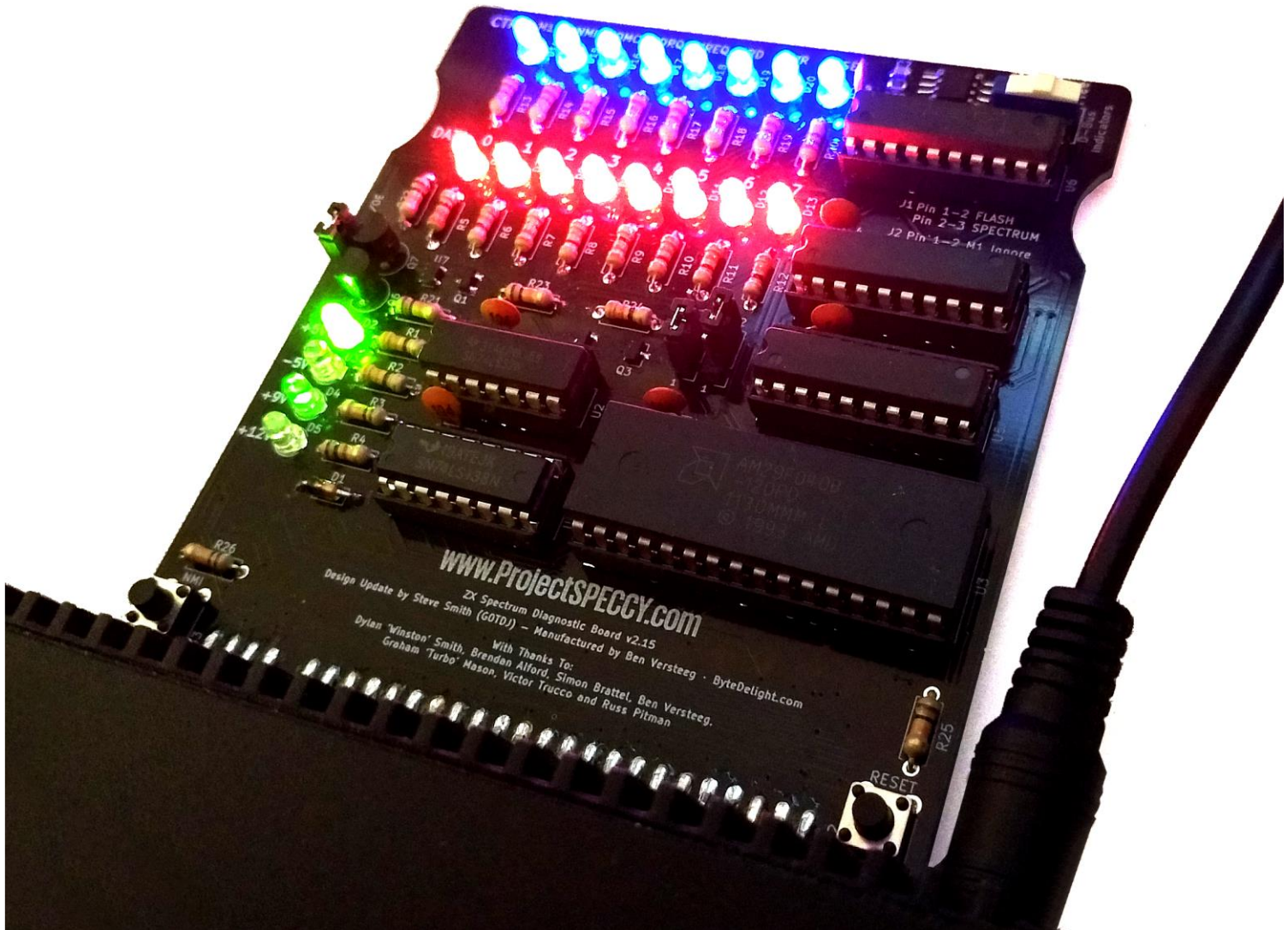# ZX Diag Cart

Manual and build guide

Developed by Dylan 'Winston' Smith, Brendan Alford, Simon Brattel, Ben Versteeg, Graham 'Turbo' Mason, Victor Trucco and Russ Pitman

Designed by Steve Smith

Manufactured by Ben Versteeg

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Overview

Thank you for buying the ZX Diag Cart!

