A ZX Spectrum Diagnostic ROM by Phil Ruston - retroleum.co.uk

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Description:

This is a ROM image that can be used to help diagnose faults with ZX Spectrum computers, testing RAM, ROM, keyboard, sound, video and various ULA / Z80 features. It is mainly aimed at the original Spectrum 16/48 but has tests for the later 128K models too. It can be installed on any ROM swap system (but certain tests require it to be running from a Retroleum SMART Card).

RAM Tests:

On power on / reset, the Spectrum should beep once and show a title / test card page (the box below the logo with vertical lines and “7-0” can help with at-a-glance lower RAM diags – more on that later.) If the border flashes red / black it means the ROM checksum failed and it's unlikely that the DiagROM would run beyond this point – suspect the CPU or shorted/broken PCB traces in this case.

Next, a test is performed to try to determine if there's a problem with the power to the lower RAM (see RAM test details for more info). If a low buzz is emitted with a black/white border then none of the lower RAMs are working, which would suggest the -5v or 12v supply is bad (suspect transistors TR4/5 or the 5v1 Zener diode, but bear in mind a bad RAM IC can pull down the supply to all the chips).

Following on, a quick test of the lower RAM multiplexor ICs is performed (these are ICs 3/4 in earlier Spectrums, but were combined into the 40-pin PCF1603P / ZX401 / 40058 chip in later models). If an issue is found, there will be a low buzz tone with a yellow/black border. Finally for this section, the border turns yellow and the lower 16K of RAM ($4000-$7FFF, part of the contended RAM group in the 128K machines) is tested, this takes about 10 seconds and garbage will appear on screen during the test.

If the test encounters bad RAM an error message along with IC numbers for the suspect ICs in the Spectrum 16/48K*, 128 +2 and +2A/3. For cases where the display is unreadable (or the Spectrum is not connected to a TV) the bad bits are also indicated by a sequence of 8 beeps (from bit 7 to bit 0) A high beep is a good bit, a low beep is a bad bit. The good/bad bit status is also indicated by stripes in the border, the topmost stripe being bit 7 (green band = bit OK, red band = bit bad).

If the lower RAM is OK, then 2 short beeps are heard.

(* Issue Two - 6A boards only - “Issue One” boards have a different chip layout and IC numbering)

Next, the Upper 32KB of memory** ($8000-$FFFF, which is part of the Uncontended RAM group for the 128K machines) is tested. Prior to the main tests, a check is peformed to make sure address line A15 isn't stuck low, and – as with the lower RAM test – a quick multiplexor test is run (the upper RAM multiplexors are IC25 & IC26 – the logic of these ICs was also combined into the PCF1603P / ZX401 / 40058 chip in later model Spectrums). The main upper RAM tests then run – this part takes about 20 seconds. Any suspect RAM chips are reported else 3 short beeps are emitted.

(** DiagROM attempts to detect the presence of the upper 32KB by writing $0000 to $8000+$8001 and then reading the same locations several times. If the word reads back $FFFF this is taken as "RAM not fitted".)

Note: The RAM tests now scan the entire memory range before reporting bad chips (the border turns red at the first detected error). This prevents annoying whack-a-mole situations where one chip is replaced only to discover more bad ones down range on subsequent tests.

Spectrum 128 Note:

If the DiagROM is able to reach its main menu, the 128K RAM Tests can be used to test all of the RAM in these models (the initial tests only test the subset of RAM that is present in the 16/48 models). The IC codes of chips reported faulty by DiagROM assume that the Spectrum128 under test is using the factory default RAM contention patterns (Toastrack/Grey +2: Odd banks contended, +2AB/+3 Banks 4-7 Contended)

Main Menu:

If at least one RAM test completes successfully, the following extra tests can be run. (If both RAM tests failed then cyan/yellow border stripes are displayed and the system freezes).

