience system crash and progress bar can only be read via LED signal linked directly to InnoOSR device.

4. Installation Requirements

4.1 M.2 (S80) 3TO7 Pin Directions

Figure 5: Signal Segment and Power Segment

4.2 Electrical Connections for M.2 (S80) 3TO7

A Serial ATA device may be either directly connected to a host or connected to a host through a cable. For connection via cable, the cable should be no longer than 1meter. The SATA interface has a separate connector for the power supply. Please refer to the pin description for further details.

4.3 Device Drive

No additional device drives are required. The Innodisk M.2 (S80) 3TO7 can be configured as a boot device.

5. SMART Feature Set

Innodisk 3TO7 series support the SMART command set and defines some vendor-specific data to report SMART attributes of SSD.

Table 11: SMART command

Value	Command	Value	Command
D0h	Read Data	D5h	Read Log
D1h	Read Attribute Threshold	D6h	Return Status
D2h	Enable/Disable Auto save	D8h	Enable SMART Operations
D3h	Save Attribute Values	D9h	Disable SMART Operations
D4h	Execute OFF-LINE Immediate	DAh	Return Status

5.1 SMART Attributes

Innodisk 3TO7 series SMART data attributes are listed in following table.

Table 12: SMART attribute

Attribute ID (hex)	Value	Raw Attribute Value						Rsv	Attribute Name
01	X								Read Error Rate
05	X	LSB	MSB	00	00	00	00	00	Later Bad
09	LSB	LSB	MSB	00	00	00	00	00	Power-On hours Count
0C	LSB	LSB	MSB	00	00	00	00	00	Drive Power Cycle Count
A3	X	LSB			MSB	00	00	00	Total Bad Block Count
A5	LSB	LSB			MSB	00	00	00	Max Erase count
A7	LSB	LSB			MSB	00	00	00	Avg Erase count
A9	LSB	LSB	00	00	00	00	00	00	Device Life
AA	X	LSB	MSB	00	00	00	00	00	Spare Block Count
AB	LSB	LSB	MSB	00	00	00	00	00	Program fail count
AC	LSB	LSB	MSB	00	00	00	00	00	Erase fail count
C0	LSB	LSB	MSB	00	00	00	00	00	Unexpected Power Loss Count

C2	LSB			MIN		MAX	00	00	Temperature
E5		ID 0	ID 1	ID 2	ID 3	ID 4	ID 5		Flash ID
EB			**MSB**	**LSB**	**MSB**	**LSB**	**MSB**	**LSB**	Later bad block info (**Read**/**Write**/**Erase**)
F1	00	LSB			MSB	00	00	00	Total LBA written(LBA=32MB)
F2	00	LSB			MSB	00	00	00	Total LBA read(LBA=32MB)

6. Part Number Rule

CODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	D	U	M	2	8	-	6	4	G	D	K	1	E	C	A	D	F	1	0	G	

Definition	
Code 1st (Disk)	**Code 14th (Operation Temperature)**
D : Disk	C: Standard Grade (0°C~ +70°C)
Code 2nd (Feature set)	W: Industrial Grade (-40°C~ +85°C)
U : Embedded series	
Code 3rd ~5th (Form factor)	**Code 15th (Internal control)**
M28: M.2 Type 2280-B-M	A: PIN HEADER 90° (Horizontal Pin Headers)
	B: PIN HEADER 180° (Vertical Pin Headers)
Code 7th ~9th (Capacity)	**Code 16th (Channel of data transfer)**
64G: 64GB / A28: 128GB / B56: 256GB	S: Single Channel
C12: 512GB / 1TB: 1TB / 2TB: 2TB	D: Dual Channels
	Q: Quad Channels
Code 10th ~12th (Controller)	**Code 17th (Flash Type)**
DK1: SATA 3TO7	F: Kioxia 3D TLC
Code 13th (Flash mode)	**Code 18th ~20th (Hidden Area Size)**
E: 64 layers 3D TLC	10G: 10GB Hidden / 60G: 60GB Hidden
K: 112 layers 3D TLC	20G: 20GB Hidden / 90G: 90GB Hidden
	30G: 30GB Hidden
	Code 21st~ (Customization Code)