This manual describes the features of the interface, as well as how to assemble it if you ordered the kit.

In the box

The complete and assembled ZX Diag Cart, or in case you ordered the kit:

- The ZX Diag Cart circuit board with SMD components already soldered
- The diodes, resistors, LEDs, capacitor, transistors, pin headers and jumpers, switches, rubber feet in separately labeled bags
- IC's and IC sockets
- Edge connector
- This manual

Hardware features

Autodetection of ZX Spectrum model

The ZX Diag Cart automatically detects to which ZX Spectrum model it is connected, so it can control the ROM signals on ZX Spectrum 16/48K, 128K+, +2, +2A or +3, and many clones.

LEDs

The ZX Diag Cart has 20 LEDs showing these groups of information:

- Control signals status, indicated by the blue LEDs
- Data lines status, indicated by the red LEDs
- Power lines status, indicated by the green LEDs

The speed of change of the LEDs is limited by a clever timing circuit, so it's easier to see what signals are acting and which are stable.

Software features

The ZX Diag Cart comes with the Integrated Diagnostic Tools.

The basic diagnostic tool tests:

- ZX Spectrum Internal ROM
- ZX Spectrum lower RAM
- ZX Spectrum upper RAM
- ZX Spectrum RAM paging*
- Interrupts

*With 128K models

Configuration

Slider switch

Slide it to the right to have the red (middle-row) LEDs show the status of the data lines present on the edge connector.
Slide it to the left to have the red (middle-row) LEDs show stages of the diagnostic software.

J1 jumper option – FLASH/SPECTRUMs

When a jumper is on pins 1-2, it will enable the integrated diagnostics software.
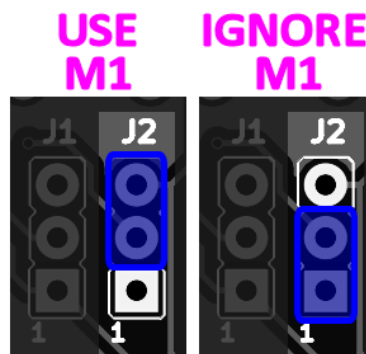When a jumper is on pins 2-3, it will have the ZX Spectrum boot as normal.
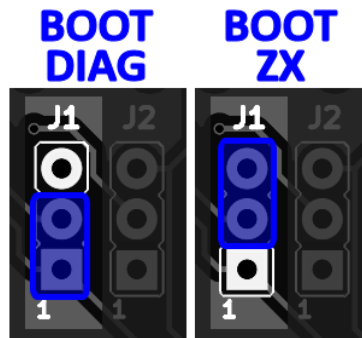
J2 jumper option – M1 Ignore / Normal

When a jumper is on pins 1-2, it will ignore the M1 line in case it's not working properly.
When a jumper is on pins 2-3, it will use the M1 line.

Of course, when the M1 line of the Z80 CPU is failing, the Z80 CPU must be replaced!

ROM1/OE jumper

This jumper is for compatibility with the Brazilian clones that use this line for audio.
When using a Brazilian ZX Spectrum clone (TK90X and TK95), disable the jumper.
Enable this jumper for original ZX Spectrum models and other clones.

Debugging your faulty ZX Spectrum with the ZX Diag Cart

This guide is NOT a complete repair guide, but a description of the functions of the ZX Diag Cart and what they indicate.

You need to develop your skills to improve your fault-finding and repair abilities.
It's very helpful to discuss your repairs in ZX Spectrum groups on Facebook (there are several big ones).

ByteDelight is also starting up a ZX Spectrum repair Wiki to help people out with this.
This is currently (26 Feb 2020) in progress. Keep an eye out on our Facebook posts and ByteDelight.com.

ZX Diag Cart Integrated Diagnostic Tools

The ZX Diag Cart comes with the ZX Spectrum Diagnostics software, developed by Dylan Smith and Brendan Alford.

There are more features that you can launch with holding a key directly after powering up – this is shown on screen. Hold the key until the specific feature is started!

