

sinclair

ZX Spectrum

ZX Spectrum+

Service Manual

Edited by Brendan Alford

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Revision 1.2

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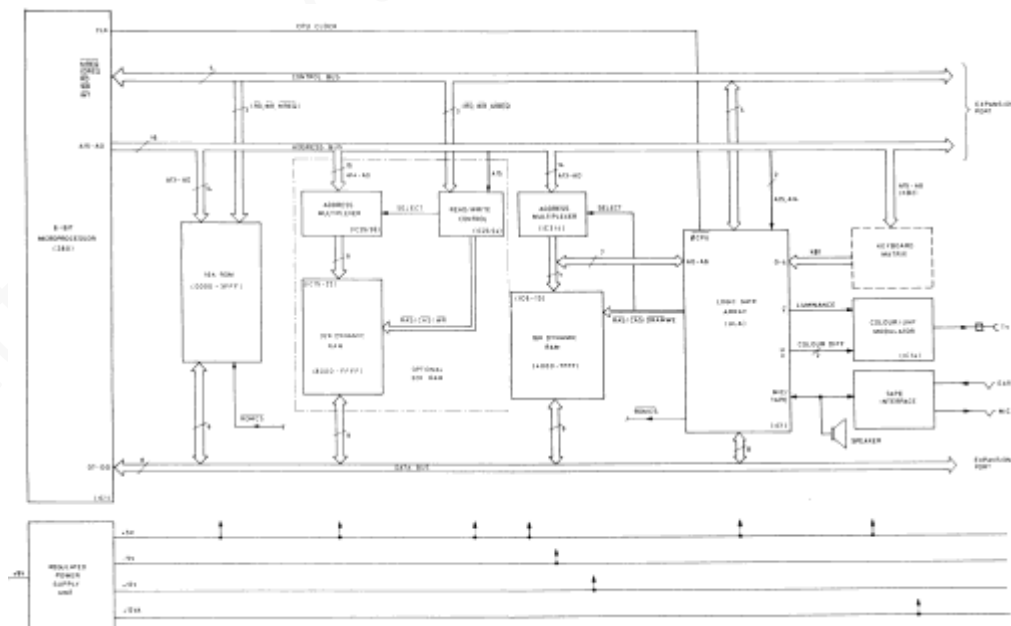
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1 INTRODUCTION

- Introduction
- Architecture
- Z80A CPU
- Memory Organisation
- Read/Write Operations
- Input/Output
- TV Picture Generation
- Keyboard Scanning
- Tape Interface
- Power Supplies

1.1 INTRODUCTION

A block diagram of the complete ZX Spectrum micro-computer is given below. It is valid for all build standards, fitted with either 16k or 48k bytes of dynamic RAM memory. Although functionally identical, detailed circuit changes have been introduced to improve reliability and to assist with manufacture. The printed circuit board layout has also been modified. Details of these changes are highlighted where necessary in the following paragraphs, and in later sections referring to fault diagnosis and repair.



1.2 ARCHITECTURE

The architecture of the Spectrum shown above is typical of many microcomputer systems in that it comprises a single microprocessor board (in this instance a Z80A or u780 CPU), a read only memory (ROM), an expandable RAM memory and an input/output section handling the keyboard, tape and TV display functions. The latter is recognisable as the logic gate array (ULA) and the three functional blocks shown in the right of the diagram.

The computer is built on a single printed circuit board which also includes a regulated power supply fed from an external 9V power pack. The keyboard matrix is part of the upper case assembly and is connected to the board via two ribbon cables KB1 and KB2. A description of each section follows.

1.3 Z80A CPU

The Z80A is an 8-bit single-IC central processing unit (CPU). It is clocked at 14.0 MHz from an external source controlled by the logic gate array (ULA) and has a standard three bus input/output arrangement. These buses are the Data Bus, Address Bus and Control Bus respectively.

1.3.1 Data Bus

D7-D10 constitutes an 8-bit bi-directional data bus with active high, tri-state input/outputs. It is used for data exchanges with the memory and with the ULA.

1.3.2 Address Bus

A15-A0 constitutes a 16-bit address bus with active high, tri-state outputs. The address bus provides the address for memory (up to 64k bytes) data exchanges and for data exchanges with the ULA. It is also used during the interrupt routine when scanning the keyboard matrix.

1.3.3 Control Bus

The control bus is a collection of individual signals which generally organise the flow of data on the address and data buses. The block diagram only shows five of these signals although others of minor importance are made available at the expansion port.

Starting with memory request (MREQ), this signal is active low indicating when the address bus holds a valid address for a memory read or memory write operation. Input/Output request (IORQ) is also active low but indicates when the lower half of the address bus holds a valid I/O address for the ULA during I/O read/write operations.

The read and write signals (RD and WR) are active low, and one or other is active indicating that the CPU wants to read or write data to a memory location or I/O device. All the control signals discussed so far are active low, tri-state outputs.

The last control signal described here is the maskable interrupt (INT). This input is active low and is generated by the ULA once every 20ms. Each time it is received the CPU `calls` the `maskable interrupt` routine during which the real-time is incremented and the keyboard is scanned.

1.3.4 CPU Clock

Returning to the CPU clock mentioned earlier in this section, the ULA is able to inhibit this input bringing the CPU to a temporary halt. This mechanism gives the ULA absolute priority, allowing it to access the standard 16k RAM without interference from the CPU (see RAM description). Switching transistor TR3 ensures that the clock amplitude is +5V rather than some arbitrary TTL level. This is essential if the CPU is to operate effectively while executing fast machine code programs of the `space invader` type.

1.3.5 Dynamic Memory Refresh

The CPU incorporates built-in dynamic RAM refresh circuitry. As part of the instruction OP code fetch cycle, the CPU performs a memory request after first placing the refresh address on the lower eight bits of the address bus. At the end of the cycle the address is incremented so that over 255 fetch cycles, each row of the dynamic RAM is refreshed. This mechanism only applies to the optional 32k expansion RAM in the 48k Spectrum. An alternative refresh method is adapted for the standard 16k RAM.

1.4 MEMORY ORGANISATION

In the standard 16k Spectrum there are 32k bytes of addressable memory equally divided between ROM and RAM.

The lower 16k bytes of memory (addresses 0000 - 3FFF) are implemented in a single ROM (IC5) which holds the monitor program. This program is a complex Z80 machine code program divided broadly into three parts one each covering the input/output routines, the BASIC interpreter and expression handling. Details of the program content, although outside the scope of this manual, are referred to as necessary.

The upper 16 bytes of memory (addresses 4000 - 7FFF) are implemented using eight 16k bit dynamic RAMs (IC6-IC13). Approximately half of this space is available to the user for writing BASIC or machine code programs, the remainder is used to hold the system variables including 6k bytes reserved for the memory mapped display area.

In the 48k Spectrum an additional 32k bytes of RAM are provided (addresses 8000 - FFFF) which are implemented using eight 32k bit dynamic RAMs (IC15-IC32). The RAM, providing extra memory space for the user, is normally fitted during manufacture but may be added retrospectively using the RAM expander kit. In addition to the RAMs, the kit includes the address multiplexer and read/write control ICs IC23-IC26. Board space and the necessary discrete components are already provided on the board.

1.5 READ/WRITE OPERATIONS

The following description should be read in conjunction with the circuit diagrams.

1.5.1 Read Only Memory (IC5)

The CPU addresses the ROM directly during memory read cycles using the address bus A13-A0. MREQ and RD enable the ROM and the ROM outputs respectively. A third input (CS) derived by the ULA (ROMCS) selects the ROM, provided the higher order address bits A14 and A15 are both low. These are reserved for accessing the RAM memory which starts with address 4000 (i.e. address A14 set). An external ROM IC select input, supplied via the expansion port on pin 25A, selectively disables the on-board ROM by pulling the select input high. By virtue of R33 placed on the ULA side of the ROM the ULA ROMCS output is effectively inhibited. Interface 1 uses this mechanism allowing the CPU to read the extension ROM in the interface for Microdrive and RS232 applications.

Links H and N, shown directly above IC5, allow a second source ROM to be fitted. The Hitachi (H) and NEC (N) ROMs use different pins for the enable and select inputs (i.e. pins 20 and 27). The links allow the inputs to be reversed accordingly.

1.5.2 Standard 16k RAM (IC6-IC13)

The eight 16k RAM ICs making up the standard 16k x 8 bit RAM memory are organised as a matrix of 128 rows x 128 columns. Thus, separate 7-bit row and column addresses are required to access any one of the locations. These addresses are supplied by the CPU on address bus A13-A0 via an address multiplexer IC3/IC4. The low order address bits A6-A0 give the row address and are selected at the beginning of the memory access cycle when initially the RAS output from the ULA is high. Later, as the row address is latched, RAS goes low selecting the high order address bits A13-A7 giving the column address.

The RAS/CAS outputs from the ULA are generated in sequence in response to MREQ and A14 from the CPU. The DRAMWE output, also from the ULA is a decode of the RD/WR waveforms telling the RAM to expect either a read or write cycle.

