The MGT Disciple and Plus D PALS, finally unveiled V2.2

(Updated March 2024)

Background

One of the biggest mysteries of the Disciple and Plus D interfaces are the PAL20L8 ICs, what they do, how to get replacements, and how to get the fusemap (jedec file / equations) that they contain. I hope this document will answer all these questions, along with a thorough explanation of each logic equation that these nice ICs contain in their silicon make up.

2024 Update

Updated by original author to correct some typos (namely N1 and NREQ, should be M1 and MREQ) and to correct the interpretation of some equations (around Inhibit switch operation and RESET behaviour). Added a section on the Plus D describing its PAL logic (V2), a section explaining interface differences (V2.1) and included RAMSOFT Technical Guide v8c text (bumped to version 9 as it adds information on Gotek usage) (V2.2).

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 From what I understand from reading some posts on usenet, the original equations were on a disc that got lost, and remained unknown for some time. I also have seen some posts from Bob Brenchley indicating that he was in touch with Bruce, and if they were found, he would have no problem with the distribution.

As these ICs have a protection bit which stops you reading their fuse map, which is usually blown, finding out their contents and replacing them is difficult. Bruce, if you are out there, thanks for a GREAT interface, and if you want me to pull this page, I'll be more than happy to do so.

How did you figure it out then?

Fortunately, a nice Dutch man called Rudi Biesma placed his ICs in a high / low device which sends every logic combination to every pin and produces a table of the outputs. It then can produce a fuse map of the IC. With this lovely Jedec file from Rudy, I disassembled it and obtained the equations using PALASM, and then set about figuring out just what the heck was going on.

What is a PAL20L8?

A PAL IC is an older type of programmable logic IC. You can program it with Boolean equations to give whatever outputs you want under certain input conditions. PALs were later replaced by GALS (which can be programmed to act like a PAL) and now GALS have been largely replaced by CPLDs. The PAL20L8 ICs in the Disciple & Plus D have been out of production for many years now, and are increasingly hard to come by. Your best bet is to search for obsolete electronic component suppliers on the web. They are available, but can be pricey as minimum order quantities are required. The ones normally found in a Disciple are manufactured by national semiconductor, and are of the A variety (A is a speed rating A is the slowest). I have successfully replaced them with MMI PAL20L8B ICs which are slightly faster, and are pin for pin compatible. PAL20L8 ICs from other manufactures may be just as compatible, but it is well worth checking as these things are expensive (around £10 each, plus the min order, which is normally > £100). Rudi Biesma tried to replace his PAL20L8s with GALS but reported no luck – this may be due to the RESET race condition described later in this document.

Where can I get fully programmed PALs for the Disciple or Plus D?

Either buy the ICs yourself and get someone with a programmer to program them, or if you are really stuck I will supply both PAL ICs, fully programmed for £30 + postage.

The Disciple PAL ICs

The two PAL ICs (IC8 & IC9) in the Disciple do the following operations:

- Page out the Speccy ROM and enable the Disciple RAM / ROM when the Z80 accesses certain memory addresses (0x0001 (*), 0x0008, 0x0066, 0x028E)
- Page out Disciple ROM & RAM when a hardware reset is performed
- Page out Speccy ROM, enable Disciple ROM & RAM during network requests
- Holding the Speccy ROM out and the Disciple ROM & RAM enabled after they have been brought in until they need to be paged out again
- Provide the IO decoding when a request is written to port 0x7B (reset / set boot ; control of DOS needs to reloaded)
- Enable the WD1772 disc controller (IC4) when an IO request is written or read at its' I/O ports (0x1B, 0x5B, 0x9B, 0xDB)
- Generate a clock pulse for IC5 flip flop when an IO write request is sent to the Disciple control port (0x1F)
- Output a clock pulse to the printer port IC11 when data is written to port (0xFB)
- Enable the joystick controller ICs (IC1 & IC10) when an IO request is read from the joystick ports (Kempston and Sinclair)
- Tell the spectrum to WAIT when data is being pushed out to the network
- Avoid paging out Speccy ROM or responding to IO requests when Inhibit switch is pressed, or when Inhibited via an OUT instruction to port 0x1F, bit 4 (Note Inhibit switch needs to be pressed for software control of it via this method to work – check the circuit diagram)

(*) Except during a hardware reset cycle

You will see these IC's actually control most of the Disciple, and nothing works without either one, as their logic equations are intertwined between them.

The Disciple PAL Equations explained

Please understand how Boolean logic symbols are represented in this document:

^ means active low (ie. ^RD means that if a read is happening, this line will be LOW)

/ means NOT

+ means OR

* means AND

^/ is seen when an active low control line is in the LOW state (i.e. active). Example: ^/MEMREQ means the MEMREQ line is LOW (active)

You will also need to have a rough understanding of how the Z80 works (what lines are set when performing IO, memory fetches, read / writes etc) and a reasonable understanding of the Disciple itself. The latter can be obtained from the excellent Ramsoft "Disciple / +D Technical Guide", although please note it incorrectly states the Disciple and Plus D are paged in at address 0x0000 which is incorrect for both interfaces.

A short note about tristate. Some IC input / outputs can have 3 levels. These are logic zero, logic one and disconnected (i.e. just floating). The third state is very handy when you only want an IC to do stuff some of the time and pretend it's not there others. Just like the disciple ROM / RAM. While physically connected to the address / data bus, unless their Chip Enable (CE) pin is activated, their pins will be internally disconnected, so won't interfere unless requested to.

It is also recommended you look at the Disciple circuit diagram to see how these ICs fit together and link to other Disciple components.

Be aware that outputs O17 and O18 of IC9 feed into inputs I1 and I2 of IC8 and output O22 from IC8 feed into input I14 of IC9, providing a logic link between all the equations – this makes it slightly harder to understand what is going on.

In the equations I've substituted wherever possible the names of the signals on the Spectrum bus the Inputs and Outputs are connected to. The references p8_022, p9_O17 and p9_O18 refer to PAL IC8 Output 22, PAL IC9 Output 17 and PAL IC9 Output 18 respectively.

Onwards with these equations. Each PAL equation is listed, with my explanation below on the next pages.

CHIP DIS_ASM PAL20L8 (PAL IC8)

Pin Descriptions

PIN 1 p9_O18

PIN 2 p9_017

PIN 3 A10

PIN 4 A0

PIN 5 A4

PIN 6 ^RESET

PIN 7 ^WR

PIN 8 ^RD

PIN 9 ^MREQ

PIN 10 A12

PIN 11 A13

PIN 12 GND

PIN 13 A15

PIN 14 A14

PIN 15 O15 (/CE Disciple RAM)

PIN 16 O16 (/CE Disciple ROM)

PIN 17 O17 (/M1 & INHIBIT Switch)

PIN 18 O18 (NC – used as flip flop)

PIN 19 O19 (NC – used as flip flop)

PIN 20 ^ROMCS

PIN 21 O21 (NC)

PIN 22 O22 (PAL IC9, I12)

PIN 23 A11

PIN 24 VCC

Disciple IC8 EQUATIONS

```
O22.TRST = VCC

/O22 = /A4 * /^RD * ^MREQ

+ /A4 * /^WR * ^MREQ

+ /A10 * /A11 * /A8 * /A4 * /^RD * /^MREQ * /A12 * /A14 *

/A13 * /A15
```

Used as a partial equation to help form other equations in PAL IC9

```
O21.TRST = VCC

/O21 = ^ROMCS

+ /p9_O18* /^RD * O17
```

Used as a partial equation to O15, O16 and O20 (ROMCS). Condition met when Spectrum ROM paged out.

When system is NOT inhibited – it will respond to an IN IOREQ to port 0xBB (page IN Disciple) and memory reads from 0x0001 (except during a hardware reset), 0x008 (RST8), 0x0066 (NMI code), 0x028E (Key scan).

```
^ROMCS.TRST = VCC

/^ROMCS = /O17

+ O21

+ /^RESET

+ /p9_O18* /^WR
```

Pull speccy rom IN when Disciple Inhibited (/O17); hardware RESET or an OUT IOREQ to port 0xBB (page OUT Disciple) and ignore memory writes to 0x0001, 0x008 (RST8), 0x0066 (NMI code), 0x028E (Key scan).

```
O19.TRST = VCC

/O19 = O18

+ /^RESET

+ /p9_O17* /^RD
```

Partial equation to O15 and O18 below. Condition met when a reset happens or an IN to port 0x7B (set/unset boot flipflop), system reset or O18 below.

```
O18.TRST = VCC

/O18 = O19

+ /p9_O17* /^WR
```

Condition met when an OUT 0x7B (set boot flipflop) or O19 (IN 0x7B, reset boot flip flop). Used as a partial to O16 and O15 below.

```
O16.TRST = VCC

/O16 = ^ROMCS * O18 * /^RD * /^MREQ * /A14 * /A13 * /A15

+ ^ROMCS * O19 * /^RD * /^MREQ * /A14 * A13 * /A15
```

O16 is the Disciple ROM CE line, so this equation controls when the Disciple ROM should be paged in. Met when the Speccy ROM is OUT and we are reading from address < 8192 and the RAM flip flop is unset (Disciple ROM at 0x0000 – Disciple not boot strapped or needing reloaded) OR if the address is < 16384 (Disciple ROM at 0x2000, system boot strapped) and the RAM flip flop is not set.

```
O15.TRST = VCC

/O15 = ^ROMCS * O19 * /^RD * /^MREQ * /A14 * /A13 * /A15

+ ^ROMCS * O19 * /^WR * /^MREQ * /A14 * /A13 * /A15

+ ^ROMCS * O18 * /^RD * /^MREQ * /A14 * A13 * /A15

+ ^ROMCS * /^WR * O18 * /^MREQ * /A14 * A13 * /A15
```

O15 is the Disciple RAM CE line, so this equation controls when the Disciple RAM should be paged in. Met when the speccy ROM is OUT and we are reading / writing from address < 8192 (RAM flip flop set) or reading / writing from address < 16384 (RAM flip flop not set).

Phew IC8 done. It was the hardest. Glad that's over. Ready for IC9?

