

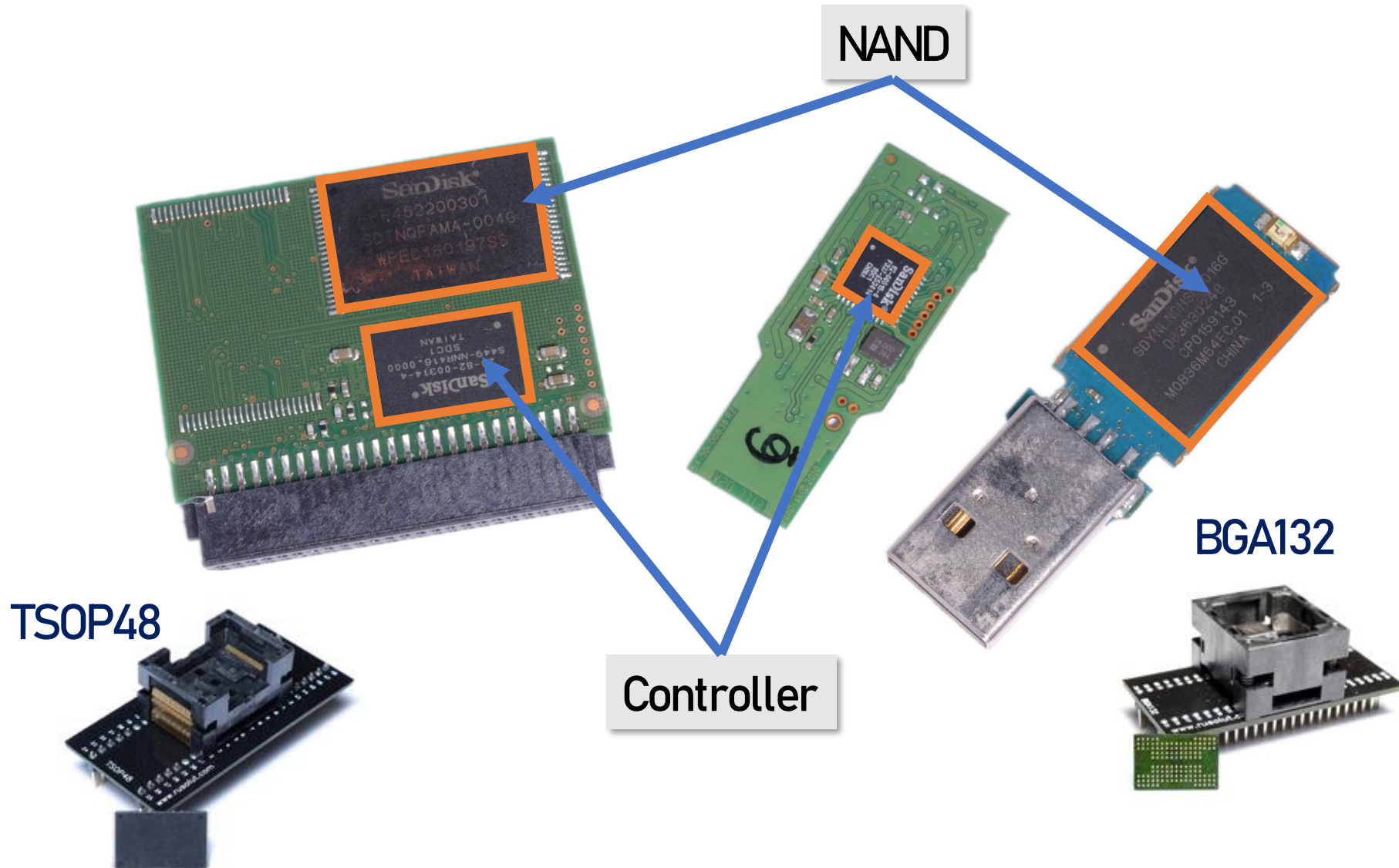
SanDisk controllers and logical image assembly from WD SSD

Michał Gmurek, Rusolut

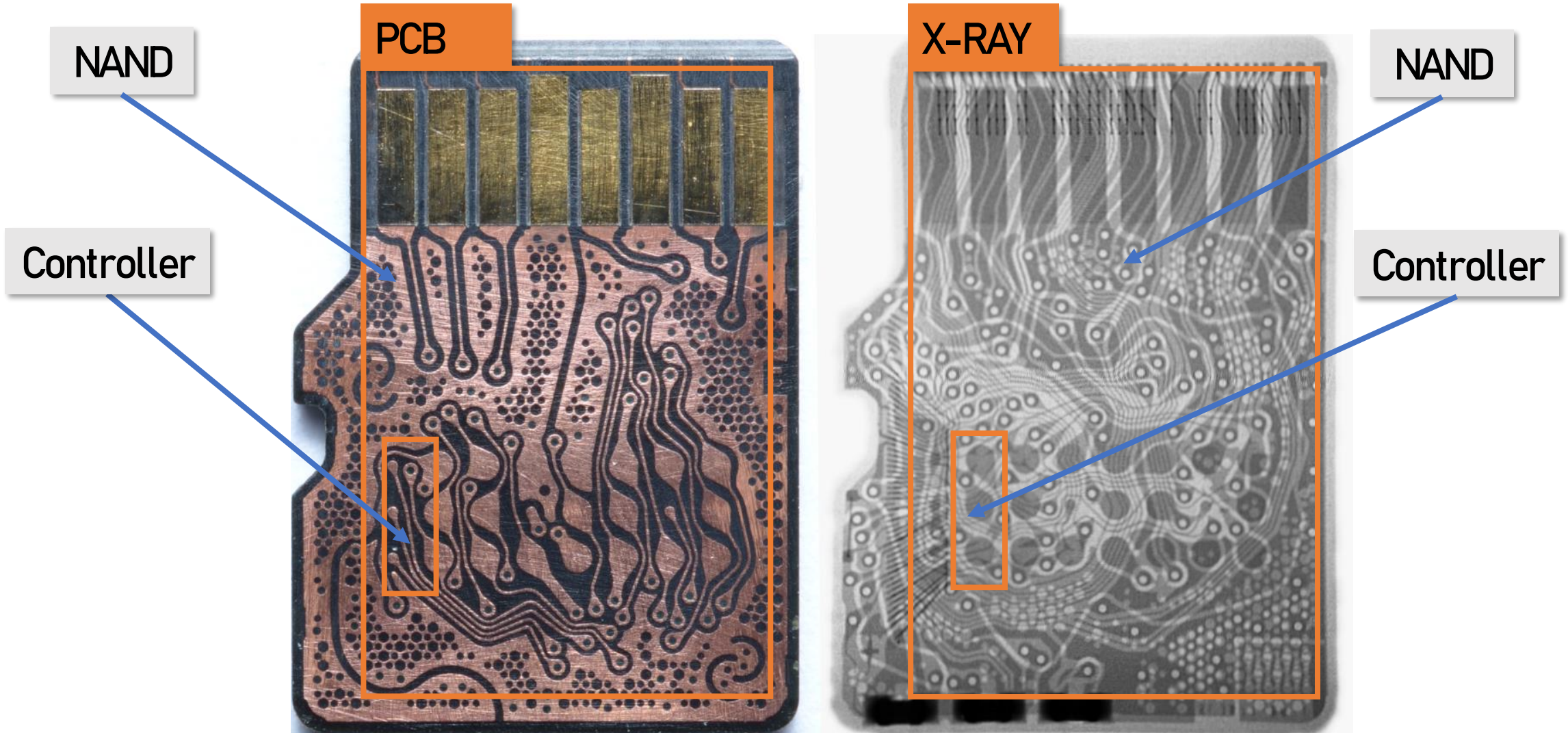
Types of SanDisk devices



Standard devices

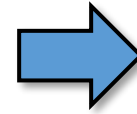
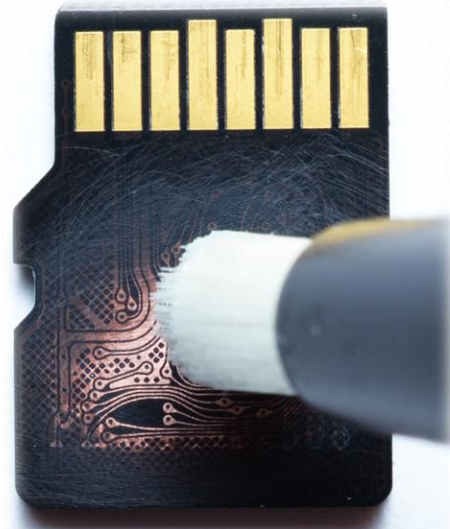
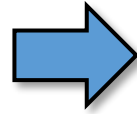


Monolith device



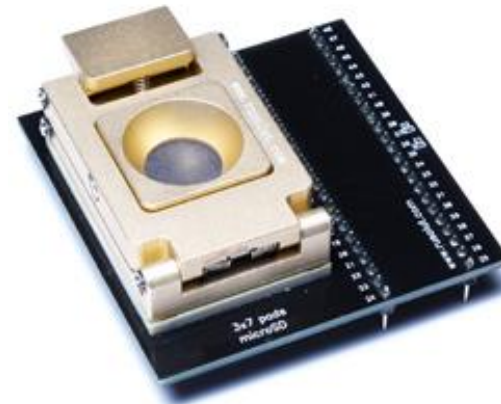
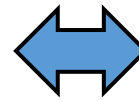
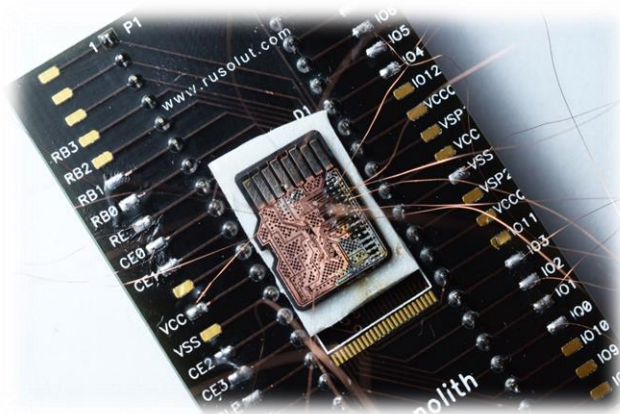
Monolith device

Soldering mask removal



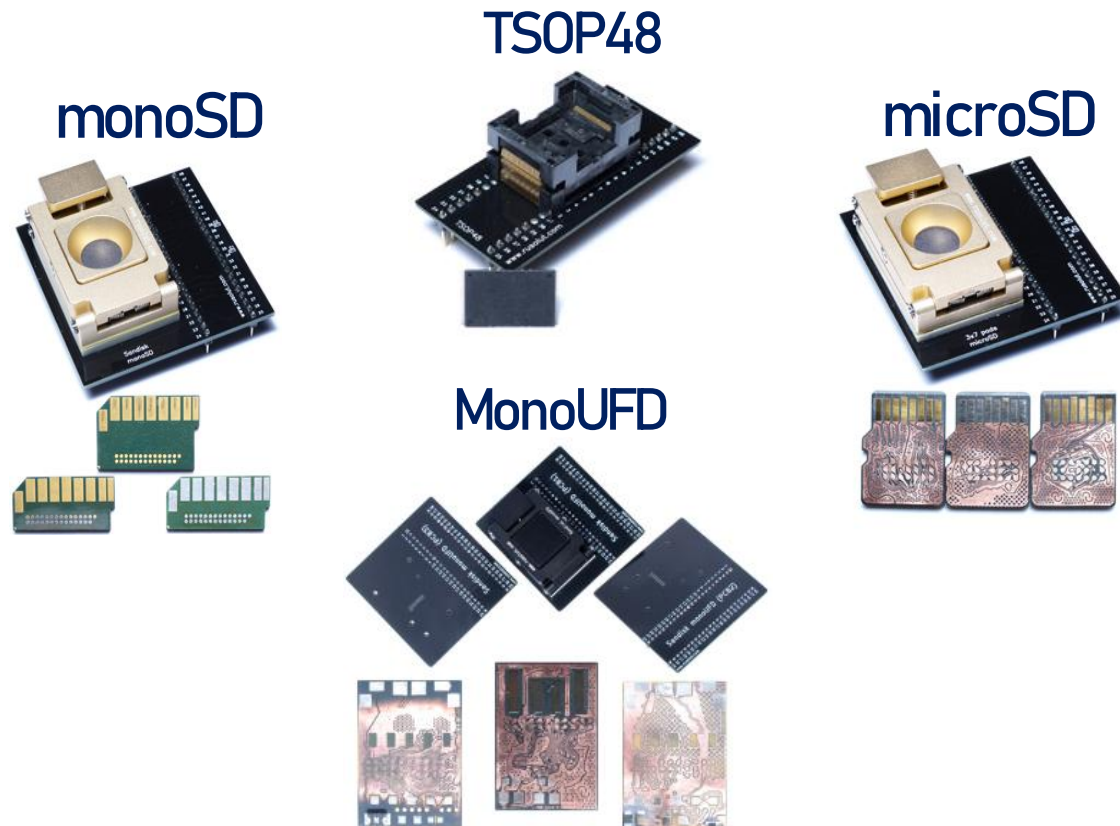
Soldering

Adapter

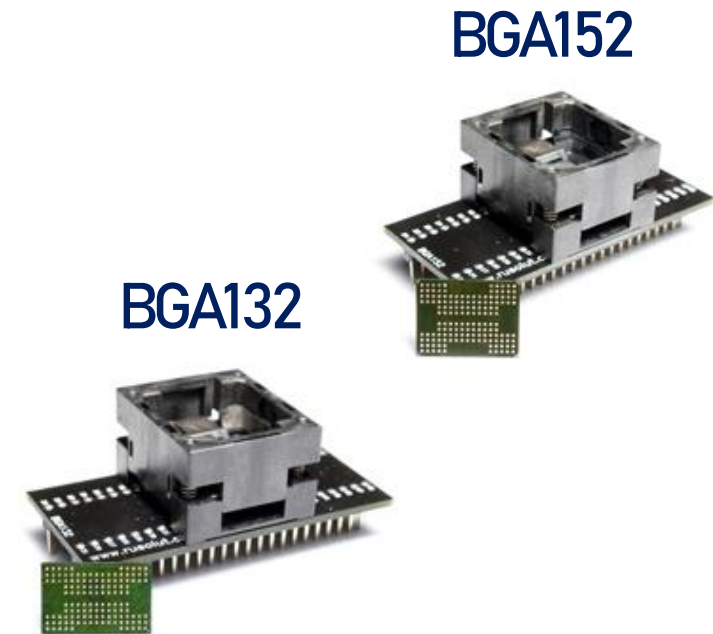


NAND Adapters for SanDisk devices

Removable Storage Media



SSD Drives



Monolith device - Pinout

Monolith Pinout Database

The screenshot displays the 'Monolith pinouts' software interface. The main workspace shows a USB flash drive with a detailed circuit board layout. The central image is labeled 'ruSolut' and has various pins and components labeled with blue lines and text: RE, Vcc, R/B0-1, CE0, I07, I06, I05, Vss, CLE, ALE, I04, I01, WE, I02, I00, CE1, and I03. The interface includes several filter panels on the left and right.