Comprehensive info about the Integrated Diagnostic Tools

Find much more detailed info about the Integrated Diagnostic Tools on its developer's page.

Enter this webpage:
https://github.com/brendanalford/zx-diagnostics/wiki/Firmware
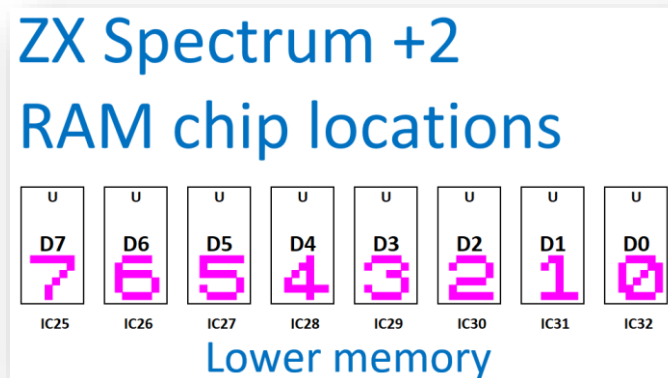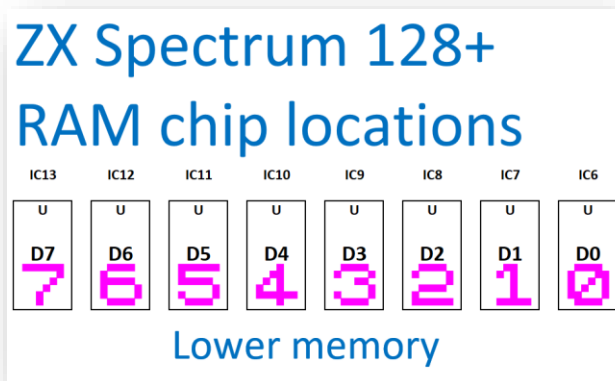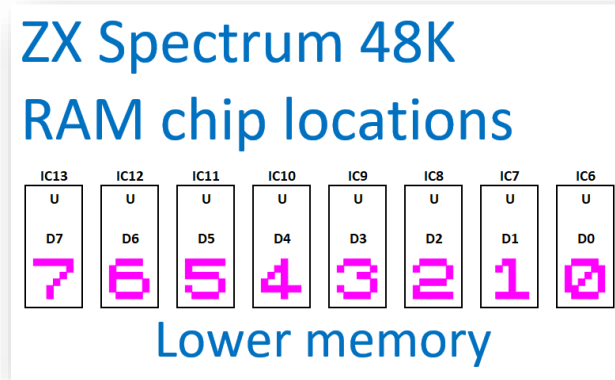
Or use the QR code on the right.

Lower RAM tests

When the ZX Diag Cart boots up, the integrated Diagnostic Tools will start with testing 'lower RAM'.
When it finds a fault, it will most often indicate which data lines do not 'work' (where it is not getting data from or storing data to correctly).

Lower RAM tests (continued)

The numbers correspond to these chips on the ZX Spectrum:

ZX Spectrum 48K
RAM chip locations

IC13	IC12	IC11	IC10	IC9	IC8	IC7	IC6
U	U	U	U	U	U	U	U
D7	D6	D5	D4	D3	D2	D1	D0
7	6	5	4	3	2	1	0

Lower memory

ZX Spectrum 128+
RAM chip locations

IC13	IC12	IC11	IC10	IC9	IC8	IC7	IC6
U	U	U	U	U	U	U	U
D7	D6	D5	D4	D3	D2	D1	D0
7	6	5	4	3	2	1	0

Lower memory

ZX Spectrum +2
RAM chip locations

U	U	U	U	U	U	U	U
D7	D6	D5	D4	D3	D2	D1	D0
7	6	5	4	3	2	1	0
IC25	IC26	IC27	IC28	IC29	IC30	IC31	IC32

Lower memory

Sometimes it's not a chip that is defective, but the feeding voltages are unstable.
Always replace all (original) electrolytic capacitors first when this kind of fault is detected.
You can order capacitor kits at ZXSpectrum.shop.