CHIP DIS_ASM PAL20L8 (Disciple IC9)

Pin Descriptions

```
PIN 1 A9

PIN 2 A5

PIN 3 A6

PIN 4 A7

PIN 5 ^WR

PIN 6 ^RD

PIN 7 ^IORQ

PIN 8 A3

PIN 9 A2

PIN 10 A1

PIN 11 A0

PIN 12 GND

PIN 13 NET

PIN 14 p8_O22

PIN 15 O15 (CLK Disciple IC5 flip flop, control port #1F)

PIN 16 O16 (/CS Disciple IC4 WD1772)

PIN 17 O17 (I2 PAL IC8)

PIN 18 O18 (I1 PAL IC8)

PIN 19 O19 (/CE Disciple IC1a joystick1)

PIN 20 O20 (/CE Disciple IC10a joystick2)

PIN 21 O21 (/WAIT)

PIN 22 O22 (CLK Disciple IC11)

PIN 23 ^M1

PIN 24 VCC
```

EQUATIONS

```
O22.TRST = VCC

/O22 = A5* A6 * ^M1 * A7 * /^WR * /^IORQ * A3 * /A2 *

A1 * p8_O22 * A0
```

Generate a clock pulse for the printer IC11 when an IOREQ write is sent to printer port (OUT 0xFB).

```
O21.TRST = VCC

/O21 = A5* /A6 * ^M1 * /A7 * /^WR * /^IORQ * A3 * /A2 *

A1 * p8_O22 * A0 * NET
```

Tell the Speccy to wait while a network request is written to the network port (OUT 0x3B).

```
O20.TRST = VCC

/O20 = /A5* /A6 * ^M1 * /A7 * /^RD * /^IORQ * A3 * A2 *

A1 * p8_O22 * A0
```

IOREQ read of joy1 port (0x1F). Set CE on IC10

```
O19.TRST = VCC

/O19 = A5* A6 * ^M1 * A7 * /^RD * /^IORQ * A3 * A2 *

A1 * p8_O22 * /A0
```

IOREQ read of joy2 port (0xFE). Set CE on IC1

```
O18.TRST = VCC


/O18 = A5* /A6 * ^M1 * A7 * /^IORQ * A3 * /A2 * A1 *
p8_O22 * A0
+ /A5* /A9* /A6 * /^M1 * /A7 * /^RD * ^IORQ * A3 *
/A2 * /A1 * /p8_O22 * /A0
+ A5* /A9* A6 * /^M1 * /A7 * /^RD * ^IORQ * /A3 *
A2 * A1 * /p8_O22 * /A0
+ /A5* A9* /A6 * /^M1 * A7 * /^RD * ^IORQ * A3 *
A2 * A1 * /p8_O22 * /A0
+ /A5* /A9* /A6 * /^M1 * /A7 * /^RD * ^IORQ * /A3 *
/A2 * /A1 * /p8_O22 * A0
```

Partial equation to IC8. Take this one a line at a time:

IOREQ to port 0xBB OR

Memory Read location 0x0008 (RST8) OR

Memory Read location 0x0066 (NMI code) OR

Memory Read location 0x028E (Keyscan) OR

Memory Read location 0x0001; Note at hardware reset the logic for this does not trigger, due to a presumed race condition on the RESET line and the Disciple logic to page itself out on RESET. This was tested on real hardware (Disciple & Spectrum +2).

```
O17.TRST = VCC

/O17 = A5* A6 * ^M1 * /A7 * /^IORQ * A3 * /A2 * A1 *

p8_O22 * A0
```

Partial equation to IC8. IOREQ to port 0x7B (reset / set boot port)

```
O16.TRST = VCC

/O16 = /A5* ^M1 * /^IORQ * A3 * /A2 * A1 * p8_O22 * A0
```

This is CE for IC4 WD1772 disk controller. Condition met when any IOREQ to ports (0x1B, 0x5B, 0xDB, 0x9B)

```
O15.TRST = VCC

/O15 = /A5* /A6 * ^M1 * /A7 * /^WR * /^IORQ * A3 * A2 *

A1 * p8_O22 * A0
```

This will generate a clock pulse for IC5 latch when data is written to the control IO port (0x1F, 31 Decimal). IC5 is the physical implementation of OUT 0x1F :

Port #1F OUT:

B0	Drive Select
B1	Side select
B2	Single / Double Density
B3	ROM bank select
B4	Inhibit switch control
B5	Through Edge connector A30
B6	Printer strobe
B7	Network

The Plus D PAL Equations explained

The Plus D has one PAL IC, a 20L8, the same as used in the Disciple. The equations are naturally different, the Plus D uses different IO ports and differs in some addresses being paged in (notably address 0x003A – Spectrum maskable interrupt). I've also noticed that it doesn't have full decoding logic so some of the IO ports can be accessed on multiple addresses. Some of the address line decoding logic is done by discrete logic (IC10A, IC10B, IC10C and IC9D), the output of which is fed into pin 23 of the PAL IC. My reading of this discrete logic says when all of the lines fed to the inputs are zero, the output will be 1. This is primarily used to decode the high address lines when doing IOREQ operations (my guess it avoids the need for another PAL IC).

Unlike the Disciple, the Plus D is NOT paged in at address 0x0001 or 0x0000 (as stated by RAMSOFT guide). And again, unlike the Disciple it doesn't have logic to do anything special on a RESET.

```
; JED2EQN -- JEDEC file to Boolean Equations disassembler (Version V063)
; Copyright (c) National Semiconductor Corporation 1990-1993
; Disassembled from alice.dpl. Date: 10-17-101
chip alice PAL20L8

i1=1 i2=2 i3=3 i4=4 i5=5 i6=6 i7=7 A6 =8 i9=9 i10=10 i11=11 GND=12
i13=13 i14=14 o15=15 o16=16 f17=17 o18=18 o19=19 o20=20 f21=21
o22=22 i23=23 VCC=24

/o22 = /MEMREQ* //IOREQ * //WR * A6 * A5 * /A2 * A1
IOREQ write access to 0xE2,0xE3,0xEA,0xF3,0xFB - WD1772 /CS
   + /MEMREQ* //IOREQ * //RD * A6 * A5 * /A2 * A1
IOREQ read access to 0xE2,0xE3,0xEA,0xF3,0xFB - WD1772 /CS
o22.oe = vcc

/f21 = /MEMREQ* //IOREQ * //WR * A6 * A5 * /A4 * A2 * /A3 * A1
   + f17
IOREQ write access to 0xE6,0xE7 (missing A7 line decode) - page out +D
Spectrum /ROMCE - Pages out Spectrum ROM by setting F21 high (flipflop with F17)
f21.oe = vcc

/o20 = /MEMREQ* //IOREQ * //RD * A6 * A5 * A4 * A2 * /A3 * A1
IOREQ to port 0xF7 (missing A7 line decode) - Printer busy / strobe LS175
o20.oe = vcc

/o19 = /MEMREQ* //IOREQ * //RD * A6  * A5 * /A4 * A2 * A3 * A1
IOREQ to port 0xEF (missing A7 line decode) - Disk control (side, A/B) LS175 clk
o19.oe = vcc

/o18 = /MEMREQ* //IOREQ * //WR * A6 * A5 * A4 * A2 * /A3 * A1
IOREQ WR to ports 0xF6,0xF7 (missing A7 line decode) - Printer output LS374 clk
o18.oe = vcc
```

/f17 = f21
Flip flop

+ /MEMREQ* //IOREQ * //RD * A6 * A5 * /A4 * A2 * /A3 * A1
IOREQ read to 0xE6,0xE7 (missing A7 line decode) - page in +D

+ /A15 * /A14* /A13 * i23 * //MEMREQ* /IOREQ * //RD * /A6 * /A5 * /A4 * /A2 * A3 * /A1
Memory read at 0x0008 (RST 8 instruction).
Note: i23 is given by discrete logic (IC9, IC10) outside of the PAL – simply put, A0,A7,A8,lA9,A10,A11,A12 must all be low for i23 to be high.

+ /A15 * /A14* /A13 * i23 * //MEMREQ* /IOREQ * //RD * /A6 * A5 * A4 * /A2 * A3 * A1
Memory read at 0x003A (Spectrum executing maskable interrupt)

+ /A15 * /A14* /A13 * i23 * //MEMREQ* /IOREQ * //RD * A6 * A5 * /A4 * A2 * /A3 * A1
Memory read at 0x0066
f17.oe = vcc

/o16 = /A15 * /A14* A13 * //MEMREQ* f21 * //RD
MEMREQ <16384 read (if paged in) enable Plus D RAM
+ /A15 * /A14* A13 * //MEMREQ* f21 * //WR
MEMREQ <16384 write (if paged in) enable Plus D RAM
o16.oe = vcc

/o15 = /A15 * /A14* /A13 * //MEMREQ* f21 * //RD
MEMREQ <8192 read (if paged in) enable Plus D ROM
o15.oe = vcc
`

Differences between the Plus D and Disciple

Aside from the obvious hardware differences (lack of joystick and network ports) there are subtle differences in behaviour between the interfaces.

Control Ports & Maskable Interrupt Address paging

The first thing that differs are the ports used to control the interface, these have different addresses and the individual bits in these ports and what they control also differ (for example the Plus D port 0xEF vs Disciple 0x1F which have similar functions, but bit order is different). This is largely down to different hardware / circuit design, the Plus D being simpler with only one PAL IC.

The addresses each interface are paged in during a Maskable Interrupt also differ (Plus D 0x003A vs Disciple 0x028E).

Reset /Initialisation Behaviour

The Disciple has logic in the PAL ICs which triggers on a RESET to page itself out, but also has logic to page itself in when accessing location 0x0001. The Plus D has neither. The Disciple does not page itself in at 0x0001 when a RESET is occurring meaning the initialisation code is not executed (luckily this avoids issues on the 128K machines where the EDITOR ROM is paged in at RESET). If the code in the Disciple at 0x0001 was to run, its code path would execute the NEW routine on the 48K ROM, which would cause a system crash on the 128K.