Monolithic device type: USB Flash disk, MicroSD card, SD card, Others.

PCB color: Copper, Gold, Silver, Green, Black, Other.

Technological pads: No pads, Technological pads.

Ground texture: Diagonal, Perpendicular, Solid, Sponge.

Device size: Short, Normal.

USB pads: Square, Round, Rounded edge.

PCB tracks: Vertical, Horizontal, Mixed.

Square pads: No pads, Square pads.

Surface mounted components: No, Yes.

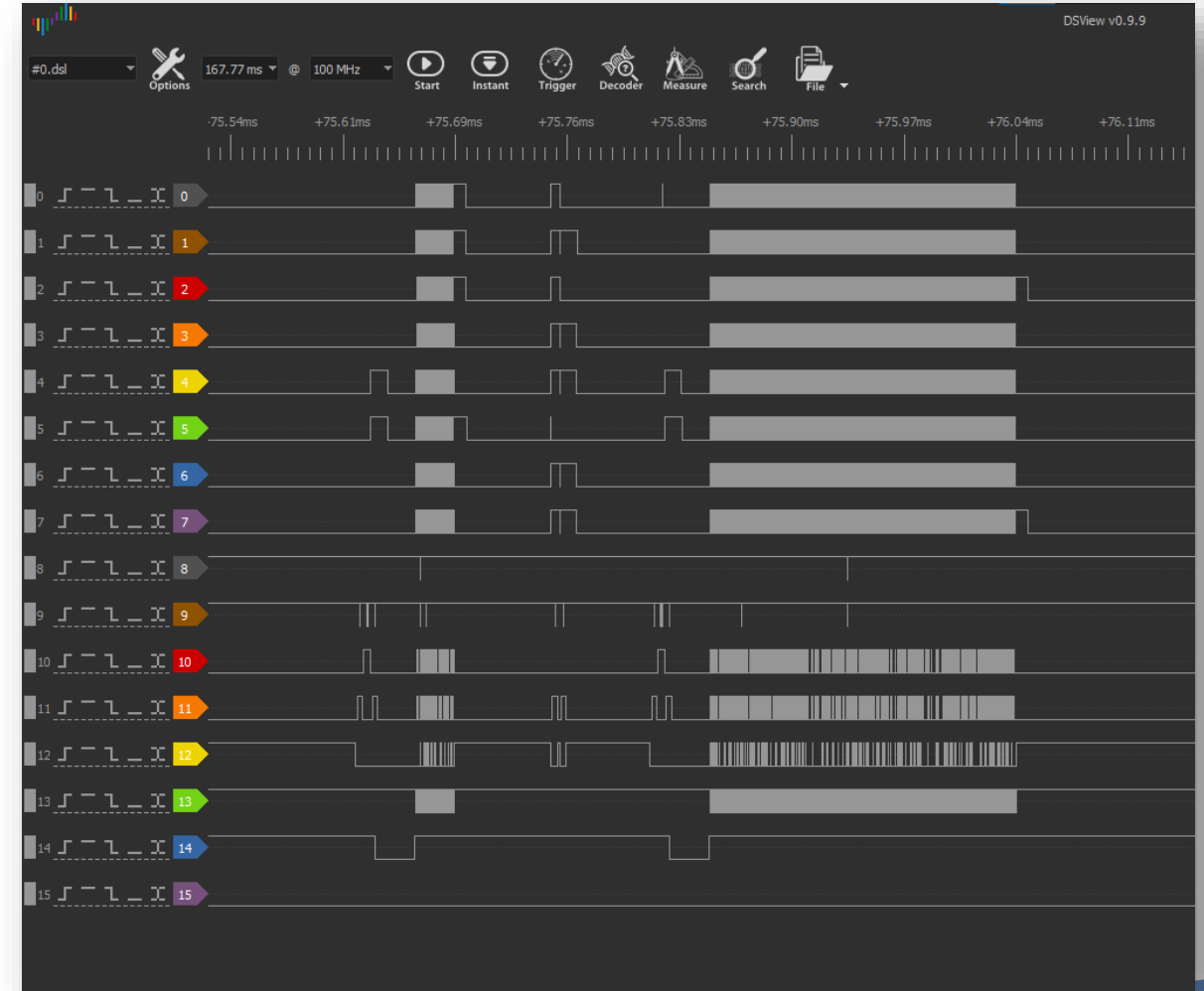
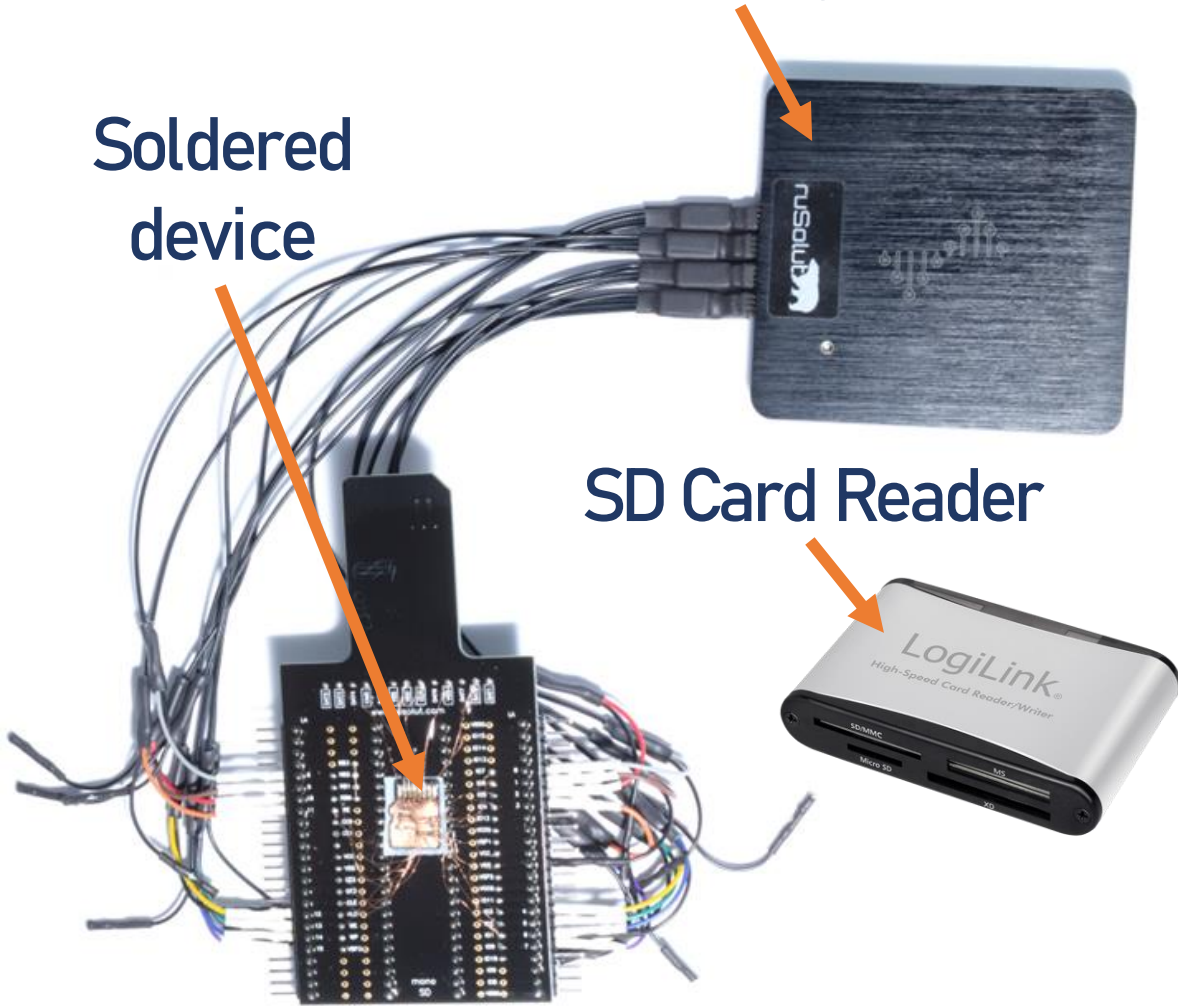
Additional filters include 'Reset all filters' and a note: '* CTRL + Click to disable a filter'.

Monolith device – Pinout analysis

Logic analyser

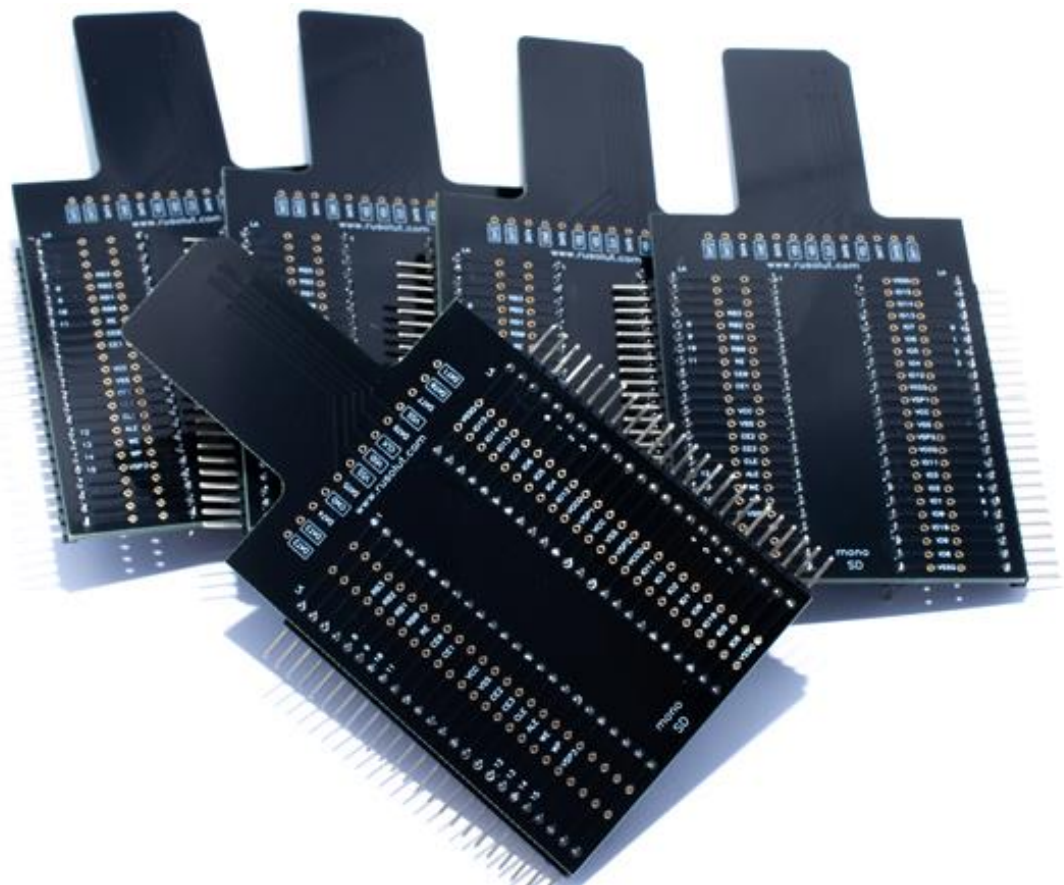
Logic analyser Software – Signal analysis