It is also apparent from the circuit diagram that the ULA can access RAM by generating a set of addresses independent of those generated by the CPU. The address port for the RAM is therefore dualled by the insertion of small value resistors (R17-R23) on the address multiplexer side of the RAM. This ensures that where there is likely to be conflict between the ULA and CPU, the ULA address has priority. Priority is assigned on the basis that the ULA must access the memory mapped display area in the RAM at set intervals in order to build up the video for the TV display. If the ULA is about to access the RAM and it detects either A14 or A15 (i.e. the CPU is also about to access the RAM) the ULA inhibits the CPU clock temporarily halting the CPU memory transaction until its own transaction is completed.

Resistors R1 to R8, in series with the data bus lines, perform a similar function to the address port resistors described above. They ensure that the ULA does not `see` CPU write data while the ULA is accessing the RAM.

Refresh for the standard 16k dynamic RAM is accomplished during normal read cycles, ie most rows are refreshed each time the ULA accesses the memory mapped displayed area during picture compilation; the remaining rows are refreshed as a result of other read cycles also known to occur at regular intervals within the refresh period.

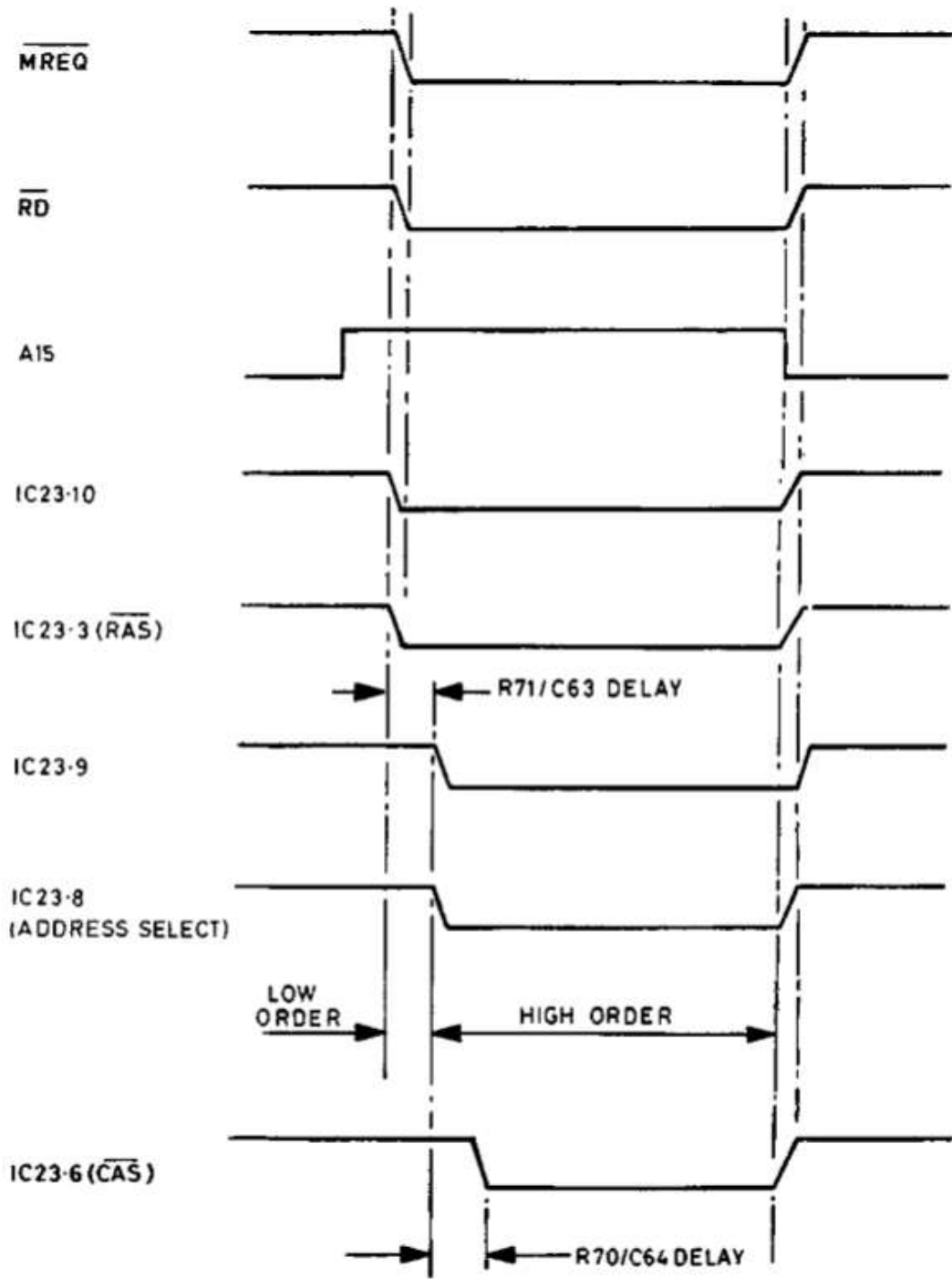
1.5.3 32k Expansion RAM (IC15-IC32)

The eight 32k ICs making up the 32k x 8 bit expansion RAM are in fact 64k ICs with either row or column drop-out, rendering one half of the memory non-functional. In order to accommodate the Texas Instruments RAM (Type TMS 4532) or the optional OKI RAM (Type MSM3732) a set of links are provided, visible on the circuit diagram above the address multiplexer IC25/IC26. These links not only cater for the different manufacturer (Issue 3 Spectrums only) but also allow, in both instances, one of the two IC versions to be selected depending on which half of the RAM (top, bottom, left or right) is functional. The links are respectively TI and OKI (manufacturer - Issue 3 Spectrums only), -3/-4 (TI version) and -H/-L (OKI version - Issue 3 Spectrums only).

NOTE: It is essential when replacing ICs in this area that all RAMs carry the same manufacturers part number and that all links are selected accordingly.

The expansion RAM is organised as a matrix of 128 rows x 256 columns (TI RAMs) or 256 rows x 128 (OKI RAMs). Thus, separate 7/8 bit row and column addresses are required to access any of these locations. These addresses are supplied by the CPU on address bus A14-A0 via an address multiplexer IC25/IC26. For example, when accessing the TI RAM, the low order address bits A6 to A0 give the row address; AR is held low on the -3 version selecting the top half of the memory and high on the -4 version selecting the bottom half. The column address is given by the high order address bits A14-A7.

Row/column address selection and RAS/CAS timing for the RAM is decoded in IC23/IC24 from inputs supplied by the CPU, i.e. address line A15 selecting addresses 8000 upwards, and MREQ heralding a memory read or write cycle. A theoretical timing diagram is shown on the next page.



1.6 INPUT/OUTPUT

The input/output section of the Spectrum is centered round the ULA (IC1). The functions performed within the device include TV video compilation, keyboard scanning and tape input/output. It also derives and controls the CPU clock (CPU) using an external 14 MHz crystal X1, and drives the loudspeaker when a 'BEEP' instruction is being executed. Each of these sections and the supporting circuits are described below.

1.7 TV PICTURE GENERATION

The video compilation section of the ULA operates in conjunction with the memory mapped picture display area in the standard 16k RAM, the colour (chrominance) modulator (IC14) and the UHF modulator. This combination produces a high resolution, 24 line x 32 character, eight colour TV display.

Using the 14 MHz clock the ULA derives line and field timing compatible with the external TV receiver. Video is derived by accessing the memory mapped display area in the RAM in a set sequence at set times throughout the picture frame. The addresses are necessarily independent of the CPU and appear on the ULA address lines A6 through A0 as two separate bytes timed by the RAS/CAS row/column address select lines.

The net result is three separate video waveforms outputs from the ULA on pins 15, 16 and 17. These carry the luminance signal Y, incorporating the line and field sync, and two unmodulated colour difference signals U and Y making the Spectrum compatible with both colour and monochrome receivers.