The most significant thing the unused initialisation code does on the Disciple is to initialise port 0x1F to zero. This has the effect of resetting all bits in Flip Flop IC3 to zero and clocking the IC (initialising the floppy interface drive & side select, printer, software Inhibit control and network). Fortunately, this not being done at RESET has no negative effect and the Disciple works fine without this. The Plus D has no paging logic at RESET or address 0x0001. Also, its hardware control port is implemented differently, via a 74LS175 IC which has a /CLEAR line, directly connected to the Z80 /RESET line, the effect being at RESET all outputs are zeroed. Note, in both Plus D ROM and Disciple ROM, the initialisation code exists at location #0001 but is not used - both interface code paths end at location #11CB (start/NEW in 48K ROM, which as stated above would cause a crash on the 128K models).

Both systems perform initialisation (e.g. printer, drive ID and side selection) as part of system boot (i.e. on executing RUN) and further initialisation as part of Maskable Interrupt handling, described below.

Hook Code 0x32 Difference

The treatment of hook code 0x32 differs on both interfaces. This is an Interface One hook code to call any address in its ROM (in fact any address at all, including Spectrum RAM). The address to call is placed in the system variable HD_11 (address 0x5CED).

On the Disciple calling this hook code simply executes a RET instruction (sensible as the Interface One ROM has a completely different memory layout), but on the Plus D it will jump to the address given in the DE register. This can create issues for Microdrive based software. I noticed in Hisoft Gens it would crash when the CAT command was given in GENS with the Plus D attached, and do nothing on the Disciple. This is because the GENS code calls the Interface One ROM routine directly (there is no hook code for CAT).

Maskable Interrupt Behaviour

Both the Plus D and Disciple are paged in every 50th of a second when the Spectrum performs a Maskable Interrupt (generated by ULA). This is done differently on both interfaces, the Plus D being paged in at address 0x0003A (2 instructions after MI handling in main Spectrum ROM) while the Disciple is paged in during the key scan routine at 0x028E. Both interfaces do an immediate RET at 0x0038 (RST 38) the effect being to ignore a maskable interrupt if they are already paged in. Both do different things when paged during the maskable interrupt routine.

The Plus D checks to see if it has been initialised and if not, does some basic initialisation (clears its 8K RAM, clears control and printer ports, sets default system variables), then takes over the printer channel (#3) finally exiting to the Spectrum key scan routine. If it has already been initialised it pages out and exits to the Spectrum key scan routine

The Disciple is more complex. If the system is initialised (RAM is at location #0000 - system bootstrapped or acting as a pupil station), the maskable interrupt routines do some network operations if the network is enabled (exiting immediately if network is quiet), take over the printer channel (#3) and finally exit to the Spectrum key scan routine. If the system is not yet initialised, (ROM is at location 0x000) the Maskable Interrupt behaves differently using the ROM routine at 0x229D. This routine performs more complex initialisation (ROM/RAM swopping as needed, system variables and control port initialisation).

Disciple ROM/RAM Swopping

This is best described by reading Rudy Biesma's comments from the Disciple ROM disassembly :

```
By examining the contents of #1DE4 when RAM is paged-in low, or #3DE4 when
it's paged-in high, this routine decides what has to be done:
- Whenever the power is turned on, the ROM resides low. #1DE4 contains #45,
so #3DE4 is examined which contains some random value (should that be #44,
the Spectrum will crash). Otherwise a 'minimal' system is created by
copying the first 2335 bytes of ROM to RAM and then setting RAM low. This
is indicated by #1DE4 containing #53.
- In case of a minimal system #1DE4 contains #53, and the routine returns
  immediately to the keyboard routine in 'main' ROM.
- By giving FORMAT nn (2nd n>=10) a minimal system can be changed to a
PUPIL system. This is indicated by a #4E value in #1DE4. In this case the
routine continues with scanning the network for activity.
- By giving RUN at a minimal system, the system file is loaded from disk.
If a system file has been loaded #1DE4 contains #44.
- To get rid of a system file the reset button has to be pressed twice or
IN 123 has to be given twice. After the first of these ROM resides low,
#1DE4 holds #45 so #3DE4 is inspected which holds #44. The contents of
#3DE4 are set to #00 and some DISCiPLE system variables are reset. Before
returning the RAM is set low again.
- When pressing reset or giving IN 123 for the second time, #3DE4 (RAM is
now high) holds #00. This means a minimal system will be created.
- By giving IN 123 or a reset once, a minimal or PUPIL system can be reset,
which results in a minimal system being created.
```

The Plus D does not do this.

Single Density Drive Support

The Plus D only supports Double Density drives (stated in manual and pin 26 of WD1772 wired to ground). The Disciple supports Single and Double Density drives.

Why did you do this you madman?

The first time round – 2003 - Amazing what'll you'll do to get your beloved disciple working again after 10 years..... and my way of giving back to both the open source and Sinclair community, as well as helping to fix other broken beautiful Disciple interfaces.

The second time round – 2024 – I was disturbed to find the Disciple was not working in FUSE for the 128k models and was determined to find out why. This also led to me decoding the Plus D PAL and revising the Disciple information.

You're wrong about something…

Tell me! This is my interpretation and may well have errors. Let me know, I'll check and correct. Email me at alandpearson@gmail.com

I just want to program my PAL chips! Can I have the jedec source files please?

By all means, download IC8 and IC9 for the Disciple and IC4 for the Plus D.

Okay what about the Plus D?

~~Hmm haven't got that far yet. The jedec source is HERE for the single PAL in it, but I haven't dissassmbled or figured out it's equations yet. Someday.~~ Done.

How can I thank you?

Thank Bruce Gordon for making such wonderful interfaces, and Rudi Biesma for sending me the jedecs and the disassembly here.

And the Disciple circuit diagram / schematic?

Oh yeah, here you go.

Thanks to Rudy Biesma for supplying the Disciple fuse maps, and Ian Worsley for the Plus D. Also thanks to Ramsoft for producing the Disciple/Plus D technical guide, and the excellent realspec emulator.

Alan Pearson, (alandpearson@gmail.com) March 2024

RAMSOFT proudly presents:

D I S C i P L E / + D T E C H N I C A L G U I D E

Revision 9 (March 2024)

SUMMARY:

DISCLAIMER

Although we have tried to be very accurate, this document may contain some errors. The authors do not assume any responsibility for any loss and/or damage directly or indirectly caused to your system by use of any information reported here.
See the credits at the end of the document on how to contact the authors.

FOREWORDS

We (Ramsoft) have been using the DISCiPLE interface for a long time and we have appreciated all the power of this disk system. We have spent many hours trying to understand the smallest details to make full use of its capabilities, and a lot still has to be known.
Now we have decided to release all the info we collected mostly ourselves, in the hope that it may be useful to anybody and that it will encourage the development of new programs and products for this wonderful system.
[A Pearson, March 2024] Very sadly, RAMSOFT appear to have disappeared from the scene, so I've bumped the version number of this 20 year old document and added a section about Gotek use and some small corrections to page-In addresses for both interfaces.

COMMON TERMS
============

  DRAM - The sector buffer.
   RPT - A system variable which points to a byte in the DRAM.
  UFIA - User File Information Area, a 24 byte structure which describes
         a file for system calls.
  DFCA - Disk File Channel Area.

1. DISCiPLE / +D features
=========================

     8 KB EPROM (for disk BIOS)
     8 KB RAM
     NMI magic button (snapshot)
     Parallel port (not bi-directional)
     Floppy disk port (controlled by VL1772 FDC)
     High speed disk operations: load 128K in less than 7 seconds.

 DISCiPLE only features:

     Two ATARI joystick ports (Sinclair 1, Sinclair 2 / Kempston)
     Two network connectors (Interface 1 compatible, 3.5mm mono jack)
     Inhibit button (to lock out the interface)
     Throughout bus connector (to plug in other devices)

2. MEMORY LAYOUT
================

When the interface memory is paged in (see below), the first 16K of the
Z80 address space have this mapping:

Address	DISCiPLE GDOS	DISCiPLE UNIDOS	+D
0x0000	8K RAM	8K ROM	8K ROM
0x2000	8K ROM	8K RAM	8K RAM

So, UNI-DOS memory mapping is the same as +D, even on DISCiPLE.
Read [3.1] to see how it is possible to swap ROM/RAM addresses on the
DISCiPLE.

3. DISCiPLE and PlusD I/O PORTS
===============================

NOTE: Joystick 1 is both Kempston (port 1Fh) and Sinclair 2 (keys
6,7,8,9,0)
      Joystick 2 is Sinclair 1 (keys 1,2,3,4,5)
      Network is an Interface 1 compatible net.

DISCiPLE I/O ports:

Port	In	Out	Notes
1Bh	FDC status	FDC command	See also section 13
5Bh	track register	track	
9Bh	sector regist.	sector register	
DBh	data register	data register	
1Fh	Joystick 1	control:	
	b0 right	drive select	
	b1 left	side select	
	b2 down	single/double density	
	b3 up	ROM bank select	
	b4 fire	Inhibit switch control	
	b5 --	ext. select (?)	
	b6 PRN BUSY	printer STROBE	
	b7 network	network	
3Bh	--	wait when net=1	(*)
7Bh	set boot	reset boot	see [3.1]
BBh	mem. page in	memory page out	(**)
FBh	--	printer data	
FEh	Joystick 2		scanned as Sinclair joy.

(*) Port 3Bh is used for network synchronization (same as bit 5 of Interface One's port EFh). Any OUT to port 3Bh will halt the Spectrum until the logic level on the network is 0. It is used to wait for the start bit of a transmission frame. The network bus carries TTL logic levels (0 = 0 Volts, 1 = 5 Volts). The bit rate is 87.5 Kbps and data are exchanged in packets of 256 bytes max using a simple data-link level protocol.

(**) DISCiPLE memory is also paged in whenever the Z80 fetches an instruction from the following addresses:
~~0x0000~~ 0x0001, 0x0008, 0x0066, 0x28E.