Soldered device

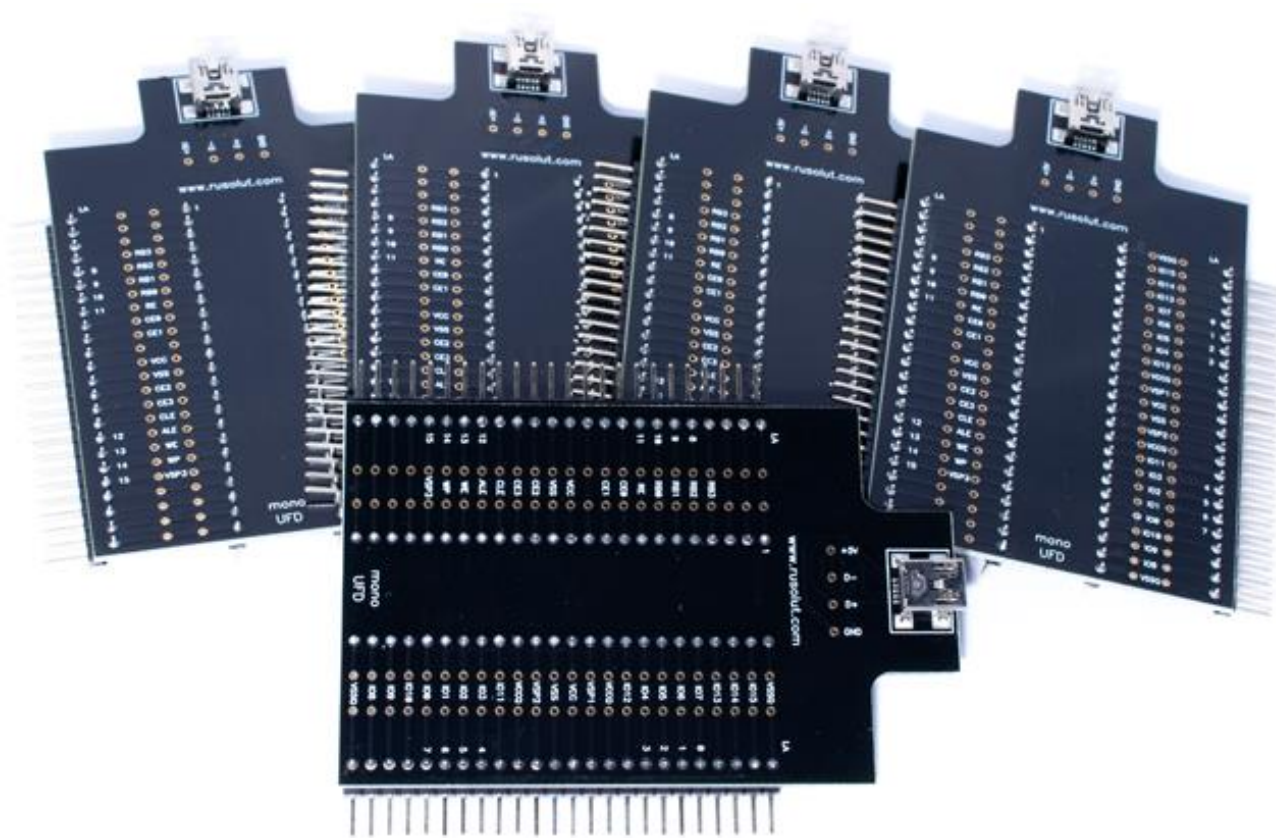


NAND Adapters for pinout analysis

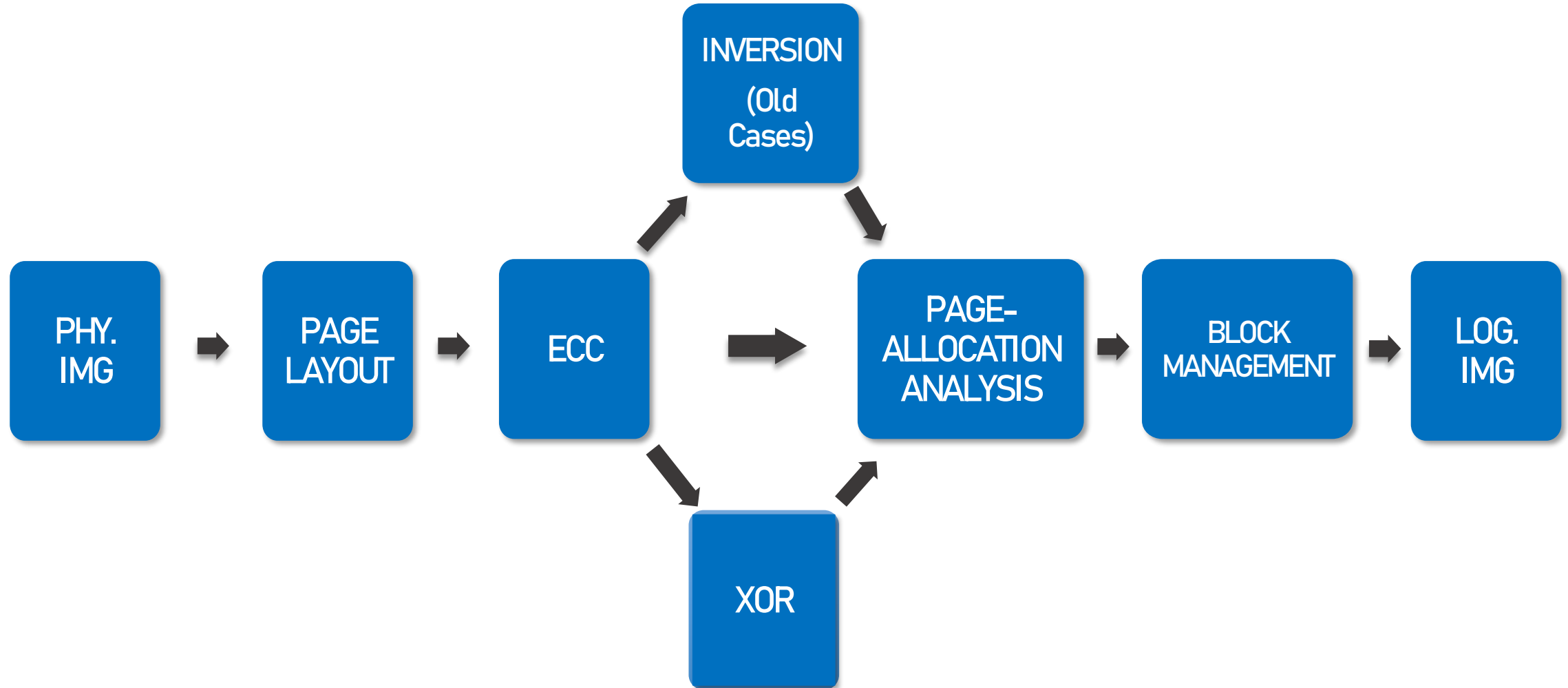
MonoSD



MonoUFD



Chip-off data recovery procedure



Fully solved case in VNR

Physical image reconstruction in VNR

The screenshot shows the VNR software interface for physical image reconstruction. The top menu bar includes 'Case', 'Workspace', 'Plugins', and 'Databases'. Below the menu, there are several toolbars: 'Element functions' (Delete, Copy, Paste, Open images, Send solution to Db), 'Solution' (Insert area, Skip area, Extract area), and 'Positi...' (Positioning). The main workspace displays a flowchart of the reconstruction process: Reader (0) -> Phy image (Chip0_0_0) -> ECC (0) -> XOR (0) -> Pair (0) -> Log image (0). A 'Markers table' is also shown. The left sidebar lists 'Elements' and 'Dump operations'. The right sidebar shows 'Solution' details: Controller, Device type, Device name, Pinout, Memory chip ID, Number of memory chips (1), and Number of crystals (1). A 'Premium Support is active till 07 Mar 2024' notice is also present.

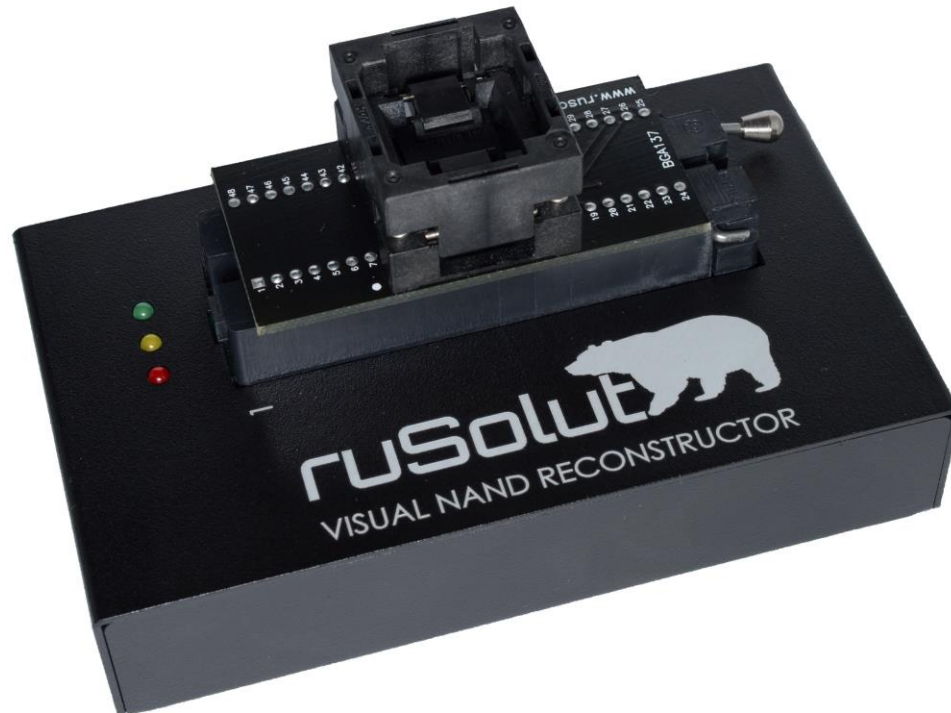
Data extraction

The screenshot shows the VNR software interface for data extraction. The top menu bar includes 'Case', 'File system viewer', and 'Workspace'. Below the menu, there are several toolbars: 'Check headers', 'Save image', 'Save selected', 'Check file system', 'Create unallocated data dump', 'Correct allocated', 'Correct unallocated', 'Correct selected files data', 'Android data extractor', 'SQLite carver', and 'Refresh'. The main workspace displays a file system tree view for 'Log image 0 X' in 'Workspace'. The tree shows a hierarchy: GPT -> Volume5 (EXT-family) /data 2.08 GB -> Root. The 'Root' directory is expanded, showing a list of files and folders. The right sidebar shows a table of files with columns: Name, Ext, Size, and Last modified.

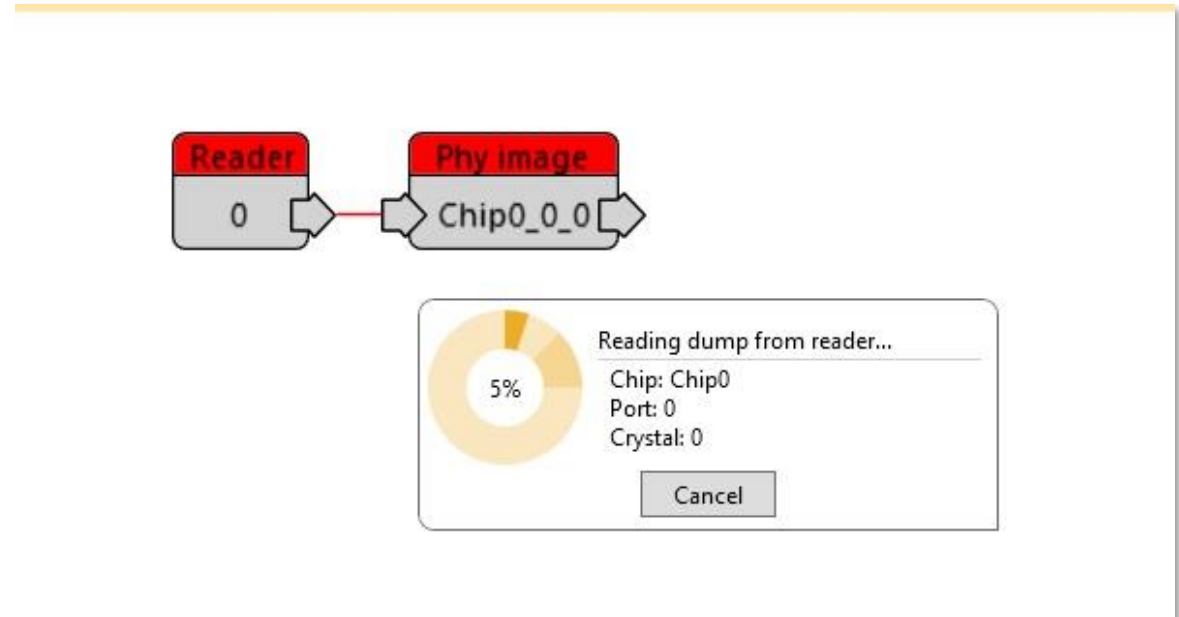
Name	Ext	Size	Last modified
app			08/13/2014 19:28:46
app-asec			01/28/1970 22:49:52
app-private			09/04/2014 17:03:49
audio			01/28/1970 22:49:52
backup			06/08/2014 19:12:01
bms			01/28/1970 22:49:54
controlcenter			01/28/1970 22:53:51
dalvik-cache			06/08/2014 19:12:01
data			10/10/2014 18:23:07
dontpanic			01/28/1970 22:49:52
drm			01/28/1970 22:53:13
efslog			01/28/1970 22:49:52
etc			01/28/1970 22:49:53
fota			01/28/1970 22:49:52
hdcp			01/28/1970 22:52:56
last_alog			06/08/2014 18:28:03
last_kmsg			06/08/2014 18:28:02
local			01/28/1970 22:49:53
lost+found			01/28/1970 22:49:50
media			08/10/2014 14:42:26
mediaserver			01/28/1970 22:49:57
misc			04/27/1970 21:03:44
property			10/03/2014 17:01:13
resource-cache			06/08/2014 18:28:15
shared			01/28/1970 22:49:52
smime			01/28/1970 22:49:52
ssh			01/28/1970 22:49:52
startupservice			01/28/1970 22:53:10
suntory			01/28/1970 22:49:54