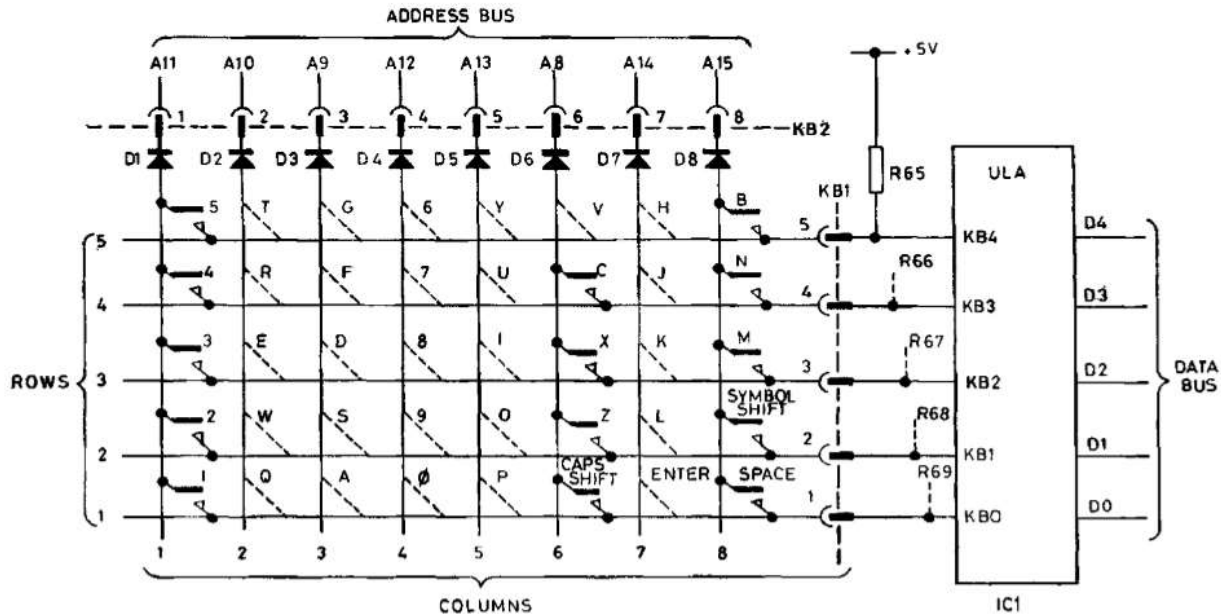
From the ULA, the colour difference signals are applied to the colour modulator IC14 via two level shifting networks. These match the ULA output levels with those required by the B-Y and R-Y inputs to the modulator. In the Issue 2 Spectrum the level shifting network is passive, incorporating two potentiometers VR1, VR2. These are required to set-up the chroma bias level on IC14 pin 3 such that the voltage difference measured between pin 3 and the colour difference signals on pins 2 and 3 respectively is nominally 0V dc. In the Issue 3 Spectrum two active networks incorporating TR8 and TR9 eliminate the potentiometers, greatly improving colour stability.

The level shifted colour difference signals, input to IC14, are then encoded, by quadrature modulating two 4.43 MHz chroma sub-carriers. The sub-carriers are generated with the assistance of an external crystal X2 and a CR lead/lag network introducing a 90 degrees phase shift between pins 1 and 18. (A further difference between the Issue 2 and 3 Spectrums lies in the bias oscillator. The early issues incorporate a trimmer TC2 allowing the chroma sub-carrier frequency to be adjusted; on the later issues the frequency is fixed). The resultant modulated colour difference signals are finally mixed producing a composite chroma sub-carrier at IC14 pin 13.

At this point the chroma signal is ac coupled to the base of TR2 and added to the inverted luminance signal on TR1 collector. The resultant composite video is then buffered and applied to an encapsulated UHF modulator operating on European standard channel 36.

1.8 KEYBOARD SCANNING

Every 20ms (i.e. once per maskable interrupt), the CPU systematically scans the keyboard recording which keys (if any) have been pressed. The scanning method is described below with the aid of the diagram below. As the diagram clearly illustrates the keyboard consists of an 8 x 5 matrix, the inter-section of each row and column bridged by a normally open switch contact. The row 'outputs' and column 'inputs' are shown connected by separate ribbon cables KB1 and KB2, one to the ULA and the other to the high order address lines A15-A8. Pull-up resistors R64 through R68 ensure that when the address bus is in the high Z state, or none of the key-switches is closed, row outputs KB0 to KB4 remain high.



When the keyboard scanning routines are entered the CPU performs successive I/O read cycles setting the IOREQ and RD lines to the ULA, low. At the same time, the I/O port addresses placed on the upper half of the address bus are modified with each cycle such that each of the address lines A15 through A8 is set low in turn, the other lines remain high.

The sequence starts with I/O port address FE driving address line A8 low. The keyboard matrix also sees this potential on column 6 applied via D6 and the ribbon cable KB2. Thus, when any of the switches on the inter-section with column 6 is pressed, the corresponding row output supplying the ULA vis the second ribbon cable (KB1), is pulled low. The row signal(s) is subsequently inverted by the ULA and placed on one of the five low order data bus lines. For example, if the CAPS SHIFT key is pressed row one output drives data bus D0 high and so on. The sequence ends with I/O address 7F when column 8 is addressed. In this instance, operation of the SPACE key drives D0 high. Clearly, the keyboard scanning routines make the distinction between the CAPS SHIFT and SPACE key by knowing which address line is being driven.

1.9 TAPE INTERFACE

When LOADING or SAVEing programs using a cassette recorder, the ULA transfers information between the MIC and EAR sockets and the data bus, performing A/D and D/A conversions as required. Since the LOAD and SAVE functions are mutually exclusive, a single pin on the ULA (i.e. pin 28) is used both for input and output. Separate I/O read/write cycles to port address 254 configure the pin accordingly. During the LOAD operation, the CPU executes successive I/O read cycles, reading the EAR input off data bus line 6. When performing a SAVE operation, the CPU executes successive I/O write cycles, this time writing data to the MIC output via data bus 3.

To ensure that I/O cycles are correctly implemented, the IOREQ line supplying the ULA is gated with address line A0 via TR6. Thus, if any memory transactions occur where A0 is high (i.e. not port address 254) then the IOREQ input is forced high inhibiting any attempt to perform an I/O cycle.

1.10 LOUDSPEAKER (BEEP) OPERATION

It should be noted that while SAVEing the level of the MIC output is barely sufficient to drive the loudspeaker via D9 and TR7 (D10). However, during the execution of a BEEP instruction the CPU writes instead to port 254 on data bus 4. This effectively boosts the MIC output, driving the loudspeaker so that the BEEP tone can be easily heard. During the execution of such an instruction the cassette recorder is not running so there is no conflict at the MIC/EAR sockets.

1.11 POWER SUPPLIES

The on-board power supply unit requires a 9V unregulated supply from the external Sinclair ZX power pack and derives the following internal supply rails:

- Regulated +5V for the IC logic circuits, the ULA and the UHF modulator.
- -5V and +12V for the standard 16k dynamic RAM.
- +12V for the colour modulator circuits.

The external power pack incorporates a mains transformer, full wave rectifier and capacitive smoothing. A thermal fuse is fitted at the transformer input.

The on-board power supply unit incorporates a 7805 regulator, deriving the +5V power rail, and an inverter stage TR4/TR5. The latter raises the level of the +9V unregulated supply to in excess of +12V. The resultant square wave at the junction of TR4 collector and the inverter coil is subsequently rectified and smoothed by D5/C44 producing the +12V output for the RAM. Additional smoothing, imparted by R62/C45, produces the +12V supply for the TV circuits free from noise generated by the RAM, and is available at the expansion port for use by peripherals. The +12V, +5V and -5V are also made available.

2 DISASSEMBLY/ASSEMBLY

Disassembly

Assembly

2.1 DISASSEMBLY

Unplug all input/output leads and turn the computer upside-down to reveal five self-tapping screws. Remove the screws. Hold the two halves of the case together and return the computer to the keys uppermost position. The top half of the case can now be separated from the bottom half, although it remains connected to it by two flexible keyboard ribbon connectors. Care should be taken not to damage the ribbon connectors. As an aid to reassembly, the lie of the connectors within the case should be noted.

To remove the board from the lower half of the case, remove one self-tapping screw (adjacent to IC22 socket) and lift out the board. It may be advantageous to make up two short pluggable extensions for the keyboard connectors in order to improve accessibility to the board.

To change either the keyboard membrane or the rubber keyboard mat it is first necessary to remove the escutcheon plate (template). This is attached to the case by double-sided adhesive tape around the edges. The template is removed by inserting a screwdriver at one end and levering it away from the case. It is not normally possible to remove the template without damage.

2.2 ASSEMBLY

Assembly is carried out using the reverse procedure to that of disassembly. Do not overtighten self-tapping fixing screws.

When replacing a keyboard component, note that the membrane keys into projections on the case. Place the keypad over the membrane and ensure that it is positioned and seated properly. Faulty installation can result in depressed keys being trapped under the template during subsequent key operations. To install the template, place double-sided adhesive tape around all four edges, locate it in position on the case and apply firm pressure around the edges (12mm tape on sides and bottom, 6mm at top).

When aligning the top half of the case with the bottom half ensure that the two keyboard ribbons are not trapped between projecting components within the case. In their correct positions, there is sufficient room for the cables to take up a comfortably curved position inside the case. If a cable is trapped and bent double, an open circuit will sooner or later result.

3 SETTING UP AND SYSTEM TEST

General Alignment

Introduction

Voltage Check

Colour Adjustment

Sub-Carrier Oscillator

14MHz Oscillator

System Test

3.1 GENERAL ALIGNMENT

3.1.1 Introduction

The Issue 3 Spectrum modification removes the need for adjustment of the colour tuning using potentiometers and trimmers. Therefore, the setting-up procedure for this board is confined to checking that the internally generated power supply voltages and two oscillator frequencies are correct. Adjustment instructions apply strictly to the Issue 2 Spectrum boards only but are generally relevant to the Issue 1 Spectrum as well.