PlusD I/O ports:

Port	In	Out	Notes
E3h	FDC status	FDC command	See also section 13
EBh	track register	track	
F3h	sector regist.	sector register	
FBh	data register	data register	
EFh	b0/b1 --	drive select	
	b2 --	--	
	b3 --	--	
	b4 --	--	
	b5 --	ext. select (?)	
	b6 --	printer STROBE	
	b7 --	side select	
E7h	mem. page in	memory page out	(***)
F7h	b0/b6 --	printer data (8 bits)	
	b7 PRN BUSY		

(***) +D memory is also paged in whenever the Z80 fetches an instruction from the following addresses:
~~0x0000~~, 0x0008, 0x003A, 0x0066.

3.1 DISCiPLE PORT 7Bh AND MEMORY ADDRESSES

Port 7Bh (123 decimal) is available only on the DISCiPLE and has a flip flop attached to it. It can be used to swap the RAM/ROM addresses in this way:

Access	ROM	RAM	Purpose
IN	0x0000	0x2000	reset ff
OUT	0x2000	0x0000	set ff

This feature is used by GDOS to know if it necessary to load the system file from disk on boot or after two consecutive resets without any DOS command between them; UNIDOS ignores this feature, so any swap attempt will result in a system crash.

In GDOS there is a variable located in RAM at offset 0x1DE4 that is set to 0x44 ('D') after a BASIC syntax check (i.e. after a RST 08h with a code lower than 1Bh) and after a bootstrap: this variable indicates that the DOS services have been called almost once. Whenever the user resets the computer, the flip flop attached to port 7Bh is reset, so the ROM will be placed at 0x0000. When the first interrupt occurs, the keyboard scanning routine is called at 0x028E and the DISCiPLE memory is automatically paged in. At offset 0x028E in the DISCiPLE's ROM there's a routine that checks if the variable we said above holds 0x44: if it's the case, then the same routine puts 00h in there to say that DOS services haven't been called since last reset; otherwise the routine sets the variable to 0x53 ('S') and copies the first 2335 (0x091F) bytes of ROM in the RAM: in this case the system file has to be loaded again.
When all is finished, the memories will be swapped again (i.e. the flip flop will be set) by OUTing to port 7Bh, the DISCiPLE paged out by OUTing to port BBh and the keyscan routine is finally executed.

INning from port 7Bh has the same meaning of a system reset for the DOS, so after reading 2 times from port 7Bh without typing a DOS command between them the system file needs to be reloaded.

NOTE that since all this is based on the keyscan routine in the Spectrum's ROM, nothing will happen by INning from port 7Bh if the call is not performed (i.e. if interrupts are disabled in IM 1 or we're not in IM 1 or keyboard is scanned in a custom way); however the last operation with port 7Bh must be an OUT before the routine in the ROM is executed if you want to keep the system safe by resetting once.

4. USER FILE INFORMATION AREA (UFIA)

This is a DOS structure often used by the kernel routines and usually pointed to by the register IX.

Offset	Len	Meaning
0	1	Drive number (1, 2 or '*' (2Ah) for current)
1	1	Program number (in the directory)
2	1	Stream number
3	1	Device density type ('d'=DD, 'D'=SD)

4	1	Directory description (see below)
5	10	File name (padded with spaces)
15	1	File type (see below)
16	2	Length of file
18	2	Start address
20	2	Basic length
22	2	Autostart line

5. SYSTEM CALLS (both DISCiPLE and +D)

To invoke system services you must use the IF1 protocol:

```
RST 8
DB #service
```

All the functions return an error code into register A.

IMPORTANT NOTES:
You cannot perform RST 8 calls from within a routine located into the interface's RAM.
You must not call ROM address 0x028E (keyboard scanning routine) from within an interrupt routine, since this would crash the Spectrum when a DISCiPLE/+D is connected; some programs crash due to this fact (eg SoundTracker v1.1) - you may try to correct the problem replacing the CALL 0x028E with a RST 0x38.
A few programs (like some games converted to disk) do not use the RST 8 mechanism but make absolute CALLs to the DOS or the BIOS routines instead - a very bad practice!

This is the list of GDOS3 (G+DOS2) hook codes with input parameters:

Implemented Interface I hook codes:

```
 CONSIN (1Bh) - Console input
CONSOUT (1Ch) - Console output
 PRTOUT (1Fh) -
 KBDTST (20h) -
 SELDRV (21h) - Select drive
 OPTMPM (22h) -
 CLOSEM (23h) -
  ERASE (24h) -
  RDSEQ (25h) -
  WRREC (26h) -
 OPTMPM (2Bh) -
 DELBUF (2Ch) -
 UNPAGE (31h) - Unpage shadow ROM
   CALL (32h) - Call shadow ROM routine
```

GDOS3 (G+DOS2) specific hook codes:

```
  HXFER (33h) - transfer file description and header to the DFCA.
                IX = UFIA address
  OFSM  (34h) - open file sector map with the info in the DFCA.
                The RTP is set to the beginning of the DRAM.
  HOFLE (35h) - open a file.
                IX = UFIA
                Combines the previous two functions.
```

```
              Sets the last 9 bytes of UFIA with the file header.
SBYT  (36h) - Save a byte to DRAM location pointed by RTP.
              A = byte to save.
              If the sector buffer is full, it is automatically saved
              to disk.
HSVBK (37h) - Save a block of data.
              DE = start address of data.
              BC = number of bytes to save.
CFSM  (38h) - Close file sector map.
              Flushes DRAM, closes file and updates the directory.
PNTP  (39h) - Output a byte to the parallel port.
              A = byte to output.
COPS  (3Ah) - Copy the screen to printer.
HGFLE (3Bh) - Get a file from disk.
              IX = UFIA
              The first sector is loaded to DRAM and RPT is set to the
              first byte.
LBYT  (3Ch) - Load the byte pointed by RPT.
              Returns A = byte read.
              If needed, another sector is read from the disk.
              RPT is updated consequently.
HLDBK (3Dh) - Load a block of data.
              DE = start address (where the data will be put)
              BC = number of bytes to read
WSAD  (3Eh) - Write the DRAM to a sector in the disk.
              D = track
              E = sector
              RPT is restored to the beginning of DRAM.
RSAD  (3Fh) - Read a sector to DRAM.
              D = track
              E = sector
              Same as 3Eh.
REST  (40h) - Reset drive and seek track 0.
              Drive number is specified into the UFIA.
HERAZ (41h) - Erase the file on disk identified by UFIA.
              IX = UFIA address.
      (42h) - Large screen dump
PCAT  (43h) - Disk catalogue
              It uses the information in the UFIA. Drive and stream must
              be set up.
              Offset +0Fh of UFIA may contain one of the following:
                02h for CAT !
                04h for CAT
                12h for CAT ! with a filename mask
                14h for CAT with a filename mask
              The filename must be stored starting at offset +05 of UFIA
              and may contain wildcards.
HRSAD (44h) - Load sector
               A = drive number
               D = track number
               E = sector number
              IX = Address to load to
HWSAD (45h) - Save sector
               A = drive number
               D = track number
               E = sector number
              IX = Address to save from
      (46h) - Open and close streams (how?)
PATCH (47h) - Pages the shadow memory
              Returns HL=0 on DISCiPLE
                      HL=1 on PlusD
```

HL=2 on DiSCDOS

UNIDOS specific hook codes:

(48h) - Load file
(49h) - Verify file
(4Ah) - Merge
(4Bh) - Save file
(4Ch) - Open file
(4Dh) - POINT (see UNIDOS)
(4Eh) - Flush buffers to disk
(4Fh) - Close file
(50h) - Clear channels
(51h) - Rename file
(52h) - Move stream
(53h) - Move file
(54h) - Select disk and directory

5.1 INTERNAL SYSTEM CALLS (both DISCiPLE and +D)

Here is the purpose of the RST commands when the DISCiPLE or the +D memories are paged in.

RST 00h - Reset
RST 08h - Call system services; the required service code must follow (1)(2)
RST 10h - Call in Spectrum ROM; the routine address must follow (3)
RST 18h - GDOS, G+DOS : reserved (for syntax check)
Uni-DOS : low-level system services; the required service code must follow
RST 20h - Print DOS error report : the error code must follow
RST 28h - Performs a RST 20h in the Spectrum ROM
RST 30h - Gets interpreter status : Z=0 if checking syntax, Z=1 if executing
RST 38h - Enables interrupts

(1) = ROM 1 must be paged in Spectrum 128K
(2) = The interface is automatically paged in by the hardware
(3) = Be sure that the right Spectrum ROM is paged in

5.2 EXAMPLE: LOADING A FILE.

Here is the simple loader that we have often used in our programs. It will load a CODE file called "blk0.DF" in memory at its original start address. This routine will work fine with DISCiPLE, +D and UNIDOS (all versions). Note: no error checking is done.

```
 LOAD:  LD   IX,UFIA          ; IX must point to the UFIA
        RST  08  DB 3B        ; HGFLE: open the file
        LD   DE,UFIA+0F       ; the file header will be put here
        LD   B,09             ; the first 9 bytes of the file
L_HDR:  RST  08  DB 3C        ; LBYT: get a byte from the DRAM
```

```
                LD   (DE),A            ; store the byte
                INC  DE
                DJNZ L_HDR             ; fetch all the 9 bytes
                LD   DE,(UFIA+10)      ; get the file start address
                LD   BC,(UFIA+12)      ; get the file length
                RST  08  DB 3D         ; HLDBK: load the whole block of
data
                RET                    ; finished!
```

Now the UFIA follows. Only the first 15 bytes must be preset by the user before calling HGFLE.
The last 9 bytes are overwritten with the 9 bytes header of the file.

```
UFIA:           DB 01,                 ; drive number ('*' for default)
                   00,
                   00,
                   'd',
                   04,                 ; file type 04 = CODE
                   "blk0.DF   ",       ; file name (padded with spaces)
UFIA+0F            00,                 ; will contain the ROM-ID
UFIA+10            00, 00,             ; will contain the file address
UFIA+12            00, 00,             ; will contain the file length
                   00,
                   00,
                   00,
                   00
```

Note that loading address and length are read from the 9 bytes header of the file itself. To force the file to be loaded at a different address, simply change the LD DE,(UFIA+10) instruction (e.g. with a direct LD DE,nn).