Physical image extraction

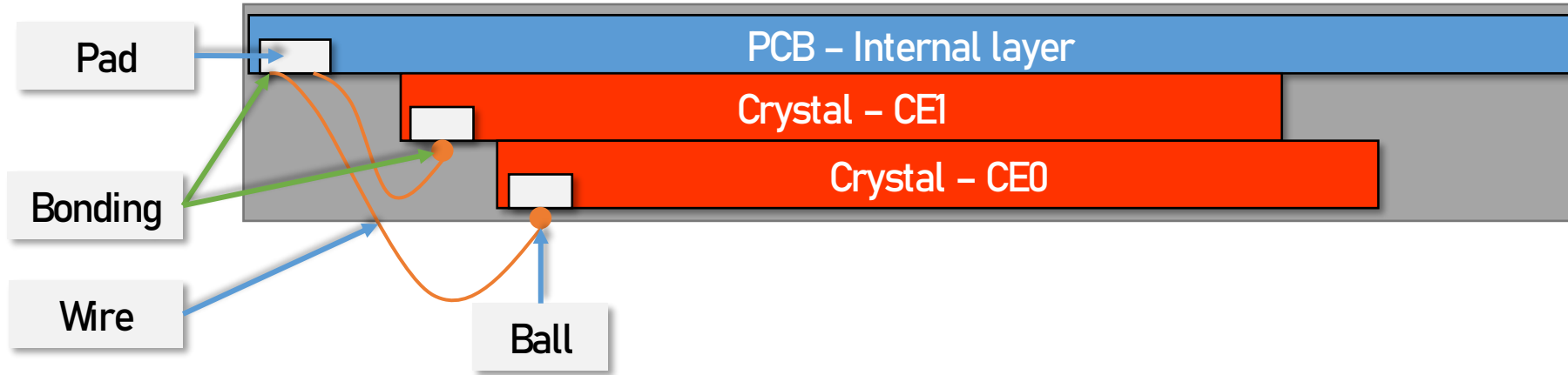
Device in the VNR Reader



Reading initialised in the software

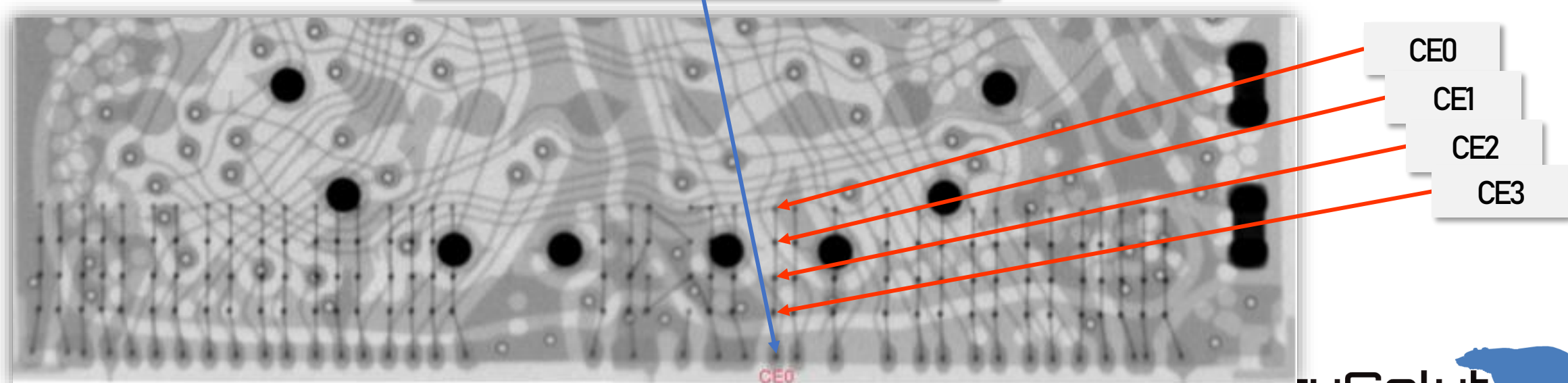


SanDisk multi-crystal devices/chips

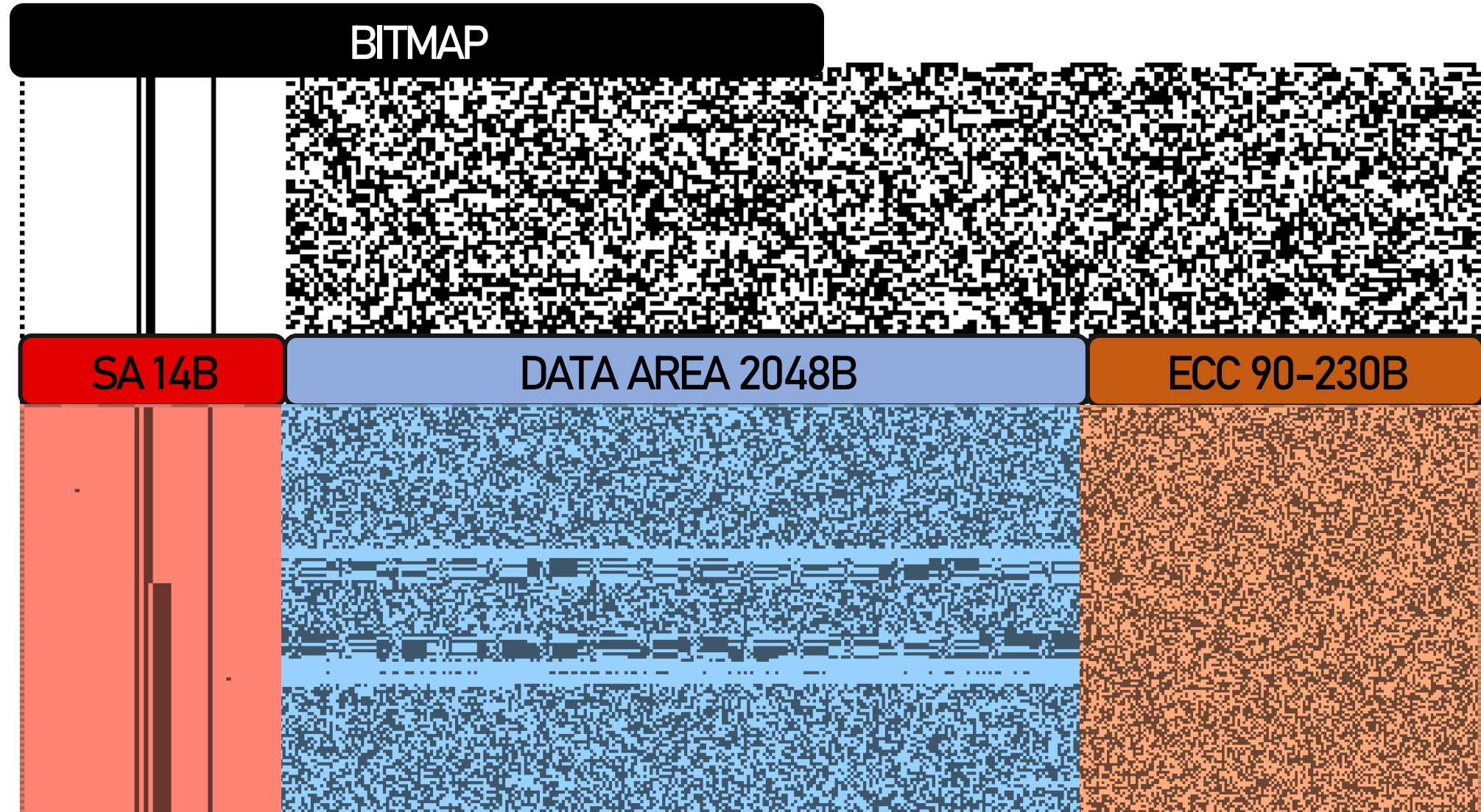


X - RAY SanDisk eMMC chip

Technological pad (Internal PCB Layer)

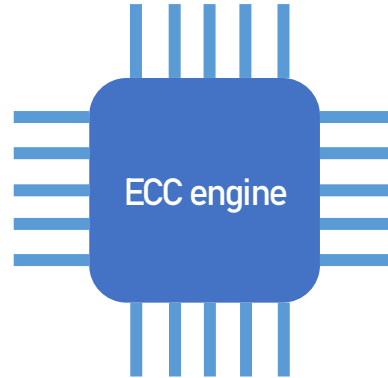
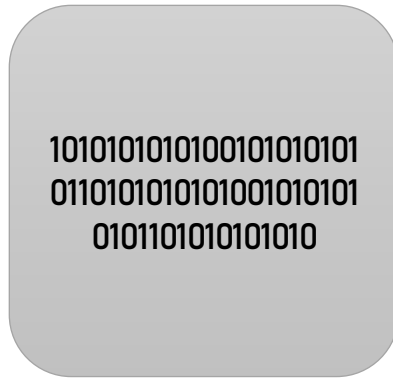


Page layout



Error Correction Code(ECC)

Scrambled data
1024 bytes



Scrambled data
1024 bytes



ECC
10-250 bytes



ECC
algorithms

Hamming code (OLD)

Reed-Solomon code (OLD)

