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

V1.54 - 24-12-2020

Description:

This is a ROM image that can be used to help diagnose faults with ZX Spectrum computers. It tests RAM, ROM, keyboard, interrupt, bus and the colour palette. It is mainly aimed at the original Spectrum 16/48 but has tests for the later 128K models too. (The Spectrum ROM test options require the Retroleum SMART Card but everything else should run on any ROM replacement system.)

RAM Tests:

On power on / reset, the Spectrum should beep once and show a title / test card page (the box below the logo with “Bits 7-0 etc” can help with at-a-glance lower RAM diags – more on that later.) The border then turns yellow and the lower 16K of RAM ($4000-$7FFF) is tested, this takes about 15 seconds and garbage appears on screen during the test - this is normal. If this test encounters bad RAM an error message is shown, with the bad bits underlined and the associated IC numbers (in a Spectrum 16/48 issue 2-6 motherboard) are indicated.

In case the display is unreadable (or the Spectrum is not connected to a TV) the bad bits are 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=bit OK, red=bit bad).

If the lower RAM is OK, then just 2 short beeps are heard. If all bits failed a single low tone buzz is heard (with cyan border stripes) – this can indicate bad voltage levels to the RAM, multiplexor (IC3, IC4) problems or - of course - that all RAMs are bad. The low buzz also occurs if an addressing error is detected (IE: IC3 or IC4 multiplexor is suspect).

Next, the Upper 32KB of memory is tested (if fitted*). This takes about 30 seconds and the border is magenta during this stage. Again, if there are problems an error message is shown, the bad bits and suspect IC numbers (for Spectrum 48 issue 2-6) are indicated. If the upper RAM is OK, 3 short beeps are heard. A low tone buzz (with blue border stripes) indicates an addressing error (suspect the upper RAM multiplexors: IC25, IC26 or maybe glue logic: IC23, IC24)

Note: The RAM tests always stop at the first detected error – more bad chips may be present beyond that point. You can use the “Compound tests” in the “More RAM Tests Menu” to scan the entire memory range to reveal all bad chips. (Pressing the NMI button or running the Data Bus Test may also show all bad RAM ICs if the chips have a fault such as a fixed data output.)

Spectrum 128 Note:

With these initial tests, if a RAM error is found during the Lower RAM stage, it will be in the Contended RAM group and if a RAM error is found in the Upper RAM test it will be in the Un-contended RAM group (this assumes the standard Spectrum 128, +2, +2A, +3 bank contention patterns). If the DiagROM is able to reach its main menu, the 128 tests can be used to test all of the 128K RAM and display the associated ID designations for the Spectrum 128 and +2. If the program cannot proceed due to errors in both RAM sections, you can use the table at the end of this document to find the suspect RAM IC numbers.

* The ROM 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".

See the **RAM Test Details** at the end of this document for tips on troubleshooting etc.

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.

<u>Main Menu:</u>

If at least one RAM test completes successfully, the following extra tests can be run:

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

Note: Before entering the menu, bits 4:0 of port 254 (the keyboard columns) are tested, if they're not set, then a warning is shown and the value of the port is displayed in binary. (The CPU's IRQ response is also briefly tested before the main menu appears.)

The items on the menus are selected with keys 1-7 (they can also be selected with a Kempston joystick using up, down and fire.) If no key is pressed in 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). Press caps shift and space to quit. The Kempston directions may flicker randomly if no such interface is connected or it is disabled (Kempston is always enabled when the DiagROM mode on the SMART Card is used).

2. Colour Test

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

3. Speaker Test:

    Plays a sequence of tones from the speaker (black / green stripes in border is normal).

4. Internal ROM Test

    Pages out the SMART card's ROM and makes a CRC16 checksum of the Spectrum's internal ROM. This is compared to a list of known checksums. The "Sinclair / Amstrad" Copyright message is also checked. (Will show an error message if the DiagROM is not being run from a SMART Card.)