1. Keyboard / Kempston joystick (ie: Port 31) test
2. Colour palette test
3. Beeper test
4. Internal ROM test
5. More RAM tests
6. System / ULA tests
7. Spectrum 128 tests

Note: Before entering the menu screen, bits 4:0 of Port 254 (the keyboard columns) are tested, if these bits are not set, then a warning is shown and the value of the port is displayed in binary – these bits correspond to the columns of keys from the keyboard matrix. The system then pauses until the issue clears (if a Kempston port is available, it will - after a while - continue on to the main menu as the options can be selected via joystick). The CPU's IRQ response is also briefly tested before the main menu appears.

The items on the menus are selected with number keys (they can also be selected with a Kempston joystick using up, down and fire – on entering a fresh menu pull Down to activate the selection bar.) If nothing is selected for a while, the RAM tests run again.

1. Keyboard Test:

Displays a keyboard diagram with pressed keys highlighted (as well as the Kempston joystick status, if applicable). Hold Caps Shift and Space to quit (or, if using the joystick, move the pointer to the X icon and press fire)

2. Colour Test:

Shows various patterns of colour & data. Any key (or Kempston fire) cycles through the tests, then quits.

3. Beeper Test:

Plays a sequence of tones from the 16/48K Spectrum beeper: First rising (with green border stripes) then falling (with black border) tones are played. If no sound is heard, check the speaker is not open circuit (should be 200 Ohms for Issue2 spectrums and 40 Ohms for Issue 3-6). If the Speaker is OK, check diodes D9 (and D10 on Issue2 Spectrums) and transistor TR7 and diode D9 on Issue 3-6 Spectrums. If all good, suspect the ULA.

4. Internal ROM Test:

If running from a SMART card, the external ROM is paged out, a CRC16 checksum of the Spectrum's internal ROM is made and the external is paged in again. The CRC is compared to a list of known checksums and the test repeats to see if the ROM is stable.

If DiagROM is not running from a SMART Card, but the external can paged out manually the user is prompted to do so – the code will automatically detect this. The internal ROM is read twice and two CRC values are generated, the user is then prompted to re-enable the external ROM. The CRCs is compared with each other and to a list of known checksum values. The test then ends.

5. More RAM Tests:

Brings up a new menu with more RAM test options – details below.

6. System ULA Tests:

Brings up a new menu with various wider system test routines – details below.

7. Spectrum 128 Tests:

Brings up a new menu with tests for the 128K range of Spectrums

The “More RAM Tests” Menu:

1. Silent loop test

Runs the 48KB Spectrum RAM tests (including code execution, but not refresh) continuously on loop in silence. The tests top immediately when an error is encountered and the address as well as the bad bits are displayed. A reset is required to quit this test.

2. Test code execution in lower RAM (a subset of the Contended RAM of 128K Spectrums)

Copies some code into RAM which is executed continuously until a key is held. If all is well the border will continue to alternate yellow / white – a problem will create a crash or - if it's recoverable -an error message. (garbage on screen is normal for this test).

3. Test code execution in upper RAM (a subset of the Uncontended RAM of 128K Spectrums)

As above but for upper RAM. Border should continue to alternate red/magenta if all is OK.

4. Lower RAM Refresh Test

Fills lower RAM with $00, waits about 30 seconds (border cycles colours during the pause) and then checks that the RAM contents haven't changed. The test then fills lower RAM with $FF and verifies. If an error is encountered the suspect chip is indicated.

5 .Upper RAM Refresh Test

Same as above except the tests are run on upper RAM. This test can show up incompatibilities with the upper RAM chips used (eg: Mixing OKI xx32 chips with certain 4164s that have a 256-cycle refresh cycle will seem to work with many programs on the Spectrum - and the normal RAM tests may pass - but the RAM will not in fact refresh properly.)