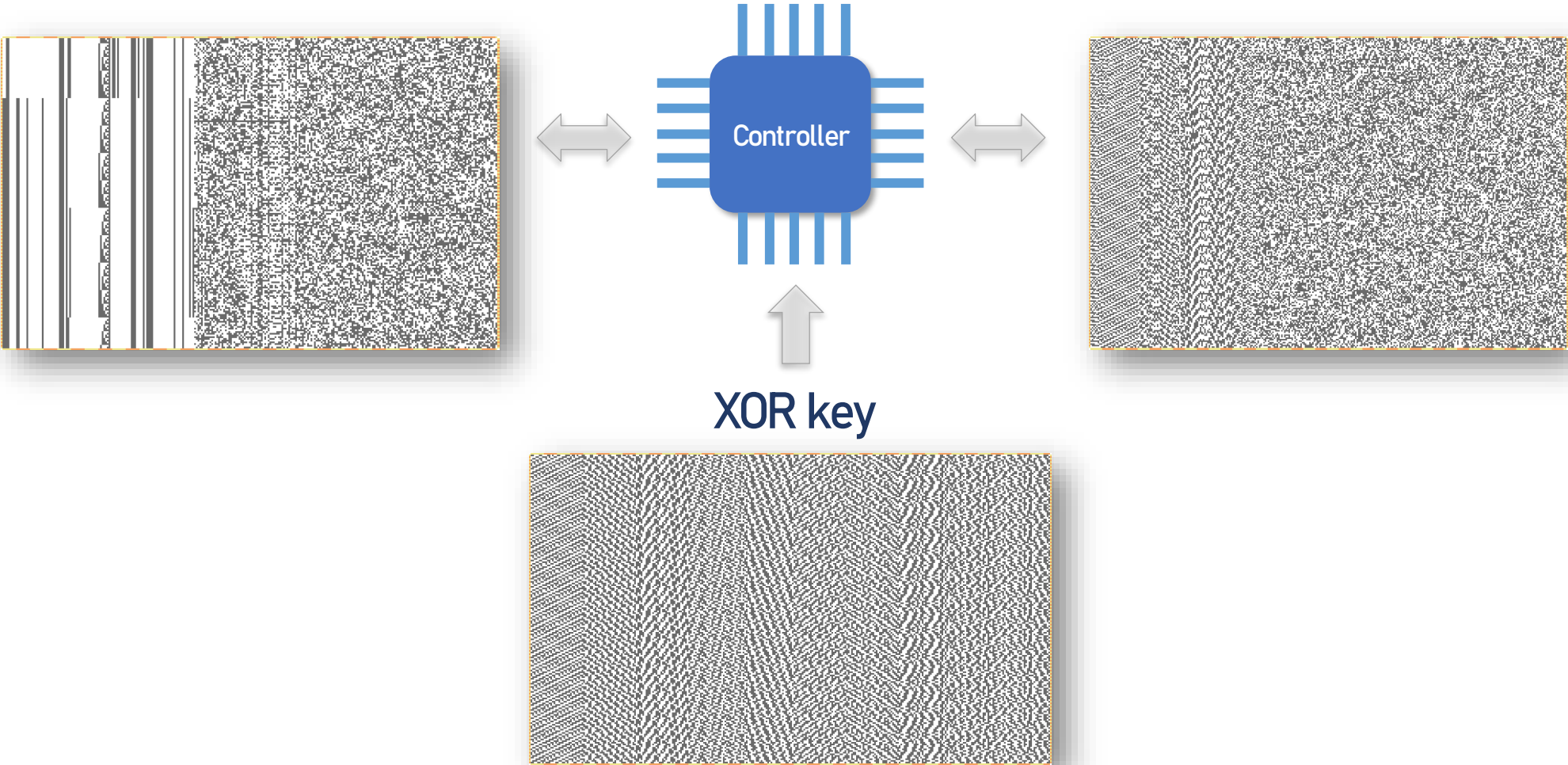
BCH

LDPC

Scrambler XOR key

DATA

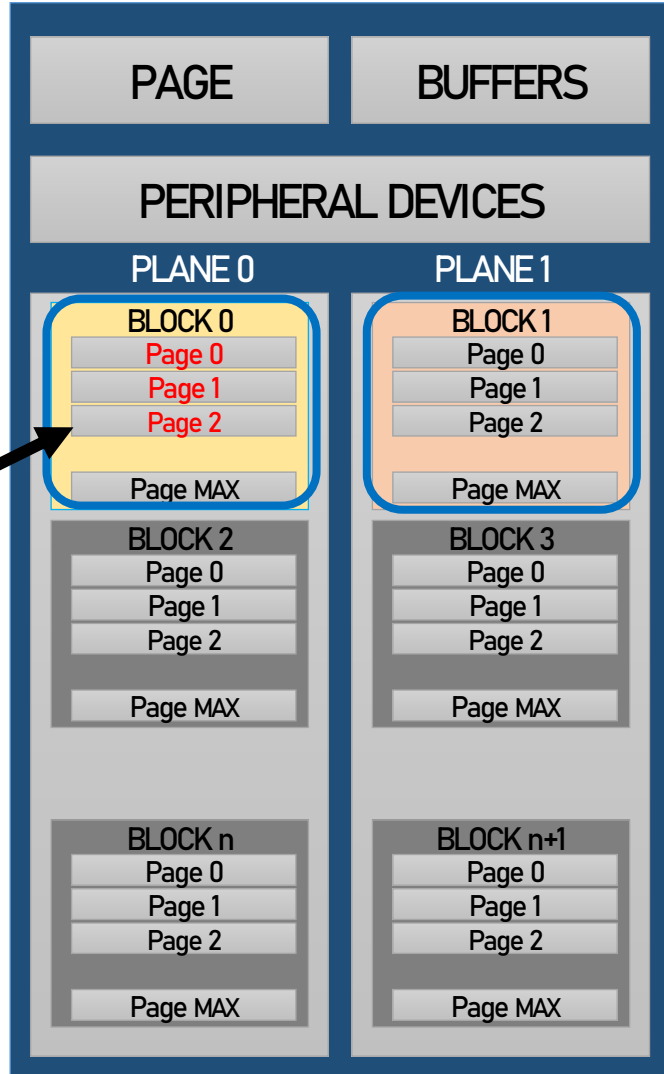
SCRAMBLED DATA



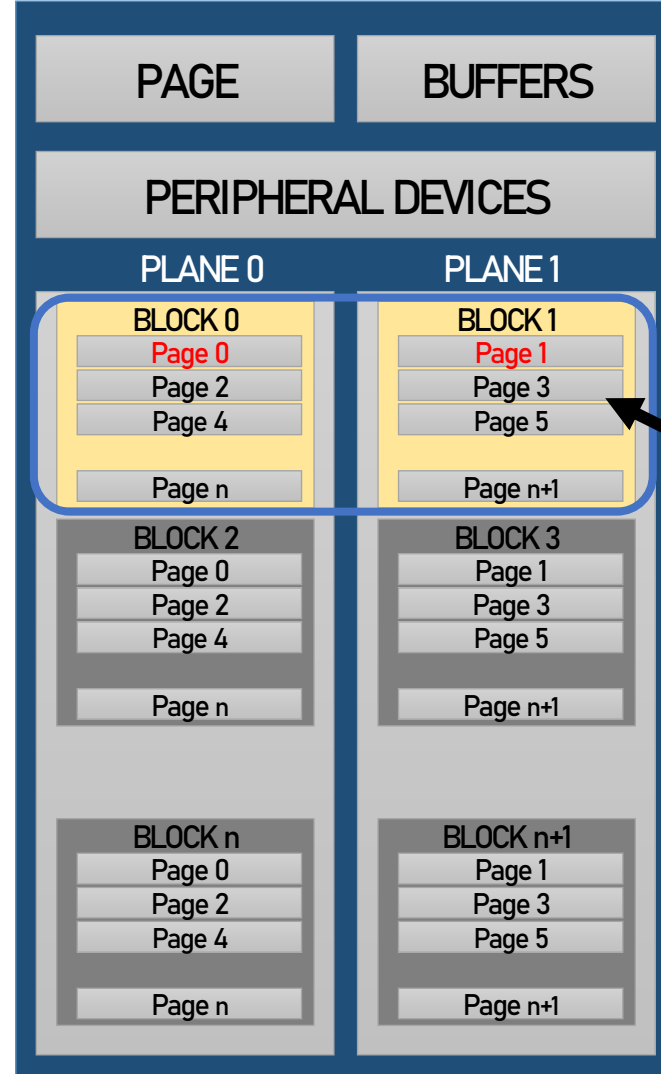
Page allocation modes

SINGLE-PLANE PAGE ALLOCATION

MULTI-PLANE PAGE ALLOCATION

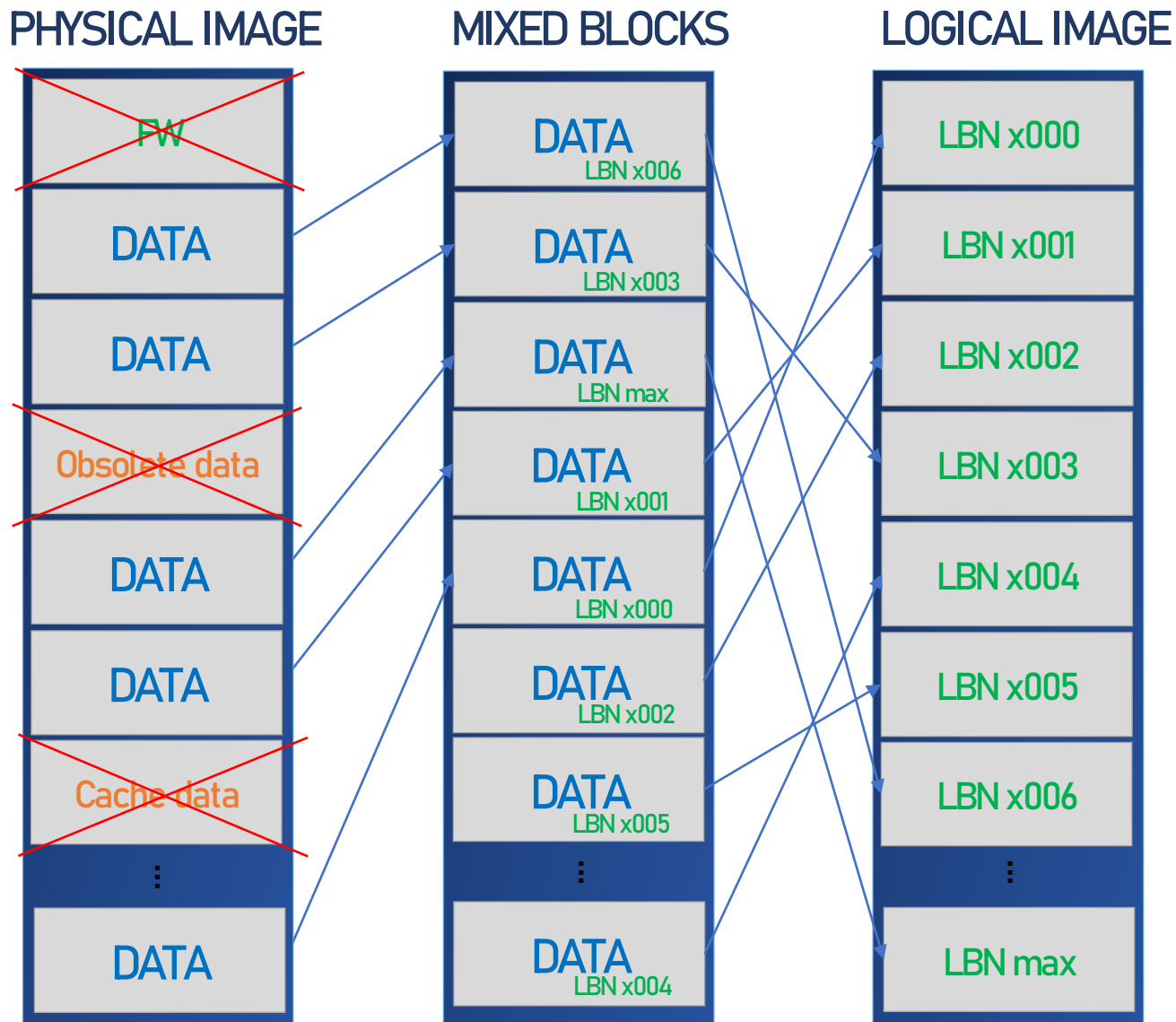


Logical block
=
1 Physical
block



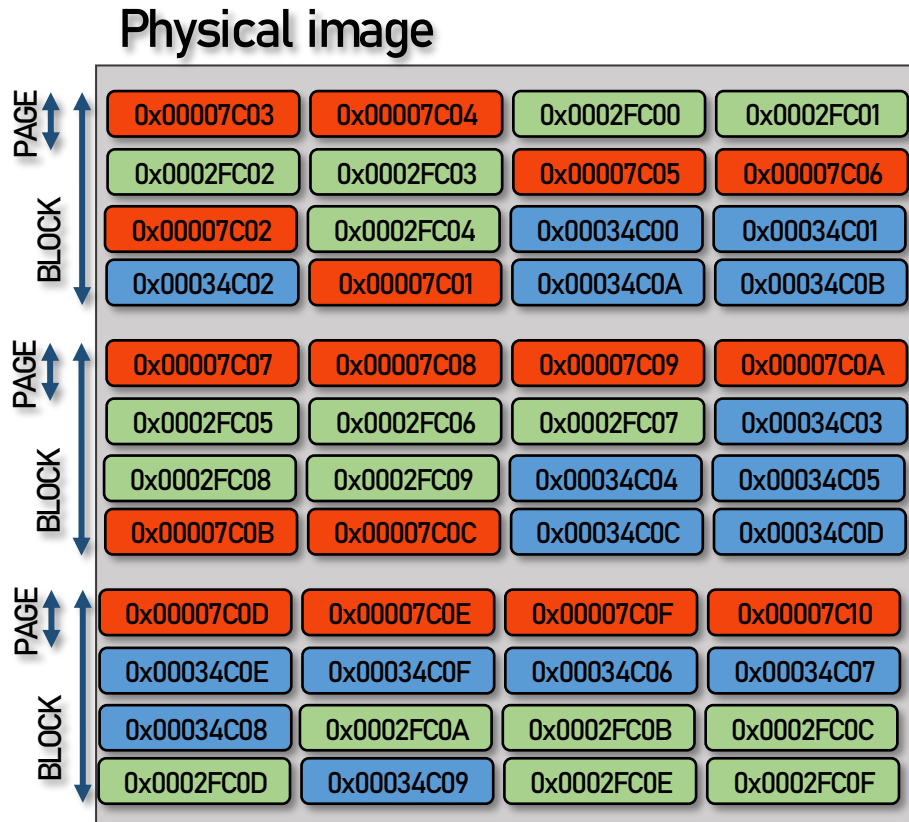
Logical block
=
2 Physical
blocks

Block management

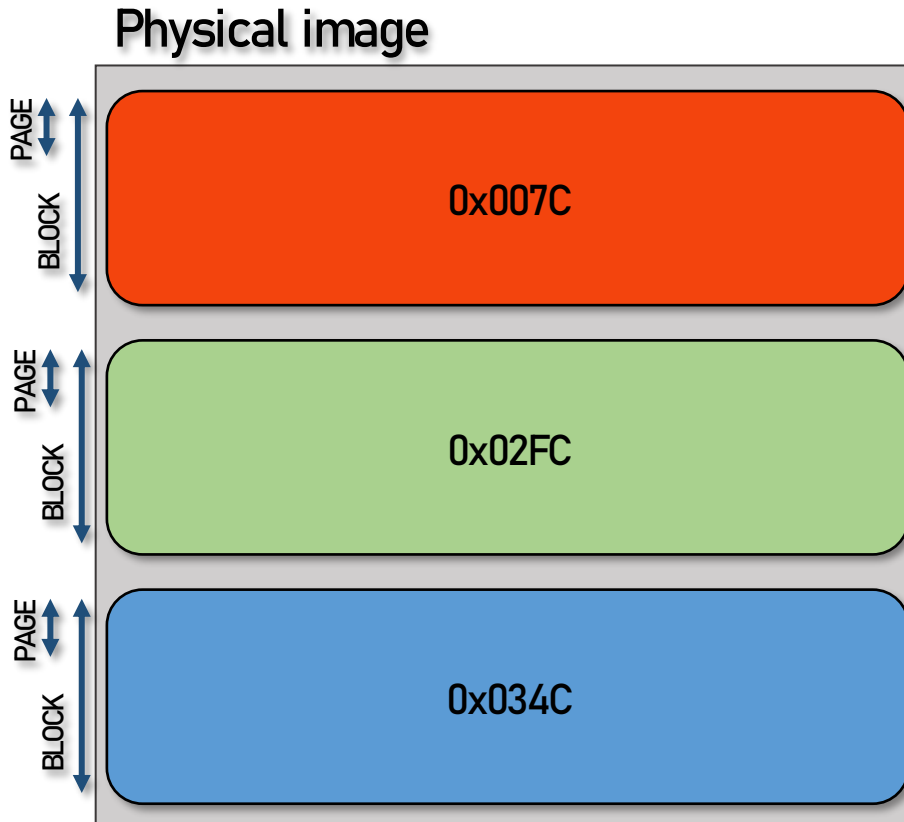


Block management

Controller allocates data using
4KB chunks.

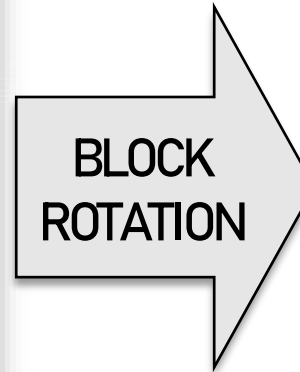
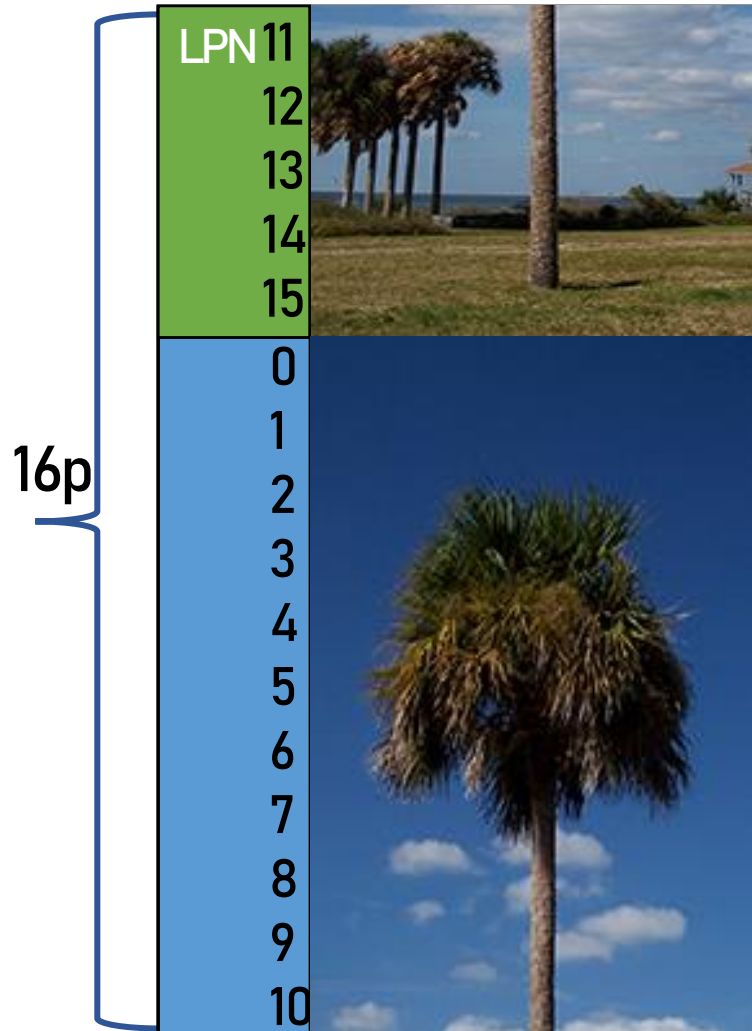


The controller allocates the
data inside the logical blocks.
Avg. log. Block size = 4096KB

