

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

V1.28 / 18-06-2016

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 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 page. The border then goes 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. Again, 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)

Spectrum 128 & +2 Note: If a RAM error is found during the lower RAM stage, it will be in the contended RAM group. If a RAM error is found in the upper RAM test it will be in the Uncontended RAM group. 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.

Other Tests:

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

1. Keyboard / Kempston joystick (Port 31) test
2. IRQ Test
3. Speaker Test
4. Floating Bus Test
5. Colour Pattern Test
6. ROM Test
7. EAR Input Test
8. More RAM Tests
9. Spectrum 128 Tests

(Upon entering the menu, bits 4:0 of port 254 (keyboard columns) are not \$1f, then a warning is shown.)

The items on the menus are selected with keys 1-9 (and from v20 onwards, 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.

Keyboard Test

Displays a keyboard diagram with pressed keys highlighted (as well as Kempston joystick status). Press caps shift and space to quit.

IRQ Test

This test makes sure the Z80 is responding to the /INT signal being driven low by the ULA at the start of every frame - a block should smoothly travel across the screen. The test ends when the block reaches the bottom right

Speaker Test:

Simply plays a sequence of tones from the speaker.

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.

Floating bus Test

The floating bus 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). This test fills \$4000-\$57ff with some data, then sits in a loop reading from an unused port (\$255) ANDing \$7 and writing the result to port \$254, so changing the border colour to reflect whatever was on the databus at the time of the read. A rainbow pattern with a break in the middle should appear in the right border. Press any key to quit. (The floating bus effect does not appear on the Spectrum 128 +2 / +3, and also on early Spectrums that have the "dead cockroach" modification)

Colour Test

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

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).

More RAM Tests

The option brings up a sub-menu:

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

3. Test code execution in upper RAM

- Options 2 and 3 copy some code into RAM which is executed continuously until a key is pressed. If all is well the border will continue to flash. Garbage on screen is normal for the lower RAM test.

4. Test IC25 / IC26 multiplexors

- Runs more intensive tests on the upper RAM to try to determine which of these two chips is bad, if any. The chip with the most votes is the most suspect.

5. Silent lower / upper RAM (where detected) test loop

- Runs the standard 48KB Spectrum RAM tests continuously but in silence (A reset is required to quit this test)

Spectrum 128 Tests

A new menu is shown with 4 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 the first and last bytes of each bank (where N is the page number) and then reading them back.

2. Video Page - 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. ROM – Checksums of the 128's two ROMs are calculated and compared to a database of known values.

4. AY Sound chip: The AY sound chip is tested by playing 3 tones (one for each channel) and then 3 bursts of white noise.

RAM Test Details:

Stage 1 - An address counter is set to the top of memory (\$FFFF for upper RAM and \$7FFF for lower RAM). Each location in the memory group is written with \$00. The top of the memory is written with \$ff then the rest of the locations in the group are tested to see if any also hold whatever was read by from the highest location – this is an attempt to detect addressing errors (EG: 74LS157 multiplexor chip failures).

Stage 2 – Various bit patterns are written to all locations then verified.

Stage 3 - Finally, pseudo-random data is written to all locations, and verified after each pass - this part is repeated 8 times with different data.

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).

If an addressing error is detected, a single low tone is heard with blue border stripes.

Interpreting the results:

In the Spectrum, each RAM chip contributes one bit to each memory address byte, so in theory a faulty chip can be identified from the bit position – the DiagROM shows the suspect IC number as per the tables on the next page.

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: not \$FFFF or \$7FFF - normally when a RAM chip fails, the program will detect it at the first address tested (\$FFFF for upper RAM, \$7FFF for lower RAM). 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.

At the start of the memory tests, address line A15 is checked for a short to GND. (If A14 is shorted to GND, there would be no display. If A14 is shorted high the ROM code would not run). If an 74LS157 multiplexor has failed in a detectable way, the program will report it. 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 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 – this allows an unattended soak test to be performed.

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”) Faulty Chip:

| 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 128s have two sets of 64KB RAM (8 chips in each group, one for each bit – same as the original Spectrum) Pages 0-3 select the Uncontended RAM group and pages 4-7 select the Contended RAM group.

Page 5 is also the Lower 16KB [\$4000-\$7FFF] which will also be 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 +2 Faulty Chip:

| 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 |

Standard Disclaimer:

The DiagROM is a hobby project - use 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