6. DISK LAYOUT

The disk has 80 tracks of 10 sectors (512 bytes double density, 256 bytes low density) each, for a total capacity of 800KB (DS/DD).
The first four tracks of the disk (tracks 0-3 side 0) are reserved for the system and contain the disk directory, leaving 780KB available for user data.
The directory consists of 80 consecutive file descriptors, each one taking 256 bytes; thus, the descriptor of file #48 resides in the first 256 bytes of sector 4 track 2.
The directory has a fixed dimension and can only contain up to 80 files. UNIDOS overcomes this limitation introducing subdirectories and allowing to specify the maximum number of file entries for each directory.

Disks formatted with DISCiPLE or +D can be read and written by common PC disk drives and viceversa.

7. FILE DESCRIPTOR FORMAT

Now we will see the details about a single directory entry.
NOTE: All numbers are in decimal.

General structure:

```
OFFSET   MEANING
  0      File type (see FILE-TYPES table); 0 = erased (free entry)
 1-10    Filename (padded with spaces)
11-12    Number of sectors occupated by the file (in Motorola byte order)
 13      Track number of the first sector of the file
 14      Sector number of the first sector of the file
15-209   Sector allocation bitmap. Each bit corresponds to a disk sector.
         A bit is set if the corresponding sector belong to the file.
         Examples: byte 15, bit 0 corresponds to track 4, sector 1;
         byte 16, bit 3 means track 5, sector 2...
         IMPORTANT NOTE:
         The s.a.b. is used only during saving operations: the s.a.b. of
         all the 80 files are merged together (OR) so that the system
         knows which sectors are free (not allocated to any file).
         During loading a faster method is used: each sector contains
         only 510 bytes of data; the last two bytes contain the
         track number and the sector number of the next sector of the file,
         respectively. The last sector of the chain contains (0,0) as the
         last two bytes.

210-255  Depend on the file type.

BASIC (type 1)
---------------
211      Always 0 (this is the id used in tape header)
212-213  Length
214-215  Memory start address ( PROG when loading - usually 23755)
216-217  Length without variables
218-219  Autostart line
NOTE: These 9 bytes are also the first 9 bytes of the file.

NUMBER ARRAY (type 2)
---------------------
211      Always 1 (this is the id used in taper header)
212-213  Length
214-315  Memory start address.
216-217  Array name, probably ignored.
218-219  Not used
NOTE: These 9 bytes are also the first 9 bytes of the file.

STRING ARRAY (type 3)
---------------------
211      Always 2 (this is the id used in tape header)
212-219  Same as for type 2
NOTE: These 9 bytes are also the first 9 bytes of the file.

CODE FILE (type 4)
------------------
211      Always 3 (this is the id used in tape header)
212-213  Length
214-315  Start address
216-217  Not used
218-219  Autorun address (0 if there is no autorun address)

48K SNAPSHOT (type 5)
---------------------
211-219  Not used
220-255  Z80 registers (in words) in the following order:
```

```
  IY IX DE' BC' HL' AF' DE BC HL I SP (see below for R and AF)
```

Register I is in the MSB of the corrisponding word (byte offset 239), so that it is loaded with:

```
  POP AF
  LD I,A
```

The Interrupt Mode is desumed by the value of the I register: if it contains 00h or 3Fh then IM1 is assumed, else IM2 is set. The IFF2 status (IFF1=IFF2) is retrieved from the P/V bit of the flag register F.

SP is actually SP-6, because the original stack is "corrupted" with the following 6 bytes (in ascending order):

```
  R AF PC  ( ----> decreasing stack )
  |     |
  SP    SP+6 (original SP)
```

(R is in the MSB of the corresponding word) so that the return code could be something like this (actually it is a bit more complex):

```
  POP AF
  LD R,A
  POP AF
  RET
```

MDRV (type 6)

This is a microdrive cartridge image. Details omitted.
NOTE: UNIDOS mdrv files are completely different from GDOS ones.

SCREEN$ (type 7)

Same as type 4 with Start=16384 and Length=6912

SPECIAL (type 8)

211-255 Any meaning assigned by the programmer.

128K SNAPSHOT (type 9)

Same as 48K Snapshot. The first byte of the file is a copy of the page register (port 0x7FFD), usually held in the system variable BANKM (23388). The 8 RAM pages are saved in ascending order from 0 to 7.

OPENTYPE (type 10)
---
210   Number of 64K blocks in the file
211   Always 9 (not sure)
212-213 Length of the last block
214-255 Not used

NOTE: Opentype files can be more than 64K in length and are usually created and handled with the stream-related BASIC statements, such as OPEN #, CLOSE #, PRINT #, INPUT # and so on.
See chapter [9] for a brief description of these statements.

EXECUTE (type 11)

210-255 Same as CODE file (type 4), but Length=510 and Start=0x1BD6 implicitly(0x3DB6 for +D). The sector is loaded into the interface RAM and executed (it should contain relocatable code!).

SUBDIRECTORY (type 12) - UNIDOS

210-212 Same as Opentype (type 10). This file is always held on contiguous sectors. The last two bytes of a sector do not contain the address of the next sector. The structure is the same as the root directory,but the first entry contains the file header number of the parent directory. The last two bytes of the last sector contain 0xFFFF.
213 Capacity (number of file entries allowed).

CREATE (type 13) - UNIDOS

210-255 Same as CODE file but the start address is ignored.

8. FILE-TYPES TABLE

This table lists the various MGT file types with their correspondent ID's. Where possible, it is also reported the file type ID used by the standard Spectrum ROM in the tape header. The ROM-ID is part of the 9 bytes header of the file (same as bytes 211-219 of the directory entry).

NOTE: under UNIDOS, add 128 for hidden files and 64 for protected files.

Code	Type	CAT string	ROM-ID
0	ERASED (free entry)	(NA)	NA
1	BASIC	BAS	0
2	NUMBER ARRAY	D.ARRAY	1
3	STRING ARRAY	$.ARRAY	2
4	CODE	CDE	3
5	48K SNAPSHOT	SNP 48k	NA
6	MICRODRIVE	MD.FILE	NA
7	SCREEN$	SCREEN$	NA
8	SPECIAL	SPECIAL	NA
9	128K SNAPSHOT	SNP 128k	NA
10	OPENTYPE	OPENTYPE	NA
11	EXECUTE	EXECUTE	NA
12 (UNIDOS)	SUBDIRECTORY	DIR	NA
13 (UNIDOS)	CREATE	CREATE	NA

9. GDOS EXTENDED BASIC SYNTAX

GDOS extends the BASIC to provide support for disk operations.
When you switch the Spectrum on, you must initialize the system; to do so, insert a disk containing the operating system file ("SYS*" on DISCiPLE and

"+SYS*" for +D) into the first drive and then enter "RUN".
The DOS also looks for the first file called "auto*" and runs it if found.
The "auto*" file is not searched for if the command "RUN boot" is entered.
NOTE: File names are case insensitive and may contain wildcards ('*' and '?').

To show the disk contents, enter:

```
CAT 1 (for drive 1)     or
CAT * (current drive)
```

You may also enter commands like these:

```
CAT 1;"a*"
CAT #3;1;"sys*"
CAT 1!
CAT #3;1!
```

so you can redirect the CAT output to any channel and you may specify a file name which may contain wildcards to show only matching files.
If the command ends with a '!' then an abbreviated catalogue is shown, containing just a list of (matching) file names.

To LOAD/SAVE a file:

```
LOAD d<dn>;"filename" [CODE|SCREEN$|DATA|etc]
LOAD p<fn>
SAVE d<dn>;"program" [CODE|LINE|SCREEN$|etc]

where <dn> is a drive number (1-2)
      <fn> is a file number (1-80)
```

You must specify 'S' to load a 48K snapshot and 'K' for a 128K snapshot.
Case of letters 'S' and 'K' is important.

Examples:

```
 LOAD d1;"screen" SCREEN$
 LOAD d*;"pippo"             loads program pippo from the current drive
 LOAD d1;"snap128"K          loads the 128K snapshot 'snap128'
 SAVE d2;"rom" CODE 0,16384  this saves the DISCiPLE memory!
```

Note: "d1" with lowcase 'd' refers to DS DD disks (80 tracks double sided); in ROM version 3 the only difference seems to be that if you use 'D' a CAT command is also performed after the operation.
Early versions of the OS used "D1" (capital 'D') for single sided disks.
This applies always when you have to specify the 'd<dn>' field.
Please use only DS/DD disks.

When saving CODE files, an autostart address can be specified as a third parameter:

```
 SAVE d*;"runme" CODE 32768, 8192, 33000
```

so when you load it back with LOAD CODE, it will be automatically launched with an implicit RANDOMIZE USR 33000.

Each file can be referred both through its name and its directory number, so if file "screen" is listed as number 7 you may also enter:

```
 LOAD p7
```

Note that if you use the abbreviated notation, each file will be loaded accordingly to its type (i.e. you can a CODE file will be loaded into memory at its start address).

Of course MERGE and VERIFY are also available with a similar syntax.

To erase a file from the disk, enter:

```
 ERASE d1;"file2del"
 ERASE d1;"*"                dangerous!
```

The ERASE command can also be used to rename a file:

```
 ERASE d1;"oldname" TO "newname"
```

To format a disk, use:

```
 FORMAT d1                   double density (250 Kbit/sec)
```

or

```
 FORMAT sd1                  single density
```

GDOS also extends streams, so that you can redirect a stream to a file and vice versa. If you open a channel for writing to a disk file, then an OPENTYPE file is created. Opentypes can be more than 64K in length. Channels are accessed with the usual PRINT, INPUT, INKEY$, etc. commands. Examples:

```
 OPEN #4;d1;"archive"
 OPEN #5;d1;"temp" OUT       open for writing only
 OPEN #5;d1;"temp" IN        open for reading
 MOVE #3 TO #4
 MOVE #4 TO d1;"temp1"
 MOVE d1;"temp2" TO #4
 CLOSE #4
```

Note that disk-mapped channels are buffered, so data is read/written to disk only when the 512 bytes buffer is empty/full.
When accessing BASIC, CODE, DATA and SCREEN$ files through streams, remember that these files start with a 9 bytes header and the actual data starts at byte 10.