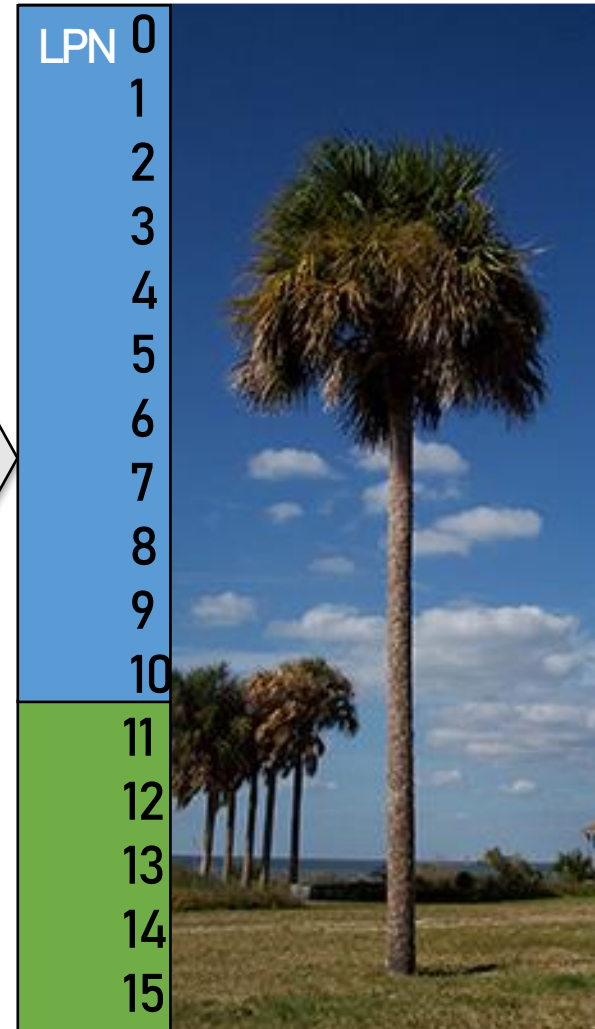


Block rotation

Block in Physical dump



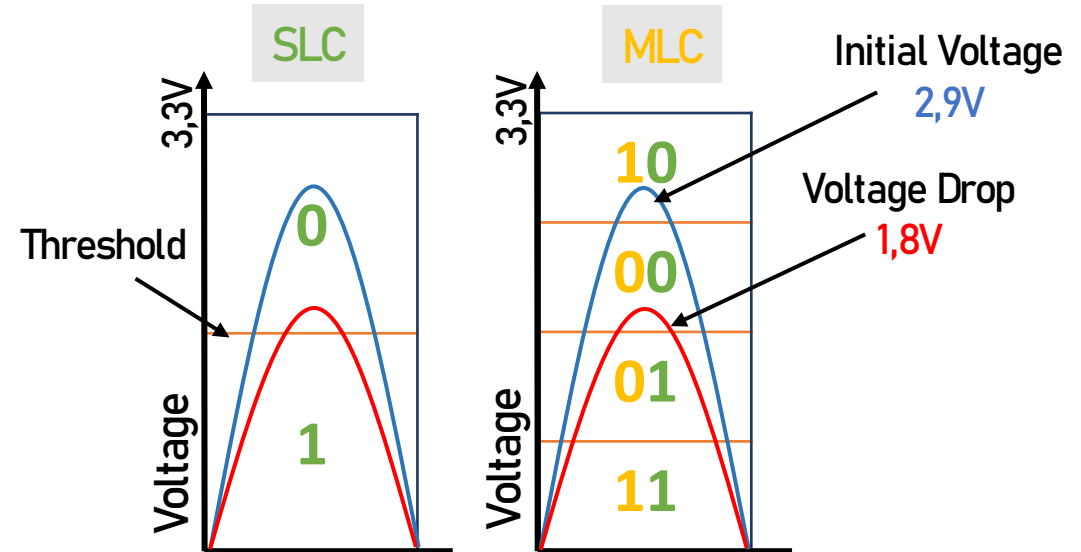
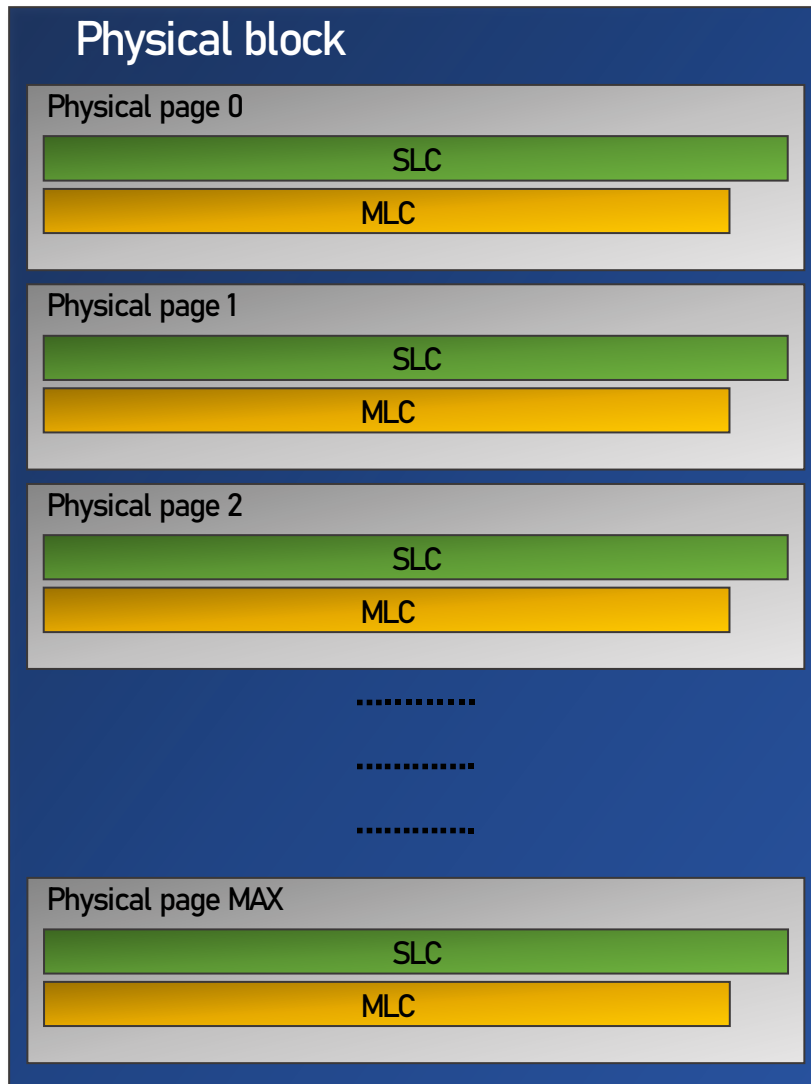
Same block after rotation