To carry out the setting up procedure it is first necessary to remove the ZX Spectrum from the case (Section 2, Assembly/Disassembly). For convenience, the keyboard may also be disconnected.

3.1.2 Voltage Check

Check that the internally generated power voltages are as follows:

Circuit Reference	Nominal Value	Tolerance
IC6 Pin 9	+5V	+/- 0.25V
IC6 Pin 1	-5V	-5.5V to -4V
IC6 Pin 8	+12V	+/- 1.2V
LT side of C52	+12VA	+/- 1.2V

3.1.3 Colour Adjustment

Potentiometers VR1 and VR2 are used to effectively null the voltages between pins 4 and 2 (for VR1) and pins 2 and 3 (for VR2) on IC14 (LM1889). To allow for thermal drift, the potentiometers are set for non-zero voltages; furthermore, these voltage off-sets are set to satisfactory but non-optimum levels in production, and optimum values may be used to advantage in servicing. The relevant figures are given in the following table - voltages are given relative to pin 3 of LM1889.

Pot	IC14 Pin No.	Factory Setting (mV)	Optimum Voltage (mV)	Optimum Tolerance (mV)	Overall Range (mV)
VR1	4	130 +/- 20	+50	-5	+45 to +150
VR2	2	75 +/- 20	-50	-50 +5	-45 to -100

3.1.4 Sub-Carrier Oscillator

The chrominance sub-carrier oscillator frequency should be 4.433619 MHz +/- 50 Hz. This frequency may be checked/adjusted by using one of two methods, listed in (1) or (2) below.

Apply power to the power socket using a bench power supply set at 9V. Current consumption will be approximately 500mA to 700mA for the 16k Spectrum and 700mA to 900mA for the 48k Spectrum.

1. Feed the Spectrum modulator output via a co-axial cable into a standard colour TV receiver. Measure the frequency of the locked TV chroma sub-carrier.
2. Connect pin 17 of IC14 (LM1889) via a 4.7pF capacitor and a lead to the frequency meter. It is recommended that this is done using a jig made up from an IC test clip. Pin 18 of this chip must be removed to minimise stray capacitance. Connect a 10k ohm resistor between the input terminals of the frequency meter. Measure the frequency and adjust trimmer TC2 if the measured frequency is outside tolerance.

3.1.5 14 MHz Oscillator

This frequency is not readily set by working to a specified frequency and tolerance. On Issue 2 boards trimmer TC1 should be adjusted to minimise the effects of beat frequencies which cause waves of distortion to flow across the screen. These are particularly apparent with certain colour combinations, e.g. red INK or green PAPER, and the phenomenon is sometimes referred to as `dot crawl`. It is stressed that adjustment of this frequency is not straight-forward, as deviations due to temperature change are easily visible; tuning should be adjusted to minimise rather than remove this effect.

Proceed as follows:

1. Set up the Spectrum to display green PAPER with red INK
2. Type-in three or four lines of characters and monitor the screen.
3. Adjust trimmer TC1 to minimise the effects of distortion.

3.2 SYSTEM TEST

The system test for the Spectrum may be undertaken using the ZXTP taped program loaded conventionally; this requires that the keyboard is connected. The test should be carried out with the Spectrum connected to its own power supply.

The test program exercises all of the Spectrum circuitry with the exception of the SAVE function. To test this function a small, possibly one line program should be typed in, SAVED and then VERIFIED as described in the instruction manual.

4 FAULT DIAGNOSIS AND REPAIR – GETTING STARTED

Introduction

Test Equipment

Modification History

Modifications - Issue 1 Board

Modifications - Issue 2 Board

32k Extension Memory - (16k-48k)

Hitachi vs NEC ROM

4.1 INTRODUCTION

4.1.1 Test Equipment

Sections 4 to 7 are intended as a guide to fault diagnosis and repair of the ZX Spectrum. It is assumed that users have a reasonable knowledge of electronic servicing, theory and standard fault-finding techniques and have access to the test equipment and tools required to carry out the task. The table below contains a list of the minimum recommended test equipment and materials.

Equipment	Specification/Manufacturer
Oscilloscope with oscilloscope probe (x10)	Rise time: 0.02 us/cm
Variable power supply unit	0 to 30V DC
Mono cassette recorder	With RECORD and PLAYBACK facilities
Mains extension lead	'Safebloc' type
Multimeter	General purpose
Colour Television	Open Market
ZX Printer	Sinclair
ZXTP Test Tape	
Blank Tape	Open Market
Double-sided adhesive tape	12mm and 6mm wide, Tesafix 959 (BDF TESA), or 3M equivalent

Engineers who are already familiar with the Sinclair ZX81 will find some similarities in the ZX Spectrum. The Spectrum, however, is a more sophisticated device with colour and sound circuitry.

The ZX Spectrum is supplied with either 16k or 48k of on-board RAM. The 16k version is wired so that it can be expanded to 48k by the addition of a number of appropriate plug-in ICs. For details of the memory upgrade, see section 7.3.

4.1.2 Modification History

Two major modifications have been implemented on the Spectrum boards:

(a) A modified layout of board (i.e. Issue 1, Issue 2 and Issue 3):

Issue 1. This layout allowed for the 16k RAM to be mounted direct on the board, with the 32k extension consisting of a subsidiary board mounting onto special DIL connectors. Approximately 26,000 units were manufactured.

Issue 2. This layout allows for all 48k of RAM to be mounted direct on the board; sockets, ready for a memory update, are fitted on 16k versions. A small number of Issue 2 units were manufactured using disc capacitors for 47uF and 100uF values, but subsequently axials were introduced.

Issue 3. This layout incorporates advanced circuitry for the colour tuning, removing the need for potentiometers and trimmers and the associated adjustment. It also allows for OKI ICs to be used in the 32k extension memory. The heatsink is also redesigned and is relocated at the back of the case.

(b) The Ferranti ULA, type 5C102, plus spider addition replaced by ULA type 5C112.

5C102. This ULA has a timing fault which was cured by connecting a 74LS00 IC mounted on a miniature board and spider. This ULA was fitted to approximately 40,000 units.

5C112. This improved ULA has no spider modification, but has either a diode or resistor or transistor connected to it. The details are:

Diode/resistor mod: 4k7 resistor from +12V to pin 30 on IC2 and diode (IN4148) from pin 30 of IC2 to pin 33 of IC1.

Transistor mod: TR6 (ZTX313) connected as follows:

Base to IC2, pin 30.

Emitter to IC1, pin 33.

Collector to IC2, pin 11.

6C001. This ULA alters the timing of the colour burst signal, and improves the performance of the Spectrum with certain television sets (e.g. Hitachi, Grundig). It also causes the screen picture to be shifted by one character width to the left.

NOTE: The values of certain components vary depending on which board and which ULA is used as follows:

Board Issue No/ ULA Type	2 5C112	2 6C001	3 6C001
Component			
R47	220R	1K	1K
R49	8K2	10K	10K
R56	220R	470R	1K
R63	220R	470R	1K

4.2 MODIFICATIONS - ISSUE 1 BOARD

A number of modifications were introduced, and these should be checked for and, if necessary, introduced retrospectively:

- 100pF capacitor between RAS and ground - necessary only when using ULA 5C102.
- 470pF capacitor between IC2, pin 28 and ground - required only when IC2 and RAM ICs are all of NEC manufacture.
- 1k resistor between RAS and 23V and 1k resistor between CAS and 12V, only when RAM ICs are of National manufacture. R57 (330R) must be removed, and the 470pF capacitor is not required.
- 47k resistor between pin 13 of LM1889 and ground - required only if the difference between white and yellow colours is inadequate.
- If disc capacitors are used for C41 and C49 (47nF) they must be replaced by axial components.
- Capacitor C46 (1uF electrolytic) should be replaced by a high temperature component.
- This modification is required for efficient operation of certain machine code software and should be implemented on all units. It has been implemented in manufacture for all ULAs 5C112E-2 and later:

D14 replaced by C67 (100pF)

R24 changed from 3k3 to 1k

R27 changed from 680R to 470R

R73 (1k) added between IC1/32 and +5V

- A significant cause of problems has been found to be failure of the internal power supply transistor TR4. The circuit may be improved by changing the value of R60 from 100R to 270R and connecting a 4.7uF electrolytic (preferably radial type) with positive end to TR5 emitter (positive end of C34) and negative end to TR5 base (to R58).

4.3 MODIFICATIONS - ISSUE 2 BOARD

A number of modifications have also been introduced for the Issue 2 board. These should be checked and, if necessary, introduced retrospectively.