The System / ULA Test Menu:

1. ULA Analysis:

a) Attempts to determine the ULA type based on the reaction of the EAR input after changing port 254 bits 4 and 5.

b) Checks the floating bus effect is present (an effect used by some games to synchronize graphics routines etc). It involves reading an unimplemented port and examining the data that appears there (it should be whatever byte the ULA was processing at the time, or $FF). The floating bus test fails if the spider mod on Issue 2 boards (or TR6 on Issue3-6) is not working, and the effect is absent on early Spectrums that have the “dead cockroach” modification. The black Amstrad Spectrum 128s (+2A / +3) altered the bus sharing circuit and the floating bus will not be detected (note: in recent years a similar effect was discovered on these machines but it is detected differently).

c) Port 254 decoding test – Ensures only writes to Port 254 actually go there. Faulty ULAs will make noise from the speaker or change the border colour with this test.

2. Z80 Analysis

Attempts to determine the type of Z80 present firstly by seeing how an unused Status Flag bit responds to the SCF instruction, and then by how the Z80 responds to the undocumented instruction “Out (C), 0” (If the DiagROM is not being run from a SMART Card this second test is visual in nature). Finally, if the ROM is running on a ****V3**** SMART Card, the CPU signal “M1” is tested.

3. EAR Input Test

This test simply reads the EAR Signal input (bit 6 of Port 254) and colours the border blue for low input and red for high input - It can be used as a convenient way of checking the tape loading levels. If the ULA is faulty the volume may need to be much higher than normal to get evenly wide stripes (also check diode D13 in this case). Sometimes the border shows noise or is red without any signal – this may indicate a worn ULA but as long as stripes do appear during tape loading, it can be given a pass.

4. 50Hz Interrupt test

Ensures the INT signal is being generated evenly by the ULA and received by the Z80. If an interrupt (IRQ) is early or late an error message is shown.

5. Snow effect test

This effect happens to due to bug in the original Spectrum ULA (which is to be considered normal). The display becomes corrupted when the I register is set between $40-$7F due to an oversight in the contention system design. (The bug does not occur on the Spectrum 128+2A or later machines.)

6. Test IC25 / IC26 multiplexors

Runs some more intensive tests on the upper RAM to try to determine which of these two chips is bad, if any. Due to the range of possible faults with IC25/26, it may sometimes state upper RAM is not stable enough to run the test – even though upper RAM itself is fine. It is worth re-running the test several times to verify the results. (It is rare that the test will state that IC25 or IC26 is bad when in fact those chips are OK.) The address multiplexor ICs were combined into the 40-pin PCF1306P / ZX8401 / 40058 chip in later model Spectrums)

7. Databus test

Pretty much the same as pressing the NMI button, this writes $00 and $ff to one location in lower and upper RAM and displays coloured bars to indicate if the byte read back matches that written (Green = same, Red = different). This can be used to identify issues on the upper and lower databus at a glance.

The Spectrum 128 Test Menu

1. Memory:

The extra memory of the Spectrum 128 is tested as follows: First, each 16KB bank at $C000-$FFFF is tested and any errors are highlighted. (Garbage will appear on screen while bank 5 is tested - this is normal). Afterwards, the memory paging system is tested by writing N to certain addresses in each bank (where N is the page number) and then reading them back.

2. Video Buffer

The 128's screen buffering system is tested by flipping the display select bit (alternating red and blue screens with text should be displayed).

3. AY Sound chip:

The AY sound chip is tested by playing 3 falling tones (one for each channel) at a constant volume, then 3 bursts of white noise, then the same tones + mixed in noise with envelope shaping (sound fades out) and finally all 3 channels play slightly different tones (stepped falling tones with envelope fade).

4. ROM Test

Checksums of the 128's ROMs (0,1,2,3) are calculated and compared to a database of known values. Results from ROM2 and ROM3 are only relevant on the +2AB and +3 (they will be same as ROM0 and ROM1 on the Toastrack and grey +2)

5. Contention Test

Analyses the contention pattern of the Spectrum 128s memory banks. Normally the “Toast Rack” and Grey +2, have banks 0,2,4,6 uncontended and banks 1,3,5,7 contended whereas the black +2A and +3 have banks 0,1,2,3 uncontended and banks 4,5,6,7 contended. (The contention patterns can be changed via hardware modifications etc – though this would mess up the IC codes of chips reported faulty by DiagROM as it assumes the standard schemes.)