Pattern of SLC Block in MLC memory

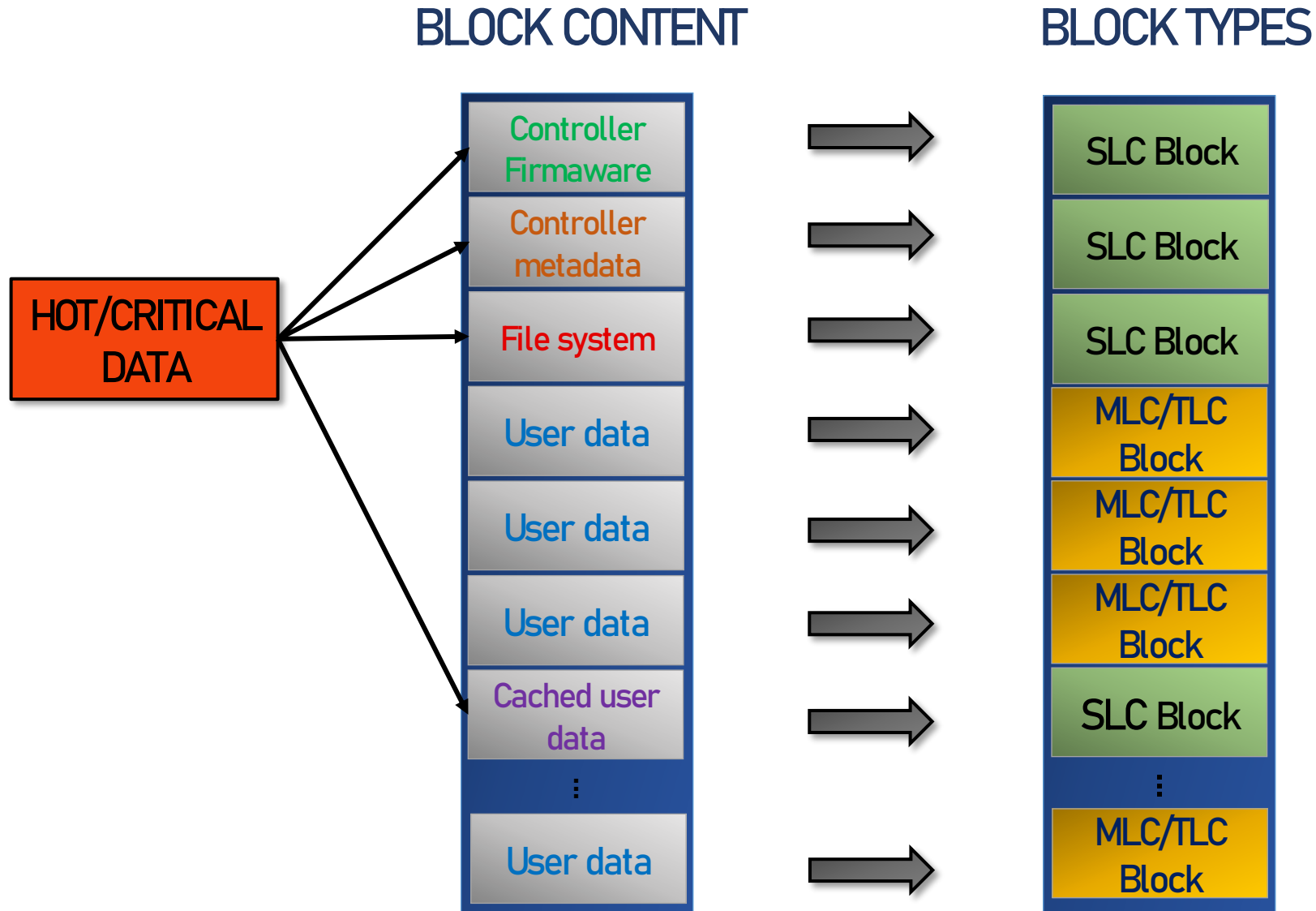


SLC Block in MLC NAND Memory

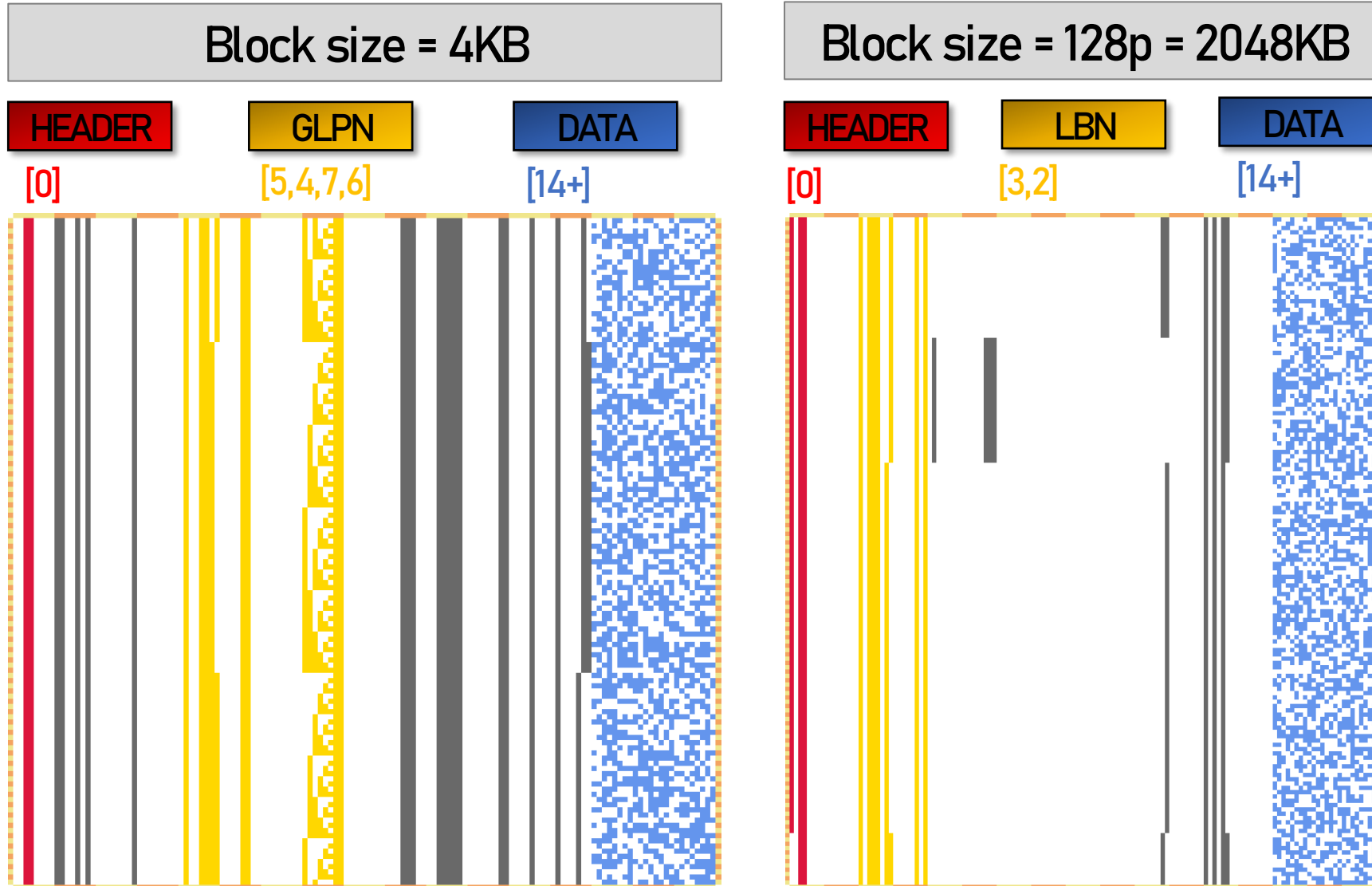


CELL	2,9V	1,8V	ECC MAP
SLC	0	0	No error
MLC	10	00	Bit error

Usage of SLC Blocks

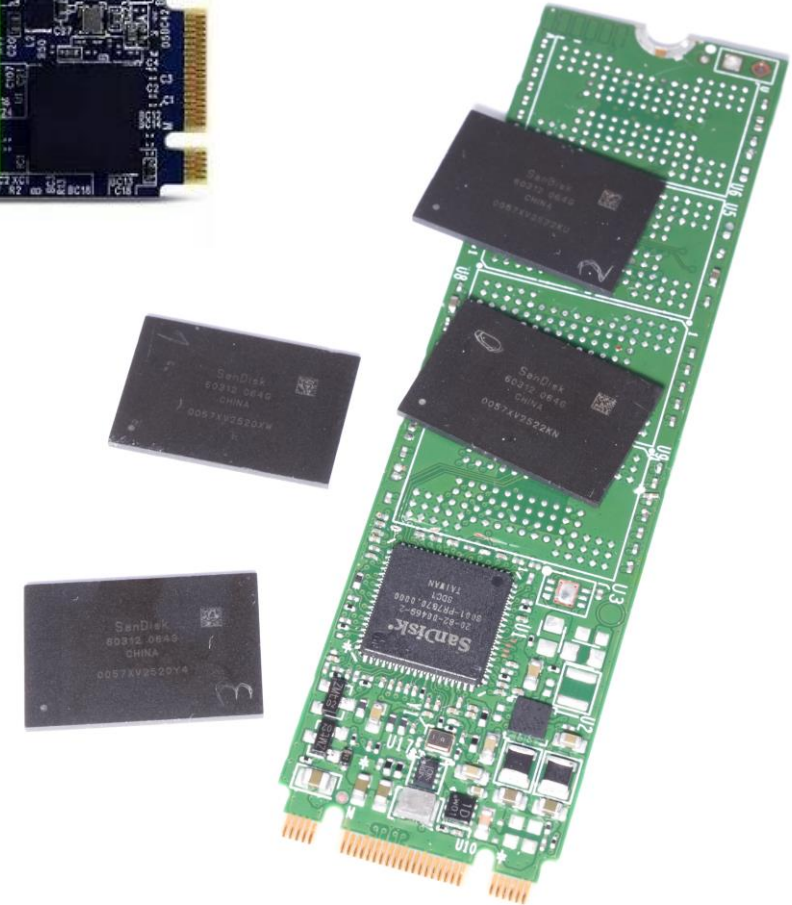


SanDisk Service Areas



Western Digital Green SSD

Sandisk 20-82-00469-2

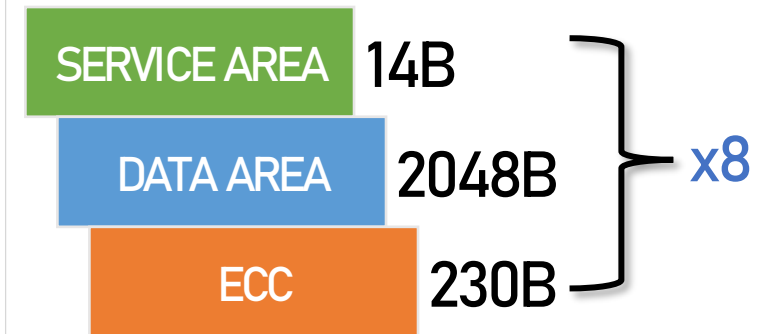


Sandisk 20-82-00469-2

Page structure

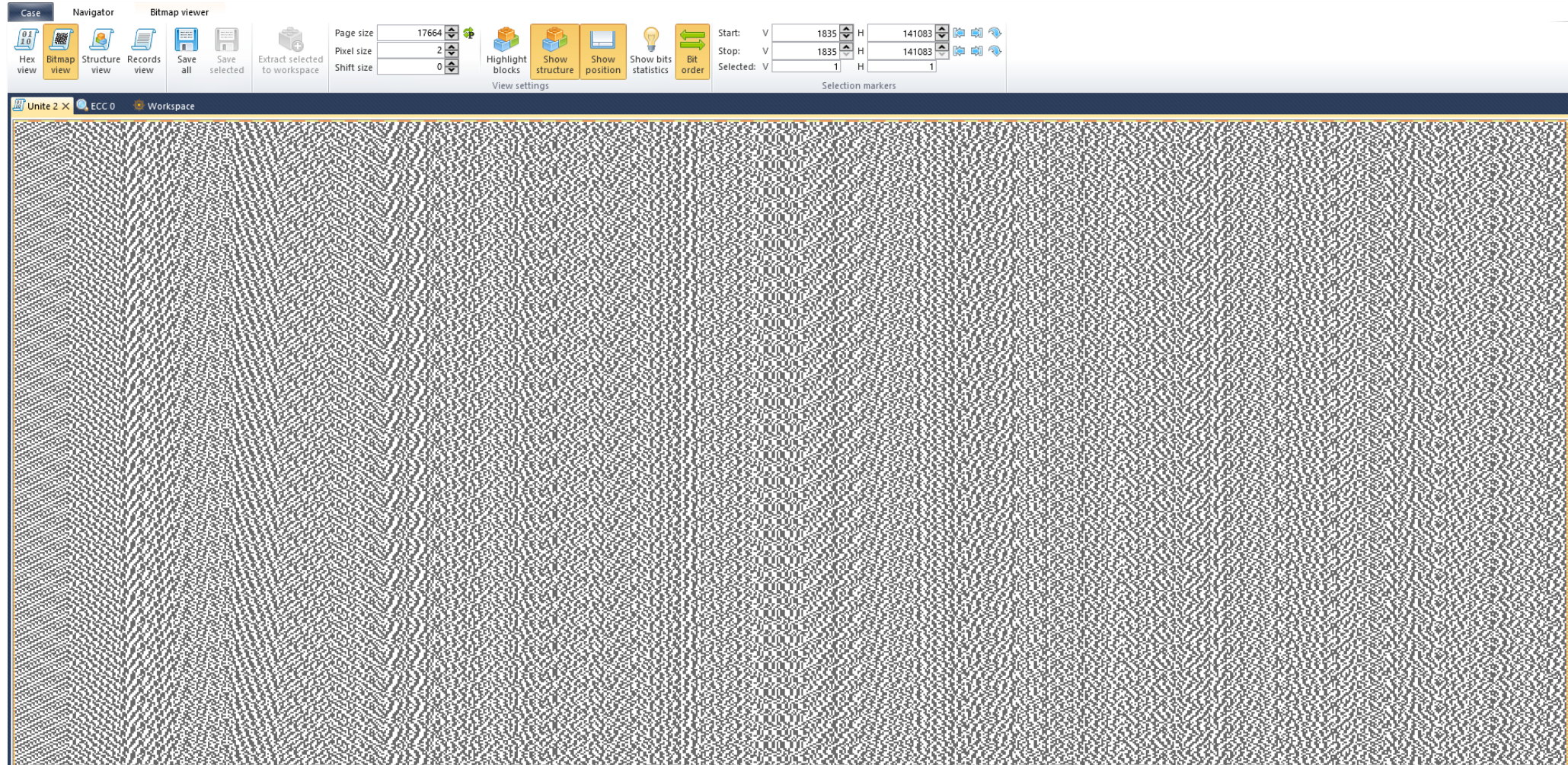
The screenshot shows a forensic tool interface with a menu bar (Case, Navigator, Bitmap viewer, Structure viewer) and a toolbar with icons for Hex view, Bitmap view, Structure view, Records view, Save all, Save selected, Extract selected to workspace, Save in file, Open from file, Copy to clipboard, Paste from clipboard, Sync position, and Add structure record. The main workspace displays a memory dump with a green vertical bar on the left. On the right, a 'Block' list shows a repeating pattern of Service Area (SA), Data area, and ECC blocks. A legend on the right side of the interface defines the block types: Block (14082048 as Block), Page (18336 as Page), Data area (2048 as Data area), ECC (230 as ECC), SA (14 as Service area), Header (0 as Header), LBN (0 as LBN), and LPN (0 as LPN).

Block	Page
0 - 13	14 SA (14)
14 - 2061	2048 Data area (2048)
2062 - 2291	230 ECC (230)
2292 - 2305	14 SA (14)
2306 - 4353	2048 Data area (2048)
4354 - 4583	230 ECC (230)
4584 - 4597	14 SA (14)
4598 - 6645	2048 Data area (2048)
6646 - 6875	230 ECC (230)
6876 - 6889	14 SA (14)
6890 - 8937	2048 Data area (2048)
8938 - 9167	230 ECC (230)
9168 - 9181	14 SA (14)
9182 - 11229	2048 Data area (2048)
11230 - 11459	230 ECC (230)
11460 - 11473	14 SA (14)
11474 - 13521	2048 Data area (2048)
13522 - 13751	230 ECC (230)
13752 - 13765	14 SA (14)
13766 - 15813	2048 Data area (2048)
15814 - 16043	230 ECC (230)
16044 - 16057	14 SA (14)
16058 - 18105	2048 Data area (2048)
18106 - 18335	230 ECC (230)



Sandisk 20-82-00469-2

Scrambler XOR key



Sandisk 20-82-00469-2

Block management

Block size
4KB

SERVICE AREA

HEADER

[0]

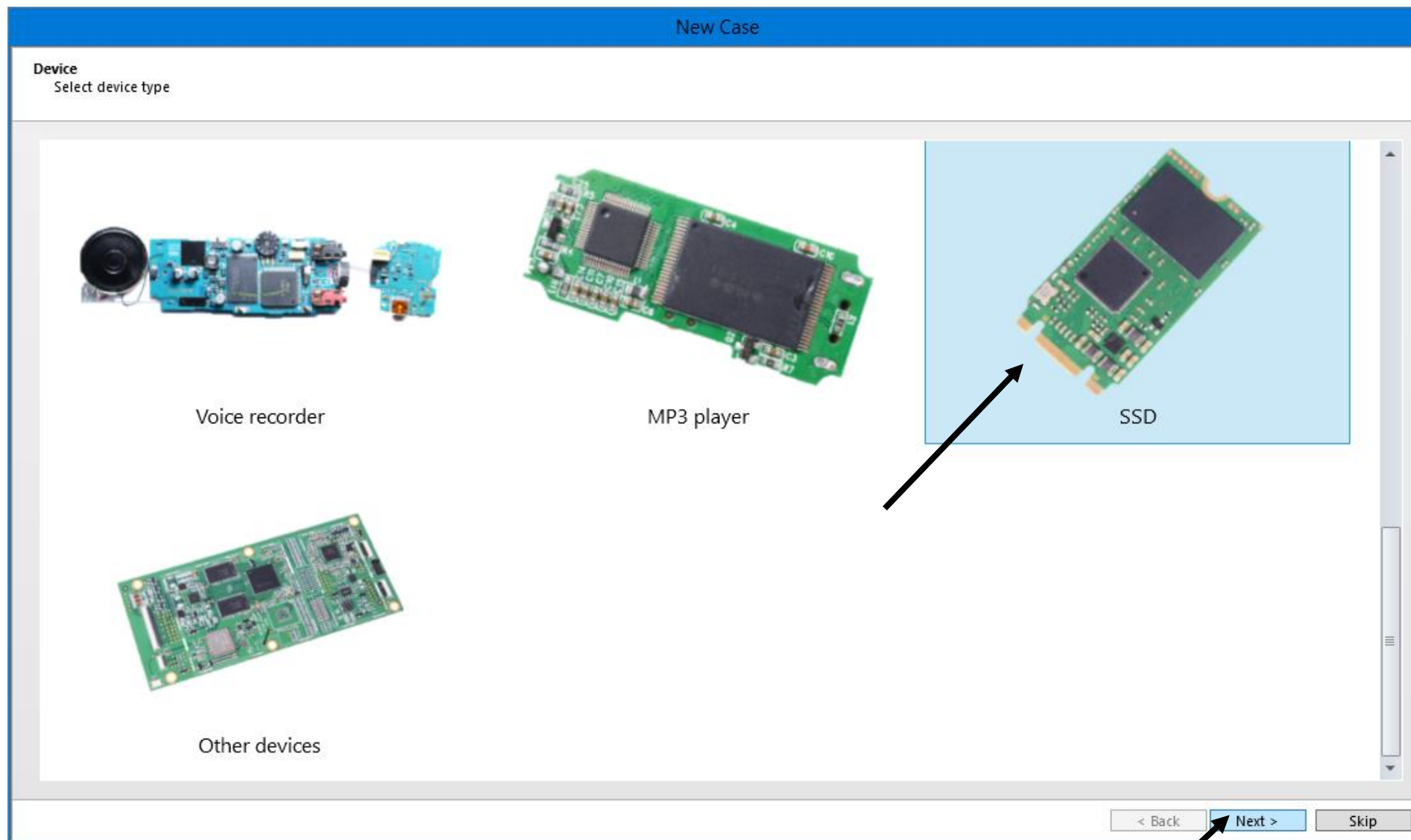
GLPN

[5,4,7,6]

The screenshot shows a forensic software interface with a hex dump of a storage device. The interface includes a top toolbar with various tools like 'Markers edit', 'Block filter', and 'Block sorter'. The main area displays a hex dump with columns labeled 00-0F and rows of hexadecimal data. A 'Markers table' is visible on the right side, listing various blocks with their addresses and markers.

Use	Bank	LBN	Header	Address	PBN	LB	RB
<input checked="" type="checkbox"/>	00	0160B080	FO	018156DC38	158513	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B0C0	FO	01807F3740	157908	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B100	FO	01807F4928	157909	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B140	FO	01807F5B10	15790A	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B180	FO	01807F6CF8	15790B	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B1C0	FO	0181561740	158508	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B200	FO	0181562928	158509	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B240	FO	0181563B10	15850A	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B280	FO	0181564CF8	15850B	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B2C0	FO	0180809D60	15791C	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B300	FO	018080AF48	15791D	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B340	FO	018080C130	15791E	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B380	FO	018080D318	15791F	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B3C0	FO	0181577D60	15851C	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B400	FO	0181578F48	15851D	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B440	FO	018157A130	15851E	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B480	FO	018157B318	15851F	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B4C0	FO	01808055C0	157918	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B500	FO	01808067A8	157919	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B540	FO	0180807990	15791A	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B580	FO	0180808B78	15791B	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B5C0	FO	01815735C0	158518	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B600	FO	01815747A8	158519	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B640	FO	0181575990	15851A	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B680	FO	0181576B78	15851B	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B6C0	FO	0180800E20	157914	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B700	FO	0180802008	157915	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B740	FO	01808031F0	157916	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B780	FO	01808043D8	157917	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B7C0	FO	018156EE20	158514	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B800	FO	0181570008	158515	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B840	FO	01815711F0	158516	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B880	FO	01815723D8	158517	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B8C0	FO	018080E500	157920	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B900	FO	018080F6E8	157921	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B940	FO	01808108D0	157922	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B980	FO	0180811AB8	157923	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	00	0160B9C0	FO	018157C500	158520	<input type="checkbox"/>	<input type="checkbox"/>