- These components should be changed if colour quality needs upgrading:

R48 changed from 4k7 to 2k2
R49 changed from 18k to 8k2
R50 changed from 8k2 to 4k7
R72 changed from 47k (or 18k) to 10k
C65 changed from 100uF to 22uF

- Early Issue 2 boards were manufactured using a considerable number of 47uF and 100uF disc capacitors. C41 (47nF) and C43 (100nF) should be replaced with axial components to prevent undue risk of short circuits.
- To prevent lifting of keyboard template, a thin strip (6mm wide) of double-sided tape was introduced to the top edge of the template. (Previously, only the other 3 edges had tape). This modification should be introduced whenever template lifting is found to be a problem.
- See Modifications - Issue 1 Board, the last two.

4.4 MODIFICATIONS - ISSUE 3B BOARD

Although functionally similar to the Issue 3 board, the layout differs. The DC converter design has been improved, providing greater power supply reliability. Component changes are as follows:

- C77 (100nF) added
- C49 changed from 47nF to 560pF
- R60 changed from 270R to 68R
- TR4 can be either ZTX650 or TIPP31

4.5 32K EXTENSION MEMORY - (16K TO 48K)

4.5.1 Board Issue 1:

The extension memory is supplied as a plug-in module which is inserted into sockets near the edge connector. The ICs used are either TI 4532-3 or TI 4532-4, and all ICs in a unit must be of the same type (i.e. all must be -3 or all must be -4).

4.5.2 Board Issue 2:

The extra memory is obtained by plugging in 4 logic ICs and 8 memory ICs (see here). The ICs used are either TI 4532-3 or TI 4532-4, and all ICs must again be of the same type. It should be noted that the RAM select signal is 0V for the -3 IC and +5V for the -4. A link on the board provides the required select level.

4.5.3 Board Issue 3:

This allows OKI ICs to be used in place of TI 4532. Again, all ICs must be of the same designation. Appropriate links (2) must be fitted in the grid located on the board between the edge connector and the `mic` jack socket. Again, the extra memory is obtained by plugging in 4 logic ICs and eight memory ICs.

4.6 HITACHI VS NEC ROM

During manufacture, wiring links are selected and inserted in the board according to whether a Hitachi or NEC ROM is used. These links are marked `H` and `N` as appropriate and are located as follows:

- Board Issue 1 - between the ROM and the heatsink
- Board Issue 2 - beneath the raised portion of the heatsink
- Board Issue 3 - adjacent to the loudspeaker

Clearly, if the ROM is changed for one of a different make, then these links must be changed as well.

5 FAULT DIAGNOSIS AND REPAIR – PSU AND MEMORY

Fault Diagnosis

Techniques

Power Supply Unit

Initialisation

Memory Check

Keyboard Structure

5.1 FAULT DIAGNOSIS TECHNIQUES

In a closed loop system such as a computer, because of the interdependence of numerous component parts, fault diagnosis is not necessarily straight-forward. In addition, because of the high speed cyclic operation, interpretation of any waveforms on control, data and address lines as being valid depends to a large extent on practical experience of the system. There are however, certain checks with valid waveforms and levels that can be carried out before substituting any integrated circuits. Experience has shown that the best method of initially checking waveforms and levels can be to compare with the same point in a known serviceable board. The following pages provide a basic fault-finding procedure and furnish a list of possible faults along with suggested ways of curing them.

With a densely populated board such as the ZX Spectrum, as careful physical examination of the board can sometimes indicate an obvious fault. Burnt-out discrete components or an overheated track show up immediately, as do the attentions of an enthusiastic amateur. Bearing in mind the latter, short circuits caused by hairline solder `splatter` can be of several ohms resistance and can cause some very misleading fault symptoms.

Providing first principles are adhered to and a common-sense approach is adopted, it will be found after a short space of time that fixing a faulty Spectrum is very much a routine operation.

5.2 POWER SUPPLY UNIT

The unstabilised external power supply unit is a source of some problems. The design is such that, at minimum input voltage (215 ac) and 1.4A output, the voltage through should not be less than 7.0V; at maximum input voltage (265 ac) and 600mA output. the voltage peak should be less than 14V.

5.3 INITIALIZATION

At switch-on the computer should automatically initialise and produce a clear screen with the statement

```
© 1982 Sinclair Research Ltd
```

- displayed in the lower left section of the screen. This indicates that most of the system is working. If the Spectrum does not initialise, carry out the following basic checks.

5.3.1 Basic Checks

It is difficult to be specific in a fault-finding guide because of the large variety of fault conditions which can occur, but the following procedure, starting with a table of checks set out in order of priority, will however isolate the major fault area.

Function	Circuit Reference	Waveform/Voltage
Voltage regulator Input	+ve side of C50	+9V DC +/- 2.0V. At less than +7V the regulator will not function correctly.
Voltage regulator output	+ve side of C34	+5V DC +/- 0.25V, no discernable ripple.
On-board power supply outputs: +5V DC -5V DC +12V DC +12VA (to IC14 only)	IC6 pin 9 IC6 pin 1 IC6 pin 8 LT end of C52	+5V DC +/- 0.25V, no discernable ripple -5V DC +12V DC +12V DC
Clock pulses	IC 1 pin 32 TR3 base and collector, IC2 pin 6	14MHz square wave at +5V amplitude
Address and data lines (following through to relevant IC's)	RT side of R17-R23 RT side of R1-R8	Waveform of amplitude 3.5V

If these tests prove satisfactory check IC1 pin 14, IC2 pin 11 and IC5 pin 28 for +5V. Also check for ground at IC1 pin 40, IC2 pin 29 and IC5 pin 14. If all is still satisfactory at this point and IC1 is the plug-in-type, replace IC1. If replacement of IC1 does not cure the fault, check the address and data lines of IC1, IC2 and IC5 for active data.

It is possible that one of the Z80A or RAM control lines has become faulty therefore, comparing with a known serviceable board if possible, check the waveforms at the following points at origin and destination:

5.3.1.1 (a) IC2

Pin 16 – INT	Pin 17 – NMI
Pin 20 – IOREQ	Pin 24 – WAIT
Pin 19 – MREQ	Pin 25 – BUSRQ
Pin 21 – RD	Pin 26 - RESET
Pin 22 - WR	

5.3.1.2 (b) IC22

Pin 4 – RAS	Pin 3 – WRITE
Pin 15 - CAS	

If no fault has been found and the computer still has not initialised, the fault could lie in the RAM. If the computer is a 48k machine the 32k of expansion RAM can be isolated. An easy way of doing this, assuming that the ICs are not fitted into sockets, is to remove the +5V from IC25. This is probably best done by very carefully cutting the track to IC25 pin 16. If this operation clears the fault condition, the expansion RAM will have to be further isolated. In either instance, the point has been reached where it is necessary to start replacing ICs.

Where the fault persists after isolating the 32k expansion RAM it would be necessary to start changing individual ICs in the order of IC13 to IC6 (RAM), IC1 (ULA), IC2 (Z80A). After each change of IC, the unit must be powered up to check for correct initialisation.

A method of fault-finding that can be used on both 16k and 48k versions is to make a `test IC` device. This may be done by using an IC test clip, to which is attached a serviceable IC (of the relevant type e.g. 4116 or 4532), to bridge across each suspect IC in turn. This method is not guaranteed to work but can often save a lot of time unnecessarily changing suspect ICs.

5.4 MEMORY CHECK

Where a Spectrum has initialised correctly but a RAM memory fault is suspected, it is possible to find the faulty address and relate it to a faulty IC by carrying out the following procedure:

Key in the instruction:

```
PRINT PEEK 23732+PEEK 23733*256
```

The value printed should be:

(a) for a 48k unit – 65535

(b) for a 16k unit - 32767

The value printed in each instance is the last valid memory location, and in a serviceable unit would be as set out above. Therefore, if a different value, n, is printed the faulty location will be n+1. If the value returned is less than 32767 the fault lies in the original 16k of RAM. The following example illustrates the method of relating a faulty location to a faulty IC.

5.4.1 Example

If a 48k Spectrum is giving a memory of 25.25k key in the following instruction:

```
PRINT PEEK 23732+PEEK 23733*256
```

Assume the answer displayed is 43200, therefore the faulty location is 43201 (stops at last valid location).