Details about the RAM tests:

Before the lower RAM test proper is performed, $0000 is written to $4000, the same address is then read 256 times. If $FFFF is read at any point it is assumed none of the lower RAM ICs are good, or there is a power supply issue. A low tone will be emitted from the speaker with black/white border in this case.

Before the main lower and upper RAM tests occur, a simple address multiplexor test is performed. If data written to the first byte of the RAM area in question appears at any other address, it suggests the multiplexors are faulty. In these cases a low buzz is heard accompanied by a yellow/black border (cyan/black border for upper RAM). Because this test relies on good RAM, it may not reveal anything if the RAM fitted is also bad.

RAM Test Phases:

1 – Bytes with all bits set/reset are written to RAM and then verified. Bits are flipped and re-tested.

2 – Bytes with a single bit set are written and read back. The bit is rotated and the test loops 8 times.

3 – An incrementing byte is written to pseudo-randomly generated addresses in the range under test, once all addresses have been written the data is read back and verified.

Before the upper RAM test is performed, address line A15 is tested – if reading from the lower half of upper RAM reads bytes from the ROM, then A15 is stuck low – if this is the case a message is shown and a burst of white noise with multicolour border stripes occurs. (The ROM wouldn't boot if it was stuck high so that cannot be tested for) RAM is then cleared and a brief attempt is made to catch addressing errors (EG: 74LS157 multiplexor chip failures). A more intensive version of the multiplexor test can be found in the ULA/System test menu. Finally various bit pattens are written to all locations then verified.

Interpreting the results:

In the Spectrum (all standard models before the black +2A), each RAM chip contributes one bit to each memory address byte***, so in theory a faulty chip can be identified from the bit position. This is very noticeable if a **lower / contended** RAM fault occurs as it'll often cause vertical lines in the display. If need be, you can use the box below the boot logo to see immediately which bit (and therefore chip) is bad: a vertical line filling a gap means the corresponding data bit is high (see the Bit Vs chip_ID tables on the next page). Of course, the DiagROM also displays the suspect IC number (and signals the bad bit with the border stripes etc) if it can reach that part the code.

Bear in mind that other faults can make it appear that the Spectrum has bad RAM when in fact the problem actually lies elsewhere (EG: The 74LS157 address multiplexors, 74LS00 or 74LS32 logic chips). Be wary of replacing chips when multiple bits fail at some arbitrary address – use the silent loop RAM tests to display the address at which the error was detected. Normally when a RAM chip fails, the program will detect it at the first few addresses tested (ie: near $7FFF, or $FFFF in the case of upper RAM – DiagROM tests from the top of RAM range downwards). Of course, it is possible for a single bit cell to fail anywhere within the address range but it's highly unlikely for other chips to have a bad bit at the same address.

If the failing address seems pretty random and multiple bits fail on subsequent passes, check the IC25/IC26 multiplexors with the appropriate test in the ULA/System RAM menu.

Spurious results can also be caused by a bad ULA, Z80, ROM or - if running the DiagROM from a device on the edge connector - dirty edge-connector contacts.

If no upper RAM is detected in a populated 48K Spectrum, check the glue logic ICs: IC23, IC24, IC25, IC26

The keyboard test will also sometimes reveal abnormal bus activity if multiple key-presses are shown when only one key is pressed (ignoring the special keys of the Spectrum+ etc of course.)

The RAM tests will run on a continuous loop if no item is selected from the menu that follows. If any errors are encountered a note is displayed on the menu screen. Use the Silent Loop test if detailed results are required upon fault detection.

** In the +2AB/+3 each chip contributes 4 bits to each byte.

Intermittent errors, especially after the Spectrum has been on for a while: Suspect the ULA or CPU. Rapidly cooling the suspect (eg: with freezer spray) may assist in locating the fault.

Should you see vertical pixel lines on screen without any RAM errors, suspect the ULA, its socket or the traces from it to the lower RAM.