To copy a file into another, use:

```
 SAVE d1;"file1" TO d2;"file2"
```

Since the SAVE TO command uses all the RAM available, when it has finished a system reset occurs.

You can LOAD/SAVE single disk sectors with this syntax:

```
 LOAD @d,t,s,address
 SAVE @d,t,s,address
```

where 'd' is a drive number (1 or 2)
      't' is the track number (0..79 + 128 if side 1)
      's' is the sector number (1..10)
      'address' is the address of the 512 bytes buffer

For example, you may read the first sector of the disk (which holds file descriptors number 0 and 1) with LOAD @1,0,1,40000.

DISCiPLE GDOS recognizes the Microdrive syntax, so you can enter commands like this:

```
 LOAD *"m";1;"pippo"
```

which will load the BASIC program pippo from drive 1. All your microdrive programs should run over GDOS without modifications. Remember that PlusD does not support the IF1 syntax.

9.1 THE NETWORK

GDOS (DISCiPLE) implements an IF1 compatible network, with some enhancements.
Up to 63 Spectrums can be connected together and share their resources (files and printers) simply through a 3.5 mm mono jack cable.
Each station is given an unique station number ranging from 1 to 63.
The station number is assigned with the command:

```
 FORMAT Ns
```

where 's' is the station numer (1-63). This command can be entered even without having the system file loaded (i.e. system not booted).

Station number 0 is reserved for broadcasting. If you enter FORMAT N0, the network is switched off; type FORMAT Ns to switch it on again.

Station numbers are divided into four classes:

Number	Purpose
0	Broadcasting
1	Master station
2-9	Assistants (they load the system file)
10-63	Pupils or assistants (pupils do not load the system file)

The following network configurations are possible:

1. Shared Access Network

In this model, station number 1 owns the resources (disk drives and printer)and acts as a master. The other stations are called pupils and can access files which are onto the master's disks and print with the master's printer. Only the master must load the system file. Since they don't have to load the system file, pupils are identified with station numbers greater or equal than 10. So, if you try to enter FORMAT N8 without the system loaded, you get an 'Invalid station number' error message.

The master can send a file "pippo" to pupil number 16 with:

```
 LOAD d1;"pippo"          first load the file, a Basic program in this
case
 SAVE N16                 send it to station 16
```

Of course you can send CODE files, SCREEN$, etc. too!
You can send the file to all the stations using broadcast:

```
 SAVE N0                   send to all
```

Station 6 can receive the program from the master entering:

```
 LOAD N1                   receive from station 1 (the master)
```

Each station can receive a broadcast message with:

```
 LOAD N0
```

Pupils can also send broadcast messages with SAVE N0 and communicate with other pupils in the same way.

The most interesting thing is that a pupil can enter disk and printing commands as if the disk drives and the printer would be connected to it. So, station number 6 can get the master's disk directory simply with:

```
 CAT d1
```

and load file "pippo" with:

```
 LOAD d1;"pippo"
```

Of course pupils can also save files onto the master's disk, and use its printer with the common

```
 LLIST, LPRINT or COPY SCREEN$
```

commands.

The master has the ability to force data transfer from and to a pupil station. On the master, if you type:

```
 LOAD F4 SCREEN$
```

then the Spectrum number 4 will stop and transfer its current SCREEN$ to the master, which can therefore see what's going on at station 4. Similarly, you can also enter:

```
 SAVE F8
```

which will force station number 8 to load the Basic program currently loaded onto the master.
Again, any variation of the LOAD/SAVE commands will work (CODE, SCREEN$...).

Of course the master can use the system normally.

2. Independent Station Network

It is very similar to the previous model, but now each station has its own disk drives and printer. Of course all the stations must load the system file in this case, and the FORMAT command must be issued after that.

For example, station 4 can send a CODE block to station 3 with:

```
 SAVE N3 CODE 32768, 16384
```

and station 3 will receive it with:

```
 LOAD N4 CODE
```

You can use station number 0 for broadcasting.
Note that the master station in the previous model is an independent station.
Important note: only stations number 1 - 10 can be independent stations. Stations 2 - 10 are called assistants (act like masters but cannot enter SAVE F- and LOAD F- commands).

3. Mixed Network

It is possible to have a network with both pupil and independent stations - the pupil stations being those without their own disk drives or printers. In this way it is possible to have more than a master.

9.2 THE SNAPSHOT BUTTON

When you press the magic button, an NMI is generated and control passes to address 0x0066 (102 dec.) of the DISCiPLE/+D memory. The consequent behavior of the system depends on the particular System version loaded. Under the standard systems (eg. systems 3a/3b/3d), you have to hold down CAPS SHIFT while pressing the button and then colored stripes appear in the border and five keys are active:

  1 = Dump screen to printer
  2 = Big screen dump (A4)
  3 = Save current screen to disk
  4 = Save a 48K snapshot
  5 = Save a 128K snapshot.

Snapshots are saved to disk with names like "Snap A" and subsequent indexes depending on their position in the directory. When saving a 128K snap, the system stops after creating the file and waits for the user to specify if the screen has changed since the beginning of the operation; the user must respond pressing either 'y' or 'n'. This happens because unlike Multiface the DISCiPLE and the +D haven't got any flip flop to store the status of port 0x7FFD bit 3 which tells which videoram is displayed. Before waiting for the user intervention, the system pages the first videoram (0x4000 page 5), so if the image displayed changes then it means that the second videoram was previously paged. Well, that's it!

After that, control is passed back to the interrupted program.

NOTE: The snapshot routine corrupts the stack with six bytes (PC,AF and R+F).
This may cause some programs which use the stack in a particular way to crash if the magic button is pressed at certain times (eg. Batman the Movie).
See the snapshot section (file type 5) in chapter [7] for more details.

NOTE: The snapshot feature cannot be used while the network is in use.

9.3 GDOS and UNIDOS ERROR MESSAGES

Here's a list of the error codes for both systems available for the RST 20h service.

Code	GDOS	G+DOS
00	Nonsense in GDOS	Nonsense in G+DOS
01	Nonsense in GNOS	Nonsense in GNOS
02	Statement end error	Statement END error
03	BREAK requested	BREAK requested
04	SECTOR error	SECTOR error
05	FORMAT data lost	FORMAT data lost
06	NO DISC in drive	CHECK DISC in drive
07	No "SYSTEM" file	NO "+SYS " file
08	Invalid FILE NAME	Invalid FILE NAME
09	Invalid STATION	Invalid STATION
10	Invalid DEVICE	Invalid DEVICE
11	VARIABLE not found	VARIABLE not found
12	VERIFY failed	VERIFY failed
13	Wrong FILE type	Wrong FILE type
14	MERGE error	MERGE error
15	CODE error	CODE error
16	PUPIL set	PUPIL set
17	Invalid CODE	Invalid CODE
18	Reading a WRITE file	Reading a WRITE file
19	Writing a READ file	Writing a READ file
20	O.K. GDOS 3	O.K. G+DOS
21	Network OFF	Network OFF
22	Wrong DRIVE	Wrong DRIVE
23	Disc write PROTECTED	Disc write PROTECTED
24	Not enough SPACE on disc	Not enough SPACE on disc
25	Directory FULL	Directory FULL
26	File NOT FOUND	File NOT FOUND
27	END of file	END of file
28	File NAME used	File NAME used
29	Not a MASTER station	NO G+DOS loaded
30	STREAM used	STREAM used
31	CHANNEL used	CHANNEL used

Code	UNIDOS
128	Nonsense in Uni-Dos
129	O.K Uni-Dos
130	Break requested
131	Corrupt sector
132	Sector missing
133	Check disc in drive
134	DOS file not found
135	Invalid filename
136	Invalid sector number
137	Invalid device/channel
138	Wrong stream type

139	Verification failed
140	Wrong file type
141	CODE parameter error
142	Directory not found
143	File has zero length
144	Reading a write file
145	Writing a read file
146	POINT outside file
147	Channel out of order
148	Illegal drive number
149	Disc write protected
150	Not enough disc space
151	Directory full
152	File not found
153	End of file
154	Filename already used
155	File still open
156	File in use
157	Channel already open
158	Protected file
159	Unavailable RST 8

10. GDOS and UNIDOS SYSTEM VARIABLES

GDOS and UNIDOS system variables are stored into the interface's RAM and can be modified with the POKE command in the following form:

```
POKE @var, value
```

where:

```
  var  is a variable number
value  is the new variable value.
```

Actually, the '@' operator is interpreted as an offset into the interface's RAM. The base addresses are the following:

```
0x2000 UNIDOS and G+DOS (+D)
0x0298 GDOS (DISCiPLE)
```

List of the system variables:

VAR# Description

0 Flash border during disk operations. Set to 0 to leave the border unaltered. This byte is ANDed with the sector number currently accessed and then sent to port 0xFE.

1 Drive 1 capacity = number of tracks + 128 if double sided.

2 Drive 2 capacity, same as above.

3 Drive stepping rate. Set to 1 for the minimum (1ms).
WARNING: Poking 0 here may lock your disk drive. It can be unlocked reinstalling the OS from tape.