Key-in:

```
POKE 43201,85: PRINT PEEK 43201 (=answer A)
```

If answer A is 85, key-in:

```
POKE 43201,170: PRINT PEEK 43201 (=answer B)
```

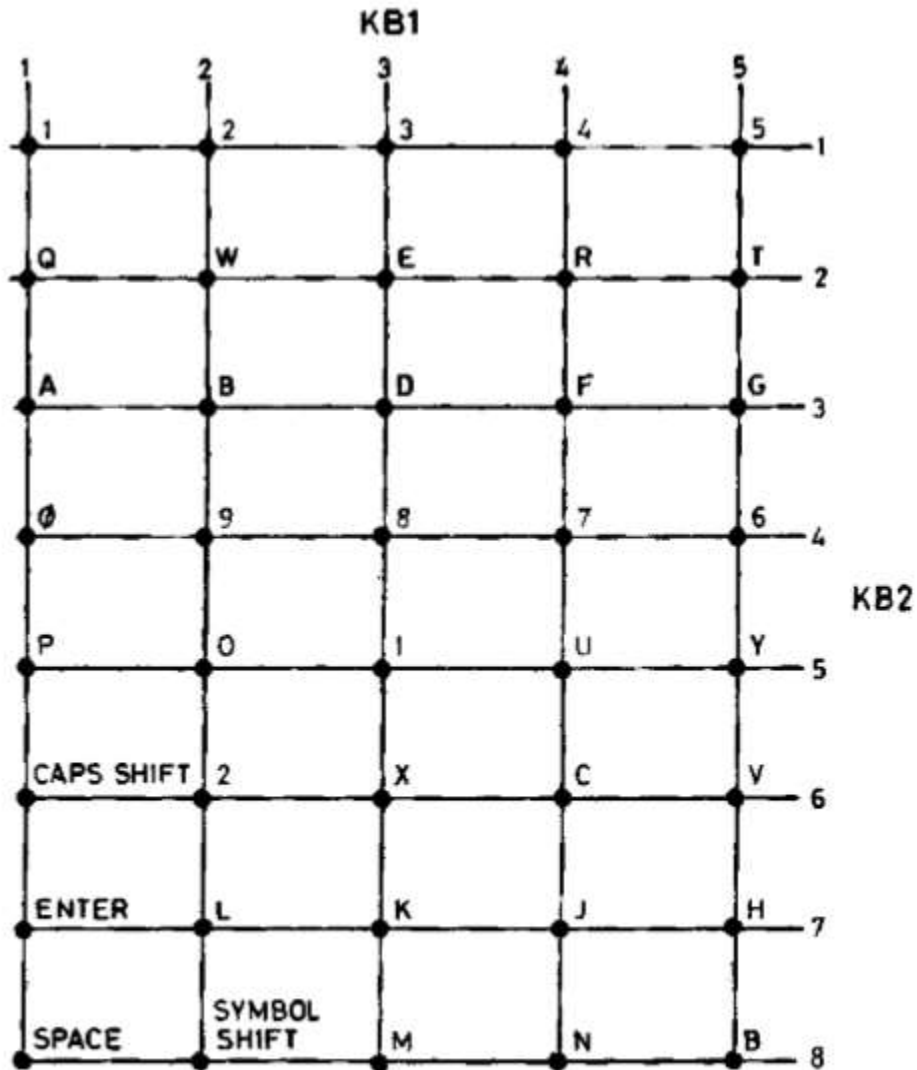
If answer B is anything other than 170 look up in following table which IC to change (e.g. if answer B is 234 change IC21). Similarly, if answer A is other than 85 refer to the table to find the faulty IC.

Data 85 IC6 – IC13	Data 170 IC15-IC22	Size of Error	Error Bit	Faulty RAM location if < 32768	Faulty RAM location if > 32767
84	171	1	0	IC6	IC15
87	168	2	1	IC7	IC16
81	174	4	2	IC8	IC17
93	162	8	3	IC9	IC18
69	186	16	4	IC10	IC19
117	138	32	5	IC11	IC20
21	234	64	6	IC12	IC21
213	42	128	7	IC13	IC22

If there is more than one faulty RAM location the first fault identified will have to be repaired before it is possible to proceed.

5.5 KEYBOARD STRUCTURE

The keyboard is connected horizontally in eight blocks of five keys and vertically in five blocks of eight keys. The diagram below shows the configuration. It follows that if any block of five keys fail the fault is with KB2 circuitry or the 8-way membrane, and that if any block of eight keys fail the fault is with KB1 circuitry or the 5-way membrane.



6 FAULT DIAGNOSIS AND REPAIR – INPUT/OUTPUT

TV screen dead, smoke appears on switch-on / Not Initializing

No Video

Corrupt Paper, after ULA change

Video Incorrect

Colour Tuning Faults (Issue 1 and Issue 2 boards)

Colour Faults (Issue 1 - Issue 3 boards)

Keyboard Faults

Regulator Coil

Speaker

Speaker Load Input Waveforms

6.1 TV SCREEN DEAD, SMOKE APPEARS ON SWITCH-ON / NOT INITIALISING

6.1.1 TR4 base-collector shorted:

Remove TR4

6.1.2 Short persists with TR4 removed

Check TR5 and C44

Visually check track

Check TR4

6.1.3 TR4 blows again

Change TR4 and TR5 (even though TR5 checks out)

Check the TR5 circuit components are to latest specification

6.2 No VIDEO

6.2.1 No video

Change IC1

Check TR1 and TR2

6.2.2 No video after ULA changed

Visually check IC1 and socket

Check for shorting between C65 and R53

Carry out Power Supply Unit check

6.2.3 No +5V input

Check voltage drop across R64

Check +5V regulator O/P and +9V regulator I/P

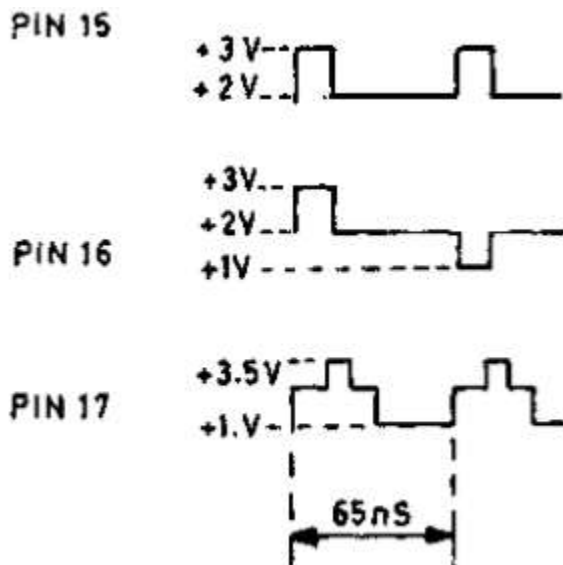
Check PWR socket not shorted

Check power unit

6.2.4 No VIDEO INPUT at IC14 pin 12

Check waveform at IC14 pin 13. If correct check TR1 and TR2

Check waveforms at IC1 pins 15, 16 and 17



If correct check VR1, VR2 (Issue 1 and Issue 2 boards)

Change IC1

If +5V and Video Input correct, change modulator.

6.3 CORRUPT PAPER, AFTER ULA CHANGE

6.3.1 Initial Check

Check IC1 socket

Check PWR socket is not intermittent

Check IC1 pin 14 for +5V with no discernable ripple

6.3.2 No 3MHz at IC2 pin 6

Low amplitude - check R25

Check TR3

Check IC1 pin 32 for 3MHz

Check IC1 pin 39 for 14MHz

Check crystal X1

Check IC1 pin 13 for +3V

6.4 VIDEO INCORRECT

6.4.1 Dark Screen

Check tuning

Change modulator

6.4.2 Dim 'Sinclair' logo

Check +12V

Check C65 for high impedance

Check R52

Check +5V on IC14 pin 3

6.4.3 Wavy lines across screen

Press down on each electrolytic capacitor to see if lines disappear. If so change that capacitor

Check crystal X2

Check/change TR1 and/or TR2

Check/change IC14

6.4.4 Self-resetting

Check TR6

6.4.5 Random dynamic squares

Change C54

Paper area too low

Change IC1

6.4.6 Diagonal lines in the border area

Change R47

6.4.7 Distorted video

Check for +3V at IC1 pin 13

Change C30

6.5 COLOUR TUNING FAULTS (ISSUE 1 AND ISSUE 2 BOARDS)

6.5.1 Initial check

Visually check IC14 circuits

6.5.2 VR1 or VR2 fails to adjust IC14 pin 13 waveform

Monitor IC14 pin 2 trimming VR2

Monitor IC14 pin 4 trimming VR1

Change IC14

6.5.3 VR1 or VR2 DC shifts IC14 pin 13 waveform

Change IC14

6.5.4 Alternate dark lines on screen

Change IC14

6.5.5 No colour after trimming TC2:

6.5.5.1 IC14 pin 17 not oscillating

Check crystal X2

Change IC14

Change X2

6.5.5.2 IC14 pin 17 oscillating but fails to tune

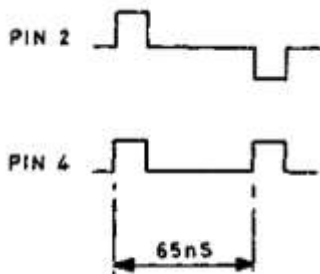
Check for broken track

Change TR2

Change IC14

6.5.5.3 IC14 pin 17 output correct but still no colour (All board Issue numbers)

With 'Sinclair' logo on screen IC14 pin 2 and IC14 pin 4 should be as follows:



If IC14 pins 2 and 4 are correct, change modulator.