Another cause of lower memory errors, can be a failing address line or something else like a problem with the control signals to the memory chips.
This will take more advanced debugging skills, which are not described in this manual.
Best is to discuss them in one of the ZX Spectrum groups on Facebook.

Also the ULA chip could be faulty.
The best way to check is *NOT* by putting in another ULA in the board with the problem - **don't do that!**.
Instead: put the potentially defective ULA chip in a working board to test it.

ROM test

If an error is detected in the ROM(s), it will be shown here.

NB: the early ZX Diag Carts (up to s/n 68, shipped out before March 2020) have a bug that will show a +2A or +3 ROM to be faulty.
This is a false positive: if the machine is working correctly, you can be sure the ROMs are OK.
We are trying to create a modification to fix this problem (26 Feb 2020).

Upper RAM tests

When an error is detected, it will often show which chip is actually faulty.

This is perfect when working on an original 16/48K machine, or a 128K+ toastrack or a +2, +2A or +3.
When using the ZX Diag Cart on a Harlequin boards, these chip numbers obviously do not make any sense (it does that since it detects the machine by the used ROM, so the ZX Diag Cart may think your Harlequin board is actually a real ZX Spectrum).

ZX Diag Cart Hardware Fault Detection Features

Blue (top-row) control signal indicator LEDs

The blue (top-row) LEDs show these control signals:

- /M1
- /NMI
- /ROMCS
- /IORQ
- /MREQ
- /RD
- /WR
- /RESET

Since all of these are 'inverted signals' on the edge connector (indicated by the '/' in the signal name), the LEDs should be ON by default, and OFF when there is activity.

If one of these signals is constantly ON or OFF, it could (but not necessarily) indicate a fault.
The M1 line is a quite often defective, which most often shows the LED to stay OFF.
Replace the Z80 CPU if so.

Some signals like /NMI, /ROMCS or /RESET could not blink at all, or much less than the other signals.

If one of the other signals is steady and the machine won't boot, you will need to:

1. Find out if that signal indeed should be active instead
2. Find the cause of the defect

Again, there way too many causes and solutions to describe in this manual.
As said, consult the ZX Spectrum community on Facebook or the upcoming Repair Wiki, if you need more info.

Red (mid-row) data line indicator LEDs

If one of these signals is constantly ON or OFF, it most probably indicates a fault.

The cause of the fault could be in:

- One of the lower memory chips
- One of the upper memory chips
- The ULA chip
- Another part on the board
- Or even a damaged track on the board, or a short somewhere (sometimes caused by soldering joints when replacing e.g. the capacitors)

Green (lower) power signal indicator LEDs

The green LEDs show if the voltages are present.

On a **ZX Spectrum 16K / 48K / 128K (toastrack) / (grey) +2**, all of these 4 voltages should be shown:

- 5V
- 9V
- 12V
- -5V

On a **ZX Spectrum +2A or +3**, only these voltages will be shown (the other power LEDs will stay off):

- 5V
- 12V

If one of these voltages are missing and the LEDs stay off, you have to debug the power circuit.
A very common cause of voltages missing, are TR4 and TR5 in ZX Spectrum 16K / 48K / 128K (toastrack).
But often the reason for those transistors to get defective, is either a lower RAM defect, or problems with the old original capacitors.
So check if there are shorts on power lines before replacing TR4 and TR5 – it can be tricky since there are 'static shorts' and 'dynamic shorts' which only occur when the machine is powered on.

NB: all 128K models also use -12V for the RS232 and MIDI interface, but -12V is not required for all other functions. Some replacement +2A / +3 PSUs do not supply -12V.

Harlequin 48K rev G and Harlequin 128K rev 2D only carry these voltages:

- 5V
- 9V

So the other power LEDs will stay off.

Easter eggs

Someone put in some Easter eggs in the ZX Diag Cart ROM (heck, I didn't even know!).
I can't explain them here, due to copyright reasons.