4 GDOS: disable Centronics printer port (0=enabled)
UNIDOS: Enable BREAK key if set.

5 Printer line length in number of characters (default 80)

  6 Printer control flag. If set the codes sent to the printer are not
     filtered (binary output). Necesssary to send control codes to the
     printer.
  7 Printer line spacing expressed in n/72 of an inch. It is sent to the
     printer before avery CR (default GDOS=12, UNIDOS=8).
  8 Number of line feeds after CR (default: GDOS=1 UNIDOS=0).
  9 Left margin for printing. This is the number of spaces inserted before
     the first character of a line (default=0).
 10 Printer flag.
     GDOS: if set then the printer driver generates the graphic
representation
     of 'œ' and ',' (default=1).
     UNIDOS: printer flag (default=0x80).
 11 GDOS: network station number (default=1).
     UNIDOS: Centronics enable, same as GDOS variable #4 (default=1).
 12 UNIDOS: printer column number (default=1).
 13 UNIDOS: CLS# screen color.
 14 Extended syntax address (2 bytes). This address is called on error
which
     are not related to hook codes and DOS syntax. Can be used to add extra
     commands. Ignored if 0.
 16 UNIDOS: Interrupt address (2 bytes).
 18 UNIDOS: Printer initialization codes (8 bytes). They are sent to the
     printer after a NEW or before pressing the 'P' key during a snapshot.
 26 UNIDOS: Set character pitch (8 bytes).
 34 UNIDOS: Set n/72 line space (8 bytes).
 42 UNIDOS: Set UDG bit graphics density (8 bytes).
 50 UNIDOS: Second initialise codes (8 bytes).
 58 UNIDOS: Codes for 'œ' (8 bytes).
 66 UNIDOS: Codes for '#' (8 bytes).
 74 UNIDOS: Codes for (C) (8 bytes).
 82 UNIDOS: Save SCREEN$ 2 parameters (7 bytes).
 89 UNIDOS: set dump graphics (8 bytes).
 97 UNIDOS: address of extra error messages (default=0x1C68).
 99 UNIDOS: error code
100 UNIDOS: address of LPRINT routine (default=0x34AA).
102 UNIDOS: DOS error return address (default=0x0000).
104 UNIDOS: snapshot workspace (20 bytes).
124 UNIDOS: called on reset (default=0x0000).
126 UNIDOS: called on boot (default=0x21A4).
7667 UNIDOS: set this to 0 to reset DOS.

11. UNIDOS EXTENDED BASIC SYNTAX

UNIDOS is an advanced operating system which runs both on DISCiPLE and PlusD and is available as an EPROM upgrade separately for the two interfaces.
To install it, get the EPROM chip specific for your interface and replace the GDOS ROM with it. Of course you also need the system disk which contains the RAM resident portion of the DOS, a file called "Uni-Dos" which is launched with the usual RUN command when the computer is switched on.
The system file is exactly the same both for the DISCiPLE and the +D (hence the name UNI-DOS, I suppose).
It is 6654 bytes in length; the "missing" two bytes contain a checksum which is constantly monitored by the DOS to detect system corruptions. This mechanism works quite well and sometimes you'll see that the system

file is loaded without an explicit statement: just don't worry! :)
Also remember that in the DISCiPLE the RAM and ROM addresses are swapped under UNIDOS. See chapters [2] and [3.1] for all the details.

The main UNIDOS features are powerful disk management with subdirectories, excellent printing facilities and a lot more of professional touches that you discover with use, making it extremely powerful.

UNIDOS provides a superset of the standard GDOS and G+DOS functions (some of them have been changed, however), so read the related chapter first if you don't know that already. Some parts are missing, such as the network routines which have been suppressed for space reasons. Also the FORMAT statement is no more part of the command set, but it is provided as a separate program in the system disk.

First of all, files now have two attributes: hidden and protected. Hidden files are not showed in the catalogue, while protected files are read-only. Also, the disk is given a name (a string containing up to 10 characters) during the FORMAT process.

As already said, UNIDOS introduces SUBDIRECTORIES. They work in the same way as you'd expect, so whenever a filename has to be specified you may use a complete path:

```
 "/dir1/dir2/file"
```

Note that the slash '/' is used to separate the directory names, just like in Unix. Pathnames can be relative to the current directory or absolute (i.e. relative to the root, starting with a '/'). There is no limit to the depth of the directory tree. The root directory has a fixed dimension of 80 file entries, while subdirectories may have any capacity.
If the string ends with the slash charachter, then it is a directory name. The special directory names "." and ".." obviously refer to the current and the parent directory, respectively.

The equivalent of the 'cd' (change directory) command is:

```
 IN d1;"pathname/"
```

with the ending slash in the pathname (because it must be a directory name); this sets the current working directory and the current drive. You may also use IN to set the current drive only, just omit the pathname and the semicolon.

There are no standard commands to create and remove directories. See the CREATE files paragraph later.

The LOAD and SAVE statements are unchanged; an extra abbreviated form has been introduced for LOAD (and MERGE and VERIFY too, of course):

```
 LOAD p"filename"
```

which loads "filename" from the current disk.
EXECUTE files can be launched with:

```
 LOAD d1;"exe"X, <address>
```

In the SAVE statement you may specify the OVER keyword to avoid the overwrite check:

```
 SAVE OVER d1;"program"
```

This will overwrite a previous file without asking for confirmation.

The ERASE command is unchanged. If NOT is added after the ERASE statement, then no error is reported. You cannot remove a file if it is currently open or it is protected.

The CAT statement has a new form:

```
CAT d1
CAT d1;"pathname"
```

You must now specify the 'd1' instead of just '1' as in GDOS. All the GDOS variants are accepted.
If you add NOT after CAT, then it will list the hidden files too.
If you specify a directory name, CAT lists the directory contents.

Now it possible to MERGE CODE files too, but the only effect is that the autostart is removed.

The MOVE statement works as usual (OVER allowed) and it can be now used to copy one file to another, replacing the old SAVE TO in this way:

```
MOVE [OVER] d1;"file1" TO d2;"file2"
MOVE [OVER] d1;"file1" TO "file2"
```

MOVE can copy snapshots, MDRV and opentype files too, even longer than 64K. It can copy entire subdirectories if a directory name (ending with '/') is specified.
Unlike SAVE TO, MOVE uses only the memory between the BASIC area and the machine stack, so it does not require a system reset when it has finished.

The CLS command can be used to reset the screen colors to those stored in the system variable 13:

```
CLS #
```

A great facility UNIDOS introduces are RANDOM ACCESS FILES, i.e. OPENTYPE files which can be accessed in random way, not only serially one byte after another.
To open a random file, the OPEN # statement is used in this form:

```
OPEN #4;d1;"file" RND
```

If you specify IN instead of RND, the file is read only but still has random access. Up to 16 channels can be attached to the same file at once. This statement:

```
OPEN #4;d1;"file" RND <length>[,<byte>]
```

creates the file of the specified length and fills it with the specified byte (if specified!).
Remember to close or clear all channels before you remove the disk from the drive, or else an error will be given when you enter DOS commands after the disk swapping.

You can work with channels using the usual PRINT, INPUT and INKEY$ commands with all the respective variants. However, some new commands are available:

```
POINT #4, <offset>
```

will set the file pointer at the specified offset of the random access channel #4. An error is given if the file boundaries are crossed.

The CLEAR statement has now two forms:

```
CLEAR #
CLEAR #*[<channel>]
```

The former clears all channels without creating an openout file, the latter closes one or all the disk channels creating an openout file and flushing the buffers.
You may flush the buffers only, without closing the file, with:

```
OUT #<channel>
```

As we said above, a special care has been involved in the PRINTING section of
UNIDOS. The LPRINT and LLIST commands work in the usual way, now redirected to the parallel port of the interface.
You can print a screen dump with:

```
SAVE SCREEN$ 1   or   SAVE SCREEN$ 2
```

each using a different preset of parameters. The second preset can be user defined, just alter the relative system variables. These are also the routines invoked by the snapshot keys '1' and '2' (see later).
The most general and powerful form of SAVE SCREEN$ is the following:

```
SAVE SCREEN$ #flag [,pass [,margin [,y [,x [,h [,w]]]]]]
```

where flag = horiz. magnification (0-7) + 8 * vert. magnification (0-7) +
+ 64 if you want color processing + 128 if you want sideways printing.
A magnification of 0 actually means 8.

pass = number of passes for a single printing line

margin = left margin in characthers

y & x = top left corner of the window to print
w & h = width and heigth of the window to print

See the system variable list for more advanced settings which affect printing.

An useful statement implements the ON ERROR GOTO mechanism:

```
LINE 9000
```

enables error trapping; all errors but OK, STOP and BREAK are catched and control is passed to the specified line, where the program can identify the error type reading system variable 99 with (PEEK @99).

UNIDOS also implements new BASIC FUNCTIONS; they are all surrounded by brackets, i.e. are in the form of (<function>).
We have just seen the:

```
(PEEK @offset)
```

which reads a system variable (and in general the RAM location offset+8192).

The length of a random channel is obtained with:

```
 (LEN #<channel>)
```

while:

```
 (POINT #<channel>)
```

returns the current file pointer (offset) or 0 if we are at the end of the file (EOF).
A specified number of bytes can be read from any channel with:

```
 (IN #<channel>, <length>)
```

Lastly, you can check if a file or directory exists with:

```
 AT d1;"pathname"
```

which returns 0 if the file does not exist or its directory number if found.

Now let's examine the last new file type introduced, CREATE files.
These are machine code programs (generally new commands or syntax extensions)that are loaded between the channel area and the BASIC area, so they are lost after a NEW or a reset.
You may LOAD and SAVE CREATE files with:

```
 LOAD d1;"pathname" USR
 SAVE d1;"pathname" USR <address>, <length>
```

You can load as many create files as you need (but the memory space is obviously affected).
The system disk provided with UNIDOS contains two create files with the following extensions:

```
 "ext_code" contains:
            FORMAT d1;"diskname"
              to format disks. The disk name is stored in the last bytes of
              the first root directory entry.
            (LINE)
              returns the current drive number + 128 if the disk is write
              protected and the value is negated if there is no disk in
drive.
            (STR$ #<channel>)
              return a null string if the channel is not open, 'd' if it is
an
              openout stream and 'D' if it is a random stream, or the
letter
              that the channel uses.
 "dir_code" contains:
            SAVE [OVER] d1;"dirname" CAT <capacity>
              creates a directory with a capacity of the specified number
of
              files.
            ERASE d1;"dirname" CAT
              removes the whole specified directory.
            (STEP [d<drive])
              returns the pathname of the last directory accessed or of the
              current directory (if the drive number is specified).
```

Now a few words about the SNAPSHOT. The active keys are the same as in GDOS

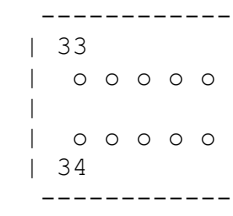
with the same meanings, plus the key 'x' to return to the interrupted program and 'p' which sends the initialization codes to the printer.
If some error occurs during the snapshot saving, then control is passed back to the snapshot menu and not to the interrupted program.