6.6 COLOUR FAULTS (ISSUE 1 - ISSUE 3 BOARDS)

6.6.1 Pin screen

Change crystal X2

6.6.2 Blue haze around `Sinclair` logo

If untunable (Issue 1 and Issue 2 boards) change IC14

6.6.3 Screen too yellow

Change IC14

6.6.4 Intermittent colour

Change TC2 (Issue 1 and Issue 2 boards)

Change IC14

6.6.5 Red, Blue or Green `Sinclair` logo

Change IC1

6.6.6 Washed out colours

Check TR2

6.7 KEYBOARD FAULTS

6.7.1 KB1 fault

Check for short on 2 or more of the 5 tracks

Change membrane

6.7.2 KB2 fault

Check for short on 2 or more of the 8 tracks

Change membrane

6.7.3 Dead keyboard

Change IC1

6.7.4 Wrong keyboard response

Change IC1

6.7.5 Keyboard response too fast

Change IC1

6.8 REGULATOR COIL

6.8.1 Coil excessively noisy

Change coil

6.9 SPEAKER

6.9.1 No speaker output

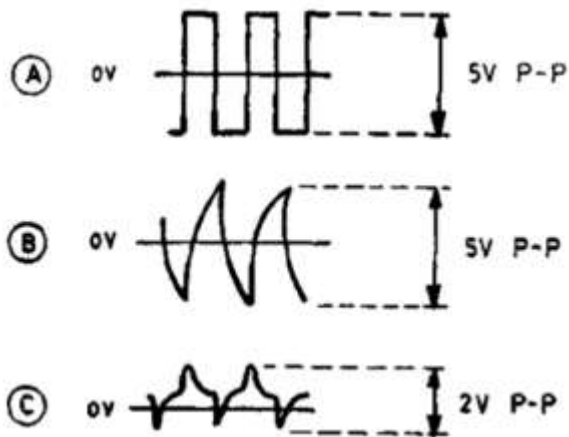
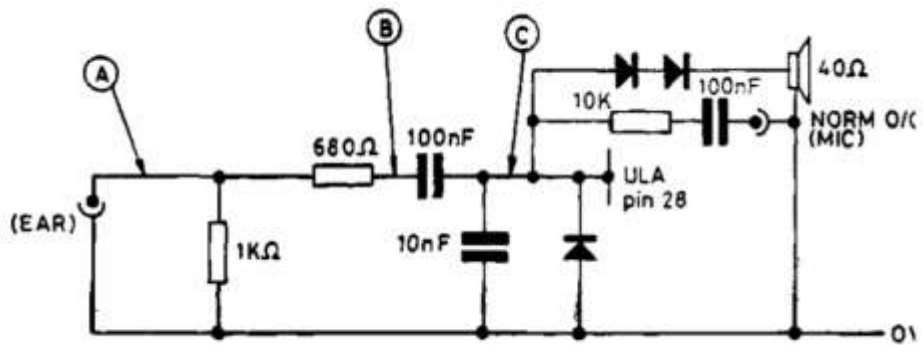
Check load input waveforms

Check TR7

Check D9

Change speaker

6.10 SPEAKER LOAD INPUT WAVEFORMS



7 FAULT DIAGNOSIS AND REPAIR – COLOUR, REPAIR AND UPGRADES

IC14 (LM1889) Pin Signals

Repair


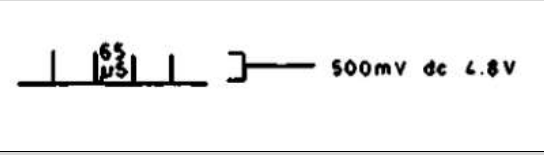
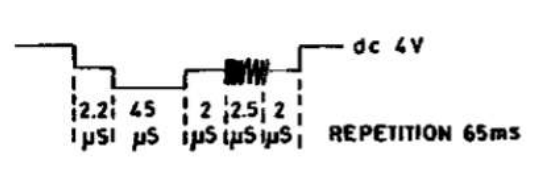
16k to 48k Upgrade

Integrated Circuits/Link Settings

Issue 2 Board

Issue 3 Board

7.1 IC14 (LM1889) PIN SIGNALS

Pin No.	Signal
1	(Chroma lead) Sinewave 500mV, 0.2us, DC 9.5V
2	(R-Y Input) 
3	(Chroma Bias) 4.8V DC
4	(B-Y Input) 
5	(Ground) 0V
12	(Video input) DC 12V unregulated
13	(Chroma subcarrier) 
14	(RF Supply)
15	(Sound tank) 'Linked' 12V DC
16	(Chroma supply)
17	(Chroma oscillator output) Square wave 0.2us 4V p-p 0.8V DC
18	(Chroma lag) Sine wave 500mV p-p 2us 9.5V DC
6,7,8,9,10,11	Not connected

Notes:

Rails and signals taken on switch-on, computer displaying `Sinclair` logo.

No keys pressed

All DC levels positive with respect to 0V

7.2 REPAIR

Renewal of components should be carried out using recognised desoldering/heatsinking techniques to prevent damage to the component or to the printed circuit board. Other points to be noted are:

- When replacing a keyboard matrix, take care that the ribbon connectors are fully inserted into the board connectors, and are not kinked during insertion.
- Make sure there is a good contact made between the voltage regulator body and the associated heatsink in order to ensure adequate heat conduction. The heatsink hole in certain Issue 3 boards allows excessive play which could cause fouling of the edge connector. Take care in re-assembly that the heatsink is fitted away from the edge connector.
- When the regulator is being replaced it is recommended that a suitable proprietary thermal grease is applied to the rear surface of the component body.
- The modulator should be replaced as a complete unit.
- When replacing plug-in ICs it is advisable to use the correct removal and insertion tools. Avoid contaminating the connection pins by handling.
- When handling ICs take normal anti-static precautions. It is recommended that only a suitably earthed, low power soldering iron be used.
- After any component has been renewed the circuit board should be examined carefully, to ensure that there are no solder 'splatters' which may cause short circuits between tracks or connector pins.

7.3 16K TO 48K UPGRADE

7.3.1 Integrated Circuits/Link Settings

For both the Issue 2 and the Issue 3 boards the memory upgrade is accomplished by plugging four logic ICs and eight memory ICs into existing board sockets. Depending on the types of memory ICs used, appropriate circuit links must be fitted on the board.

7.3.2 Issue 2 Board

The ICs used on this board are as follows:

IC	Type
IC15-IC22	TI 4532-3 or TI 4532-4 200ns (or 250ns)
IC23	74LS32
IC24	74LS00
IC25, IC26	74LS157 (NOT National Semiconductors)

Notes:

- All external RAM ICs must be of the same type (i.e. all -3 or -4 variants)
- LINK 3 on the board (IC26, pin 10) should be fitted if IC15-IC22 are type 4532-3
- LINK 4 should be fitted if IC15-IC22 are type 4532-4

7.3.3 Issue 3 Board

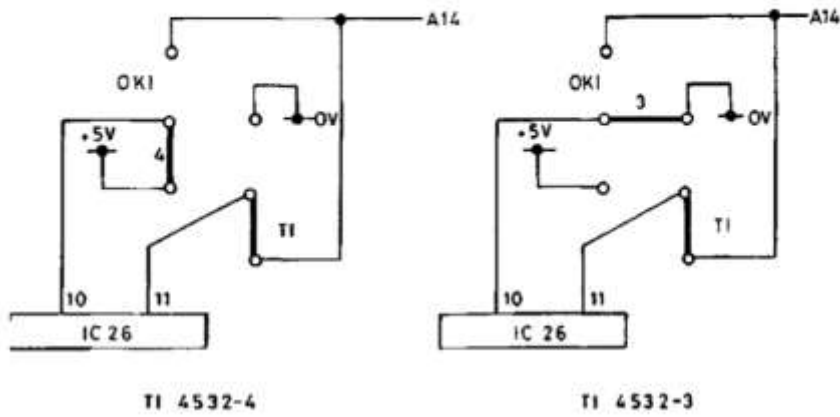
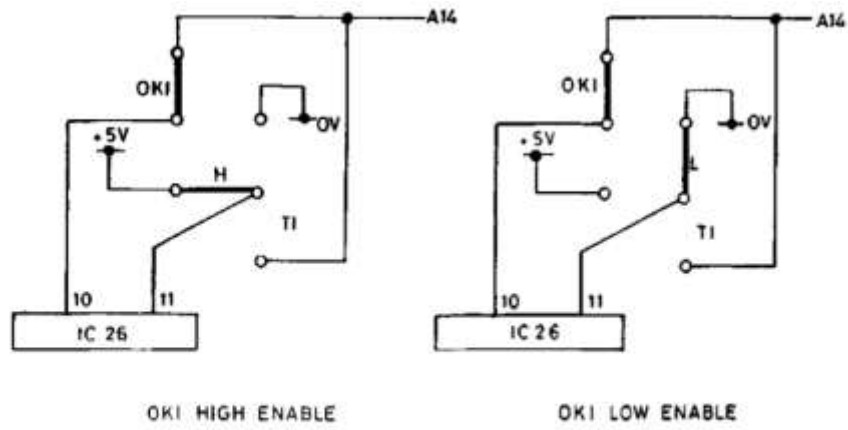
The ICs used on this board are as follows:

IC	Type
IC15-IC22	TI 4532-3 or TI 4532-4 or OKI MSM3732 200ns (or 250ns)
IC23	74LS32
IC24	74LS00
IC25, IC26	74LS157 (NOT National Semiconductors)

Notes:

- All extension RAM ICs must be of the same type.
- Two links must be fitted on the board (grid located between edge connector and mic jack socket) depending on memory manufacturer and type (high or low enable).