Western Digital Green SSD



Western Digital Green SSD

New Case

Controller
Select controller model

Find controller

Filter controllers by vendor

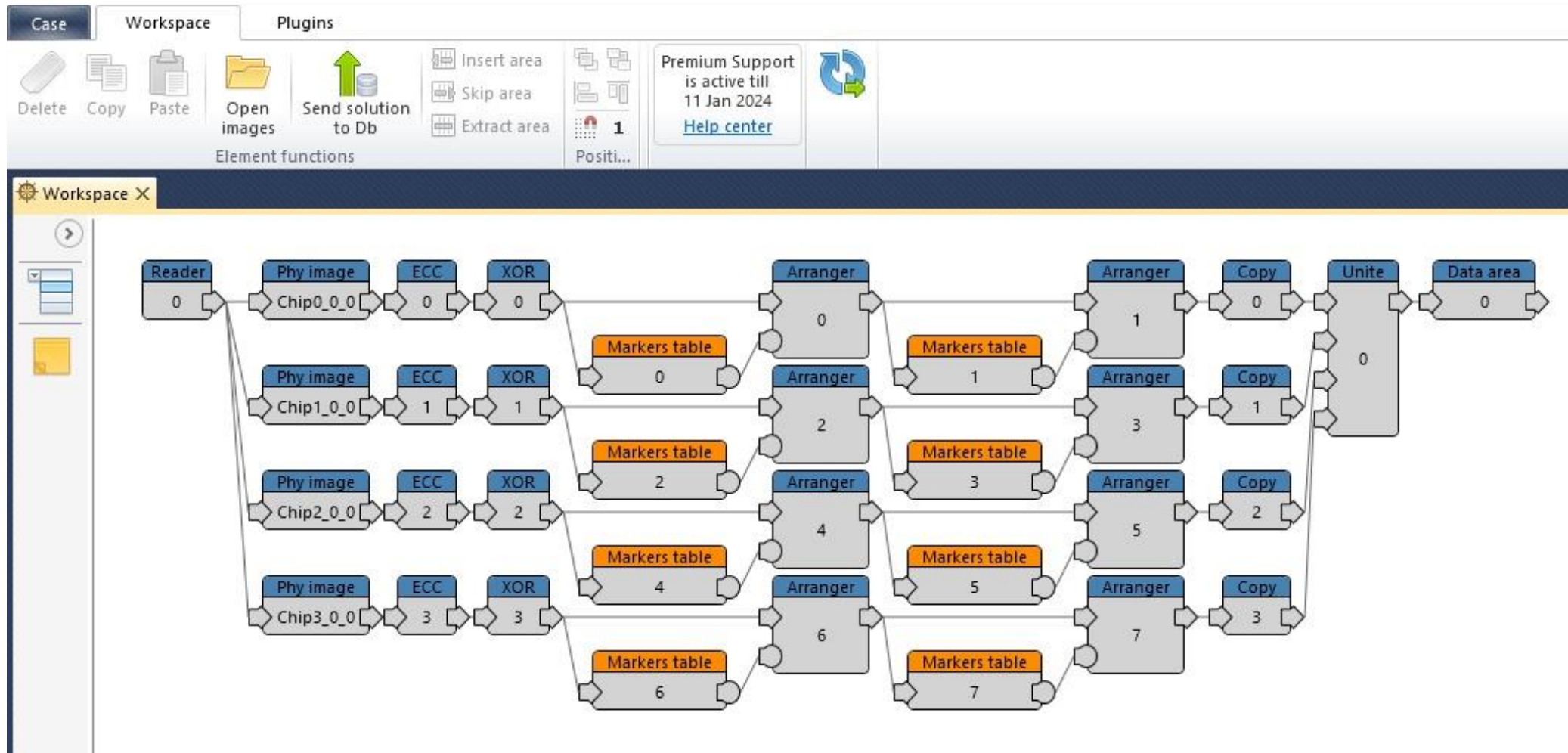
- AlcorMicro(AU)
- Black blob
- Chipsbank(CBM)
- FirstChip(FC)
- Indilinx(IDX)
- Innostor(IS)
- Intel
- ITEtech(IT)
- JMicron(JM)
- Marvell(88SS)
- Other
- Phison(PS)
- Samsung
- SanDisk**
- SiliconMotion(SM)
- Skymedi(SK)
- SolidStateSystem(SSS)
- Toshiba(TC)

20-82-00162-2	20-82-00256-1	20-82-00369-1	20-82-00381-A0
20-82-00387-A0	20-82-00394-A0	20-82-00469-2	20-82-00515-4
20-82-00515-5	20-82-00523-5	20-82-00549	20-82-00605-2
20-82-00709-A0	20-82-00709-A1	SanDisk_monolith	SanDisk_universal

< Back Finish Skip

Western Digital Green SSD

Full-Solution will be loaded to the workspace if all conditions are met.



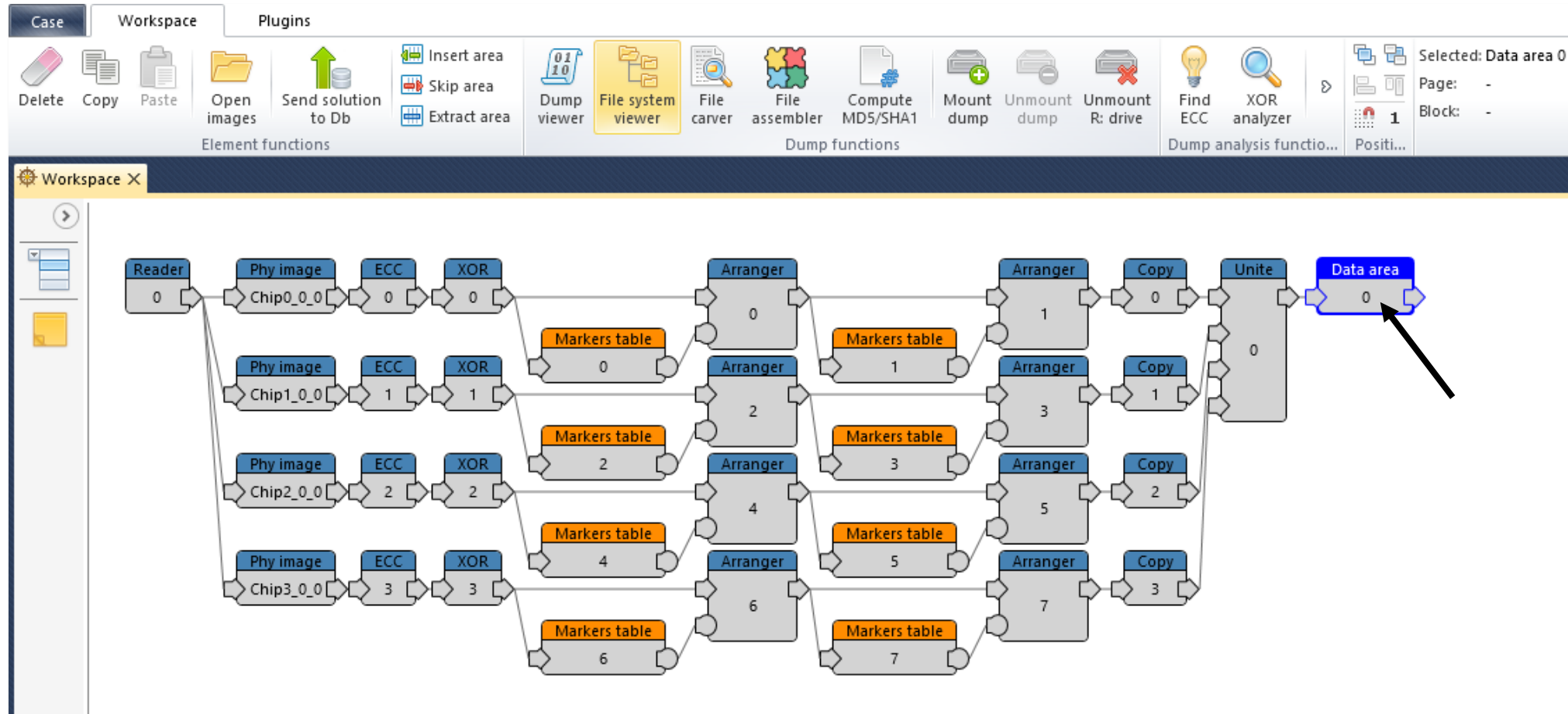
Western Digital Green SSD

Save the content of each Virtual Image on the Shadow copy element.

The screenshot displays a forensic tool interface with a top toolbar and a main workspace. The toolbar includes icons for 'File carver', 'File assembler', 'Compute MD5/SHA1', 'Mount dump', 'Unmount dump', 'Unmount R: drive', 'Find ECC', and 'XOR analyzer'. A 'Copy source dump' icon is highlighted with a black arrow pointing to it. The main workspace shows a data flow diagram with the following components: 'Reader' (0), 'Phy image' (Chip0_0_0, Chip1_0_0, Chip2_0_0, Chip3_0_0), 'ECC' (0, 1, 2, 3), 'XOR' (0, 1, 2, 3), 'Markers table' (0, 1, 2, 3, 4, 5, 6, 7), 'Arranger' (0, 1, 2, 3, 4, 5, 6, 7), 'Copy' (0, 1, 2, 3), 'Unit', and 'Data area' (0). Black arrows point from the 'Copy' elements in the diagram to the 'Copy source dump' icon in the toolbar. On the right, a 'Parameters' panel is visible with the following settings: 'Element Name: 0', 'Dump Length (bytes): 67166821632', 'Automatic structure: checked', 'Shadow copy File: shadowCopy_', 'Block size: 1048576', and 'Map: checked Show'. A green vertical bar is present at the bottom of the parameters panel.

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A logical image is available on the data area element. Now it's possible to run a file system viewer/ file assembler or file carver to extract the data.



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FILE SYSTEM VIEWER

The File System Viewer interface displays a workspace for 'Volume0 (ExFAT) 223.56 GB'. The left pane shows a tree view with 'Root' expanded, listing folders like 'SRECYCLE.BIN', '500Mb_BigJPEGs', and 'FOTO_Rusolut_15.10.2121'. The right pane shows a detailed file list with columns for Name, Ext, Size, and Last modified.

Name	Ext	Size	Last modified
SRECYCLE.BIN			02/27/2023 17:40:52
500Mb_BigJPEGs			11/24/2021 15:16:28
DATA SET - BIG PIC			09/29/2021 12:52:30
FOTO_Rusolut_15.10.2121			10/15/2021 15:02:42
MicroCamera_videos			08/01/2022 10:58:02
mSD whole soldering			09/29/2021 13:28:36
Phison Dynamic xor logical block size 3 times smaller than physical			03/22/2022 14:59:00
Sandisk XOR			05/06/2022 11:36:42
System Volume Information			02/27/2023 17:36:08
Test Data			09/29/2021 12:54:26
UFD_vias			09/29/2021 13:29:12
Video for carver			09/29/2021 13:26:12
VirtualMachines			09/29/2021 13:40:52
100MB77	dmp	100.00 MB	08/19/2022 12:55:32
100MBzeros	dmp	100.00 MB	04/15/2021 16:27:12
77_patern_1GB2	bin	1024.00 MB	02/04/2022 12:40:52
A. Mickiewicz, Pan Tadeusz	txt	473.21 KB	09/22/2020 11:17:04
Postprocessed	mp4	1.21 GB	12/14/2020 23:56:50
Soldering to second layer	mp4	60.97 MB	12/05/2020 18:24:58
Soldering to second layer youtube	mp4	68.96 MB	12/06/2020 19:04:36
Soldering to vias	mp4	109.11 MB	12/05/2020 13:25:36
Soldering to vias device 1	mp4	1.22 GB	12/15/2020 02:17:12
Soldering to vias device 2 youtube	mp4	117.26 MB	12/05/2020 18:09:52
Soldering to vias youtube	mp4	117.26 MB	12/05/2020 18:09:52
SolderingToPads	mp4	409.79 MB	12/03/2020 22:49:02
SolderingToPads youtube	mp4	417.93 MB	12/05/2020 00:25:50
Stitchd&Trimmed	mp4	1.21 GB	12/13/2020 22:32:08
Tolkien J.R.R. - Wladca piersieni t. 1 - Druzyna piersienia	txt	1000.01 KB	09/22/2020 11:18:02
Tolkien J.R.R. - Wladca piersieni t. 2 - Dwie wieze	txt	850.33 KB	09/22/2020 11:18:56
Tolkien J.R.R. - Wladca piersieni t. 3 - Powrot krola	txt	738.57 KB	09/22/2020 11:19:10
ZEROES1GB1	bin	1024.00 MB	09/16/2019 12:05:52

FILE CARVER

The File Carver interface shows a workspace for 'Dump/peg/Good:00010443264.jpg'. The left pane shows a tree view with 'Dump[63694]' expanded, listing folders like 'Jpeg[61500]', 'Zip[1680]', and 'Doc[5]'. The right pane shows a detailed file list with columns for Name, Ext, and Size. A preview of a recovered image is shown on the right side of the interface.

Name	Ext	Size
Dump[63694]		
Jpeg[61500]		
Critical damage[63]	Jpeg	13578 Kb
Good[61293]	Jpeg	13578 Kb
Medium damage[42]	Jpeg	11865 Kb
St error[102]	Jpeg	11865 Kb
Zip[1680]		
Footer not found[480]	Jpeg	11865 Kb
Contains bad files[32]	Jpeg	8034 Kb
Good[1132]	Jpeg	8034 Kb
Good[1132]	Jpeg	8034 Kb
zip_datades_not_supp[26]	Jpeg	8034 Kb
[16]	Jpeg	8034 Kb
Doc[5]		
Good[5]	Jpeg	8034 Kb
Xis[3]	Jpeg	8022 Kb
Good[3]	Jpeg	8022 Kb
Xis[7]	Jpeg	7952 Kb
Good[7]	Jpeg	7952 Kb
Odt[497]	Jpeg	7952 Kb
Good[486]	Jpeg	7860 Kb
Footer not found[4]	Jpeg	7860 Kb
Contains bad files[7]	Jpeg	7860 Kb
Doc[1]	Jpeg	7803 Kb
Good[1]	Jpeg	7803 Kb
Ppbr[1]	Jpeg	7335 Kb
Good[1]	Jpeg	7335 Kb
000010443264	Jpeg	7335 Kb
000083102976	Jpeg	7197 Kb
000010391808	Jpeg	7197 Kb
000084346880	Jpeg	7096 Kb
000010507776	Jpeg	7096 Kb
000084769024	Jpeg	7072 Kb
000010522112	Jpeg	7072 Kb
000010584832	Jpeg	6967 Kb
000084924672	Jpeg	6967 Kb
000010362368	Jpeg	6830 Kb
000082975744	Jpeg	6830 Kb
000010406400	Jpeg	6749 Kb
000083151360	Jpeg	6749 Kb
000084308736	Jpeg	6730 Kb
000010481408	Jpeg	6730 Kb
000010065536	Jpeg	6307 Kb