Needed to assemble the kit

If you ordered the kit, you additionally need these tools to assemble it:

- Solder wire
- Soldering iron
- Preferably a desoldering pump and/or solder wick
- Side cutter to cut the legs of parts
- Coffee or tea - and a beer for when you're finished

SMD parts

These SMD parts have already been soldered on with the DIY kit:

Part nr	Part	Package
C7	10nF	0805
C8	100nF	0805
C9	100nF	0805
R27	1M	0805
R28	100K	0805

Part nr	Part	Package
Q1	BSS84	SOT-23
Q2	BSS138	SOT-23
Q3	BSS84	SOT-23
U7	74HC1G66	TSOP5
U8	LM555	SOIC 5mm

DIY Steps

These steps show the most logical/easy sequence to assemble.

1. Diodes

Part nr	Part
D1	8V2

2. Resistors

Part nr	Part
R1	330
R2	330
R5	330
R6	330
R7	330
R8	330
R9	330
R10	330
R11	330
R12	330
R24	330

Part nr	Part
R4	1K
R13	2K2
R14	2K2
R15	2K2
R16	2K2
R17	2K2
R18	2K2
R19	2K2
R20	2K2

Part nr	Part
R3	10K
R21	10K
R22	10K
R23	10K
R25	10K
R26	10K

3. IC sockets

Part nr	Package
U2S	DIP 14
U1S	DIP 16
U4S	DIP 20
U5S	DIP 20
U6S	DIP 20
U3S	DIP 32

4. LEDs

Part nr	Part
D6	LED red (GND up)
D7	LED red (GND up)
D8	LED red (GND up)
D9	LED red (GND up)
D10	LED red (GND up)
D11	LED red (GND up)
D12	LED red (GND up)
D13	LED red (GND up)

Part nr	Part
D14	LED blue (GND up)
D15	LED blue (GND up)
D16	LED blue (GND up)
D17	LED blue (GND up)
D18	LED blue (GND up)
D19	LED blue (GND up)
D20	LED blue (GND up)
D21	LED blue (GND up)

Part nr	Part
D2	LED green (GND left)
D3	LED green (GND right)
D4	LED green (GND left)
D5	LED green (GND left)

← GND

We added a couple of spare LEDs.

5. Capacitors

Part nr	Part
C1	100n
C2	100n
C3	100n
C4	100n
C5	100n
C6	100n

6. Transistors

Part nr	Part
Q6	BC548
Q7	BC548

7. Pin headers and jumpers

Part nr	Part	Package
J1	Header + jumper	3 pin
J2	Header + jumper	3 pin
J3 ('ROM/OE')	Header + jumper	2 pin

8. Switches

Part nr	Part
S1	Switch slide SPDT
S2	Tactile 7mm TH
S3	Tactile 7mm TH

9. Edge connector

Slightly bend the pins of the edge connector as shown on the photo, leaving some space for the board between the two rows.
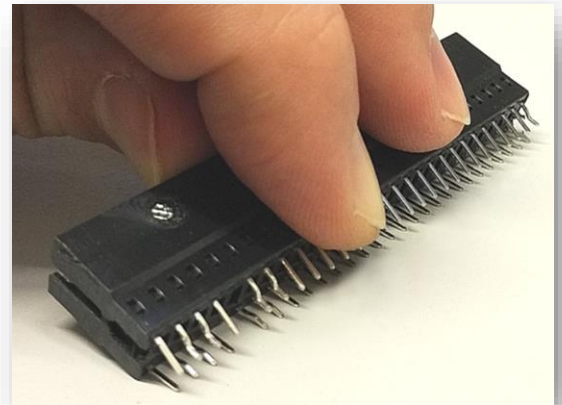
Solder on the edge connector, with the key in the correct position (where there is no pad on the circuit board).

Make sure it's oriented in the same angle as the board (check from the side).

10. Rubber feet

Put them right next to the recesses, making sure they're aligned (it's no problem when a pin is underneath):

Firmware upgrades

Check out: https://www.bytedelight.com/?page_id=585

11. IC's

The AM29F040 already contains the ZX Spectrum Diagnostics software.

Part nr	Part	Package
U1	74LS138	DIP 16
U2	74LS32	DIP 14
U3	AM29F040	DIP 32
U4	74LS273	DIP 20
U5	74LS273	DIP 20
U6	74LS273	DIP 20

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Manufactured by Ben Versteeg

ByteDelight.com   BYTEDELIGHT   **ZXSpectrum.shop**