NMI Response:

If an NMI is detected at any time, the program will display "=>> NMI<<=", do a live test of the upper and lower databuses for 5 seconds and then restart. The bus test continually writes $ff and $00 to $7FFF, reading back the byte after each (same for address $FFFF) – if any bits do not read back as expected their associated colour bar is red instead of green. Flickering bars indicate unstable bus signals. Bad RAM chips are usually responsible for red bars.

Limitations:

In theory, the DiagROM will at least boot without **any** working RAM or internal ROM (the CPU, of course, needs to be working:) so you should at least hear the boot beep and see the border change from black to yellow for the lower RAM tests then magenta for the upper RAM tests. However, chips can fail in many ways, and if a bad chip is locking up the data or address bus then no code will run at all so the DiagROM wont be able to help.

(Just minor) changes in v1.71: -

- Fixed target box detect in "close keyboard/joystick test with pointer"
- Added a short delay following upper RAM error after init tests
- Removed contended stack ops from beeper test which were slightly distorting the purity of the tone
- Cosmetics (eg: "M1 failed" text is now easier to read)

Standard Disclaimer:

DiagROM is a hobby project and a free download – use it as a guide only, and at your own risk.

To report issues, or for more information, contact me (Phil Ruston) at: diagrom@retroleum.co.uk

Bad bits ← → Chip ID table

SPECTRUM 16/48 Faulty Chip

Bad Bit:	(Lower 16K)	(Upper 32K)
0	IC6	IC15
1	IC7	IC16
2	IC8	IC17
3	IC9	IC18
4	IC10	IC19
5	IC11	IC20
6	IC12	IC21
7	IC13	IC22

Notes: **Issue One** boards use different chip I.Ds and the chips / bits are not in sequence!

Bad lower RAM chips normally result in vertical lines on the display (when the diagROM is running). If no such lines are present, it is possible there is a fault with IC3 or IC4 (74LS157) especially if text appears in the wrong place etc.

SPECTRUM 128 ***("Toast Rack")***

Bad Bit:	Contended RAMs	Uncontended RAMs
0	IC6	IC15
1	IC7	IC16
2	IC8	IC17
3	IC9	IC18
4	IC10	IC19
5	IC11	IC20
6	IC12	IC21
7	IC13	IC22

SPECTRUM 128 +2 (Grey Amstrad version)

Bad Bit:	Contended RAMs	Uncontended RAMs
0	IC32	IC17
1	IC31	IC18
2	IC30	IC19
3	IC29	IC20
4	IC28	IC21
5	IC27	IC22
6	IC26	IC23
7	IC25	IC24

The "Toast Rack" and grey +2 Spectrum 128 have two sets of 64KB RAM (8 chips in each group, one for each bit – same as the original Spectrum) One group of eight chips is for Contended RAM (banks 1,3,5,7) and the other is for Uncontended RAM (banks 0,2,4,6). Page 5 is also the Lower 16KB [$4000-$7FFF] which will also tested by the standard Spectrum 48 RAM test. Page 2 is the first half of the upper RAM address space [$8000-$BFFF] - this is also tested by the standard Spectrum 48 RAM test at start-up (The second half of the Standard Upper RAM test [$c000-$FFFF] will check the Spectrum 128's page 0.)

SPECTRUM 128 +2A/3 (Black Amstrad version):

Bad Bit:	Contended RAMs	Uncontended RAMs
0	IC3	IC5
1	IC3	IC5
2	IC3	IC5
3	IC3	IC5
4	IC4	IC6
5	IC4	IC6
6	IC4	IC6
7	IC4	IC6

The black Amstrad +2A and +3 have two groups of RAM chips (each group has a pair of 64K x 4bit chips). One pair of chips is for Contended RAM (banks 4,5,6,7) and the other is for Uncontended RAM (banks 0,1,2,3). Note the contention arrangement is different to the Toast Rack / +2. Pages 5 and 2 form part of the standard Spectrum 48K memory map – this is the same as the Toast Rack / +2 machines.