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.

More RAM Tests

1. Upper RAM Scanner:

   Allows viewing of the Spectrum's upper RAM ($8000-$FFFF) as linear bitmap data. This can be used to spot bad locations visually, under manual control.

2. Test code execution in lower RAM

   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

   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 $FF, 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 $00 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 ($8000-$FFFF). This test can show up incompatibilities with the upper RAM chips used (eg: Mixing OKI xx32 chips with certain 4164s which require 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.)

6 / 7. Compound lower / Upper RAM Tests

Scans the entire relevant memory range before reporting bad RAM ICs. (The other RAM tests stop at the first bad memory address which may lead to whack-a-mole situations if multiple chips are bad. These tests help avoid this.)

8. Silent loop test

   Runs the 48KB Spectrum RAM tests (including code execution, but not refresh) continuously on loop in silence. A reset is required to quit this test.

System / ULA Tests

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. This effect is 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 entirely absent on the black Amstrad Spectrum 128 +2A / +3 and early Spectrums that have the “dead cockroach” modification.

    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).

3. EAR Input Test

    This test simply reads the EAR Signal input (bit 6 of Port 254) and colours the border blue for 0, and red for 1. 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 even width stripes. Also check diode D13 in this case).

4. 50Hz Interrupt test

    Ensures the INT signal is being generated evenly by the ULA and received by the Z80. If OK, a message should scroll smoothly and no error message will be 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.)

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 indentify issues on the upper and lower databus at a glance.

Spectrum 128 Tests

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 tones (one for each channel) and then 3 bursts of white noise.

4. ROM Test

Checksums of the 128's ROMs are calculated and compared to a database of known values.

5. Contention Test

Analyzes 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.)

Details about the RAM tests:

Stage 1 – For upper ram, address line A15 is tested – if reading from $8000-$800F reads bytes from $0000-$000F, A15 is stuck low (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.

Stage 2 - Pseudo-random data is written to all locations sequentially, and verified after each pass - this part is repeated 4 times with different data.

Stage 3 - The RAM is written with random data in random address order, then checked.

If an error is encountered the expected byte ("XP") and byte actually read ("RD") are displayed along with the address at which the error occurred. The bits that do not match are indicated via the aforementioned audio/visual methods and the corresponding suspect IC(s) are listed.

When a test finds a bad location, that address is examined intensely for a short time - if the byte changes, the program warns that it is unstable with an on-screen message (and a burst of white noise with multicoloured border). Bad chips are often unstable.

If an addressing error (associated with the multiplexors) is detected, a single buzz is heard with cyan/black border stripes.

If all the lower RAM chips failed at the first address tested, two low buzzes are heard with red/white then black/white border stripes - the voltage to the lower RAM and the multiplexors IC3/4 are suspect.

If all the upper RAM chips failed at the first address tested, two low buzzes are heard with black/white then red/white border stripes - the multiplexors IC23/24 and upper RAM glue logic IC25/26 (or PCF1306P chip in the later Spectrum motherboards) are suspect.

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** 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 is bad, and therefore which RAM chip (see the bit /chip_ID tables on the next page). But 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 (IE: way below $FFFF or $7FFF - normally when a RAM chip fails, the program will detect it at the first few addresses tested. 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 arbitrary 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. The upper RAM scanner can be used to help spot intermittent faults visually under manual control. For example, if - upon filling the RAM with $01 and then rotating the bits a few times – there are sections of RAM where the pattern is intact but becomes out of step then suspect the 74LS157s (IC25/IC26 for upper RAM).

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 keypresses 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.

Bad bits ← → Chip ID table

SPECTRUM 16/48

Bad Bit:	Faulty Chip (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.

Changes in v1.54:

- **Added Compound RAM Tests to More RAM Tests Menu**
- **Improved Interrupt Test**

Standard Disclaimer:

The DiagROM is a hobby project - use as a guide only, and at your own risk.

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