Note that on the +D the snapshot button is disabled during the processing of a DOS command.

12. CONNECTORS PINOUTS

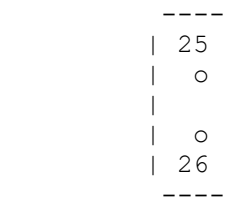
The following pinouts are viewed from the back of the interface.

DISC CONNECTOR



1-33 Ground (0V)	22 Write data	
8 Index	24 Write gate	
10 Disk1 select	26 Track00	
12 Disk2 select	28 Write protect	
16 Motor on	30 Read data	
18 Step dir.	32 Side select	
20 Step pulse		

PRINTER CONNECTOR



1 Strobe	13 D5	
3 D0	15 D6	
5 D1	17 D7	
7 D2	21 Busy (input)	
9 D3	2-22 Grounds (0V)	
11 D4		

The parallel pinout allows direct connection to a Centronics connector simply through a flat cable.

12.1 CONNECTING A PC 5.25" DRIVE

Petri Andras sent an interesting document to explain how to connect a common 5.25" (1.2 MB) PC disk drive to the DISCiPLE and +D. Although not all drives are suitable for the purpose, the chances to succeed are quite good; you can decide whether your drive will work or not with a simple test described below.
Note that the procedure requires a certain experience, so you'd better ask an expert friend if you are not familiar with such operations. Take care, we are not responsible for any damage caused to your system.

SUITABILITY TEST. The floppy drive must be able to operate in "low density" mode.
This is the crucial point, as the DISCiPLE expects a specific RPM from the floppy drive; the PC floppy controller, however, handles different densities without changing the floppy drive's RPM, by re-programming its internal clock frequency. Therefore many PC floppy units, especially later ones, do not support RPM changing at all. There is a line of the interface for switching the floppy's RPM (Pin 2), but the floppy unit may ignore it.

This is the operative test: apply power to the floppy with the flat cable removed, insert a disk into it, move the jumper to DS0 as described above, short-circuit pins 11-12 and 15-16 (with two small alligator clamps on the edge connector). Now the floppy LED will light on and you can hear the drive motor running. Take a third alligator clamp or a piece of wire, and short pins 1 and 2. If the RPM of the disk changes (the difference is audible), then the floppy unit is OK.
If no change occurs, remove power, get a multimeter and search for a jumper that is connected to pin 2 of the floppy's edge connector. If you are lucky, you will find one; try to set it into a different position and test again.

THE PROCEDURE. The floppy drive must be connected to the edge connector on the PC floppy cable that is BEFORE the twist (where drive B: is connected in a real PC). If the floppy cable has an old-style 5.25" edge connector only after the twist (newer PC floppy cables), the edge connector must be disassembled, the twisted wires of the flat cable must be straightened, and the connector must be re-assembled to the cable. This operation requires a little dexterity, but a real Speccy hacker surely has it ;-)

The floppy drive has a set of four jumpers somewhere, described as DS0, DS1, DS2, DS3 (or something similar, numbered from 0 to 3). The jumper is ALWAYS in the DS1 position in the case of PC floppies. This must be moved to DS0 if you want to use it as Disk 1 on the DISCiPLE. (Disk 2 must have this jumper on DS1).
Technical note: This jumper actually determines the Drive Select line that activates the floppy unit. The original Tandon/Shugart floppy interface supported four Drive Select lines and a common Motor Enable line. The PC floppy interface uses DS1 and MotorEnable for disk selection and motor enable for drive A:, and DS0 and DS2 for drive B:. The twist in the floppy cable ensures that the two floppy units can be jumpered identically.

12.2 Using the Plus D / Disciple with a Gotek (Flash Floppy)

CABLING: There are various ways of doing this, but by far the easiest method is to use a straight floppy cable with no twists and close the Gotek S0 jumper (Gotek drive id0; Shugart standard). If a second drive is to be connected, it should be jumpered as drive B (most drives are by default) and again connected to the same cable with no twists. As straight floppy cables are harder to get in 2024, I found it easier to buy a small box of IDC 34 way connectors and clamp them to an existing cable before the twists. The Gotek will also work with a twisted cable, but will need drives jumpered appropriately which can be difficult as some drives are missing the drive select jumpers altogether now.

FLASH FLOPPY CONFIGURATION: You will need to create a flash floppy FF.CFG file on the USB stick with the following config directive:

```
# Index pulses suppressed when RDATA and WDATA inactive?
# Values: yes | no
index-suppression = no
```

Both interfaces look for index pulses in their firmware, which the Gotek suppresses; the Plus D in particular will fail to format disks and sometimes write files if this isn’t done. This can be seen at Plus D ROM address 0x06C5 (TRACK_0 routine) in the V2 ROM (G+DOS 2a). The ‘CHECK DISK in drive’ message will be frequently displayed without this configuration.

13. VL1772 PROGRAMMING INFO

Here is the low-level technical information about the VL1772 floppy disk controller. Some devices equipped with this component are MGT DISCiPLE, MGT PLUS D, MGT SAM COUPE and ATARI ST. It seems to be almost compatible with other FDC devices such as 1791 and 1793.
See section 3 for the port addresses of the FDC registers in the DISCiPLE and the +D.

-COMMAND REGISTER (W)-

Commands are divided into four classes. The lower 4 bits of the command byte have a different meaning depending on the command class; remember to OR them with the command codes given below.

Type 1 commands:

```
  b0-b1 = Stepping rate
          00 =  6 ms
          01 = 12 ms
          10 = 20 ms
          11 = 30 ms
     b2 = Verify track
     b3 = Load/unload head at beginning
```

Command name	Code	Comments
RESTORE	0x00	Restore disk head to track 0
SEEK	0x10	Seek a track (send the track number to the DATA reg.)
STEP_NUPD	0x20	Step using current dir without updating track register
STEP_UPD	0x30	Step drive using current direction
STEP_IN_NUPD	0x40	Increase track without updating track register
STEP_IN_UPD	0x50	Increase track
STEP_OUT_NUPD	0x60	Decrease track without updating track register
STEP_OUT_UPD	0x70	Decrease track

Type 2 commands:

```
     b0 = f8 (deleted dam) / fb (dam) if set in READ commands
     b1 = Enable side compare
     b2 = 15 ms delay
     b3 = Compare for side 1/0
```

Command name	Code	Comments
READ_1SECTOR	0x80	Read one sector
READ_MSECTOR	0x90	Read multiple sectors
WRITE_1SECTOR	0xA0	Write one sector
WRITE_MSECTOR	0xB0	Write multiple sectors

Type 3 commands:
---

  b0-b1 = 0
     b2 = 15 ms delay
     b3 = 0

Command name	Code	Notes
READ_ADDRESS	0xC0	Read address The controller reads the header of the first sector encountered and produces 6 bytes which must be read: track number, side number, sector number, sector size and a two-byte checksum.
READ_TRACK	0xE0	Read a whole track (including headers and control data)
WRITE_TRACK	0xF0	Write a whole track (used to format the track)

Type 4 commands:
---

     b0 = Not ready to read transition
     b1 = Ready to not read transition
     b2 = Index pulse
     b3 = Immediate interrupt, requires reset
  b0-b3 = 0000 -> Terminate with no interrupt

Command name	Code	Notes
FORCE_INTERPT	0xD0	Force interrupt (stops the current command)

-STATUS REGISTER (R)-

Some bits assume a different meaning depending on the last command issued.

After a Type 1 command:

Bit	Meaning	Comments
0	BUSY	Wait BUSY=0 for a new command
1	INDEX PULSE	Index pulse
2	TRACK00	Signals head on track 00
3	CRC ERROR	Sector corrupted
4	SEEK ERROR	Seek error
5	HEAD LOADED	Head loaded
6	WRITE PROTECT	Disk is write protected
7	MOTOR ON	Motor is on or drive not ready

After a Type 2/3 command:

Bit	Meaning	Comments
0	BUSY	Wait BUSY=0 for a new command
1	DRQ	Need to send or read data from DATA register

2	LOST DATA	Error (eg you did not respect I/O timings)
3	CRC ERROR	Sector corrupted
4	RECORD NOT FOUND	Non-existent track/sector or no more data to read
5	REC.TYP/WR.FAULT	Read: record type; Write: write fault
6	WRITE PROTECT	Disk is write protected
7	MOTOR ON	Motor is on or drive not ready

-TRACK REGISTER (RW)-

Contains the current track number.

-SECTOR REGISTER (RW)-

Current sector number for read/write operations.

-DATA REGISTER (RW)-

Here you may read and write the data to the controller. Check the status register before reading or writing data.

14. CREDITS AND CONTACT INFO

This document was written by Luca Bisti of Ramsoft.
Stefano Donati wrote chapters 3.1, 5.1, 9.3 and helped with errors correction.

Thanks to Dominic Morris who provided info about hook codes 43h, 44h, 45h and 47h.
Petri Andras sent the document reported in chapter 12.1.
Mario Prato found that the +D memory is paged in when address 0x3A is fetched.

Version 9 was updated by Alan Pearson (not associated with RAMSOFT who seem to have disbanded) which has corrections to the addresses where memory is page in for both +D & Disciple as well as information on using a Gotek floppy emulator. THANK YOU RAMSOFT IF YOU ARE OUT THERE.

You may contact these people at the following addresses:

* THE RAMSOFT STAFF:
  Ramsoft WHQ (WWR)... ramsoft@bbk.org

* Dominic Morris ..... djm@jb.man.ac.uk
* Petri Andras ..... petri@mit.bme.hu

You can always get the latest version of this tech at the RAMSOFT homepage:

http://www.ramsoft.bbk.org	(World Wide Ramsoft)

V9, March 2024 - Above link now defunct try here instead :
https://spectrumcomputing.co.uk/entry/1000117/Hardware/DISCiPLE Interface