7.3.4 Issue 3 Links vs IC Manufacturer and Type



8 PARTS LIST

Introduction

Notes to Part List for Issues 2, 3 and 3B

General capacitor change

Case Assembly

Capacitors

Coil

Connectors

Crystals

Diodes

Integrated Circuits

Resistors

Transistors

Miscellaneous

8.1 INTRODUCTION

Parts lists for the ZX Spectrum are provided in table form; one for the case assembly and another for the board assembly. The latter covers the Issue 2 and 3 Spectrums and is related to the board layout diagrams for these machines.

The board assembly parts list also lists the alternative components which the service engineer will occasionally find on production versions of the Issue 2 board or may introduce retrospectively in order to improve performance. These components are listed in the column headed `ISSUE 2 MODS` with references to the notes against them. These notes are explained below.

8.2 NOTES TO PARTS LIST

1. The alternative values given for R47, R49, R56 and R63 are used if the ULA fitted it Type 6C001.
2. The alternative values for R48, R50, R72 and C65 are introduced to improve the colour quality.
3. C74 is essential on all Issue 2 boards and should be fitted retrospectively. At the same time R60 must be replaced with the larger value.

4. The introduction of alternative components for R24 and R27 is essential. At the same time C67 replaces D14 and R73 is added.
5. Issue 2 boards fitted with the Type 5C112 ULA have either a transistor (TR6) or diode/resistor modification (see Issue 2 circuit diagram for details).
6. On Issue 3 boards only crystal X2 must have a close tolerance specification (ie 10ppm absolute, 10ppm 20C to 60C, 5ppm per year.)
7. On Issue 3B boards, the dc converter design has improved reliability. R60 is changed from 270R to 68R and C49 is changed from 47nF to 560pF. Capacitor C77 (100nF) has been added.

8.3 GENERAL CAPACITOR CHANGE

Early Issue 2 units were manufactured using a considerable number of 47nF and 100nF disc capacitors. Where these occur, the service engineer should take the opportunity to replace C41 and C49 with axial types.

8.4 CASE ASSEMBLY

Description	Manufacturer
Assembled board as appropriate	
Moulded Upper Case	
Moulded Lower Case	
Keyboard Mat (Rubber)	
Keyboard Membrane	NFI
Keyboard Template	
Rubber Feet	
Self Tapping Screws (case fixings), 5 off	
Double-sided adhesive tape – 12mm wide; Tesafix 959	BDF Tesa
Double-sided adhesive tape – 6mm wide; Tesafix 959	BDF Tesa
Self Tapping Screw (board fixing), 1 off	

8.5 CAPACITORS - ALL AXIAL TYPES UNLESS OTHERWISE STATED

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Rating/Tol.	Type
C1-C8	47nf			47nf	25V, 10%	Ceramic
C25	22uf			22uf	10V, -10%+80%	Electrolytic
C26	47nf			47nf	25V, 10%	Ceramic
C27	1uf			1uf	50V, -10%	Electrolytic
C28	22uf			22uf	10V, -10%+80%	Electrolytic
C29/C30	47nf			47nf	25V, 10%	Ceramic
C31/C32	100nf			100nf	25V, 10%	Ceramic
C33	47nf			47nf	25V, 10%	Ceramic
C34	22uf			22uf	10V, -10%+80%	Electrolytic
C35	10nf			10nf	25V, 10%	Ceramic
C36	47nf			-	25V, 10%	Ceramic
C37/C38	33pf			33pf	25V, 10%	Ceramic
C39	10nf			10nf	25V, 10%	Ceramic
C40/C42	47nf			47nf	25V, 10%	Ceramic
C43	100nf			100nf	25V, 10%	Ceramic
C44/C45	100uf			100uf	16V, 10%+80%	Electrolytic
C46	1uf			1uf	50V, 10%+80%	Electrolytic
C47	22uf			22uf	10V, -10%+80%	Electrolytic
C48	47nf			47nf	25V, 10%	Ceramic
C49	47nf		<u>2</u>	47/560pf	25V, 10%	Ceramic
C50	22uf			22uf	10V, -10%+80%	Electrolytic
C51	-			-	-	-
C52/C53	150pf			150pf	25V, 10%	Ceramic
C54	470pf			-	25V, 10%	Ceramic
C55-C62	47nf			47nf	25V, 10%	Ceramic
C63	47pf			47pf	25V, 10%	Ceramic
C64	100pf			100pf	25V, 10%	Ceramic
C65	100uf	22uf	<u>2</u>	22uf	20V, 10%+80%	Electrolytic
C66	47nf			47nf	25V, 10%	Ceramic
C67	-	100pf	<u>4</u>	100pf	25V, 10%	Ceramic
C68-C71	-	-		100nf	25V, 10%	Ceramic
C72/C73	-	-		16pf	25V, 10%	Ceramic
C74	-	47uf	<u>3</u>	4.7uf	5V min	Electrolytic
C75	-	-		100nf	25V, 10%	Ceramic
TC1/TC2				-		
C76	-	-		47nf	25V, 10%	Ceramic
C77	-	-	<u>7</u>	100nf	25V, 10%	Ceramic

8.6 COIL

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Rating/Tol	Type
Coil	SPECTRUM	-	-	SPECTRUM	-	1703

8.7 CONNECTORS

Reference	Description	Manufacturer/Part Number
EAR	3.5mm jack socket	
MIC	3.5mm jack socket	
PWR	2.1mm co-axial socket	
KB1	5-way ribbon connector	Molex 5229-05CPB
KB2	8-way ribbon connector	Molex 5229-08CPB

8.8 CRYSTALS

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Manufacture Type
X1	14.000000MHz	-	Note	14.000000MHz	
X2	4.433619MHz	-	<u>6</u>	4.433619MHz	

8.9 DIODES

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Manufacture Type
D1-D9	1N4148	-	-	1N4148	Signal
D10	1N4148	-	-	-	Signal
D11-D13	1N4148	-	-	1N4148	Signal
D14	1N4148	-	<u>4</u>	-	Signal
D15	BA157	-	-	BA157	Rectifier
D16	5V1	-	-	5V1	Zener

8.10 INTEGRATED CIRCUITS

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Manufacture Type
IC1 (ULA)	5C102	5C112	<u>1</u>	6C001	Ferranti
IC2 (CPU)	Z80A/u780	-		Z80A/u780	
IC3/IC4	74LS157N	-		74LS157N	Not National
IC5 (ROM)	SPECTRUM	SPECTRUM		SPECTRUM	NEC/Hitachi
IC6-IC13	4116	-		4116	150ns
IC14	LM1889	-		LM1889	
IC15-IC22	TI4532	-		TI4532 48K only	Texas
				MCM3732	OKI
IC23	74LS32N	-		74LS32N 48K only	
IC24	74LS00N	-		74LS00N 48K only	
IC25/IC26	74LS157N	-		74LS157N 48K only	Not National

8.11 RESISTORS - ALL 1/4W, 5% UNLESS OTHERWISE STATED

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3	Rating/Tol	Issue 3B
R1-R8	470R			470R		
R9-R16	8K2			8K2		
R17-R23	330R			330R		
R24	3K3	1K	<u>4</u>	1K		
R25	180R			180R		
R26/R27	680R			470R		
R28	10K			10K		
R29	1K5			10K		
R30	1K			10K		
R31	220K			220K		
R32	100R			100R		
R33	680R			680R		
R34	15R			15R	½ or 1W	
R35	10K			10K		
R36	680R			680R		
R37	1K			1K		
R38	3K3			-		
R39	3K3			-		
R40	1K			-		
R41	1K5			-		
R42	1K			1K		
R43	3K			3K	2%	
R44	5K1			5K1	2%	
R45/R46	1K			1K		
R47	220R	1K	<u>1</u>	1K		
R48	4K7	2K2	<u>2</u>	2K2		
R49	8K2	10K	<u>1</u>	10K		
R50	8K2	4K7	<u>2</u>	4K7		
R51/R52	2K2			2K2		
R53	390R			390R		
R54	100K			100K		
R55	56R			56R		
R56	220R	470R	<u>1</u>	1K		
R57	330R			-		
R58	1K			1K	2%	
R59	1K8			1K8	2%	
R60	100R	270R	<u>3,7</u>	270R		68R
R61/R62	15R			15R		
R63	220R	470R	<u>1</u>	1K		
R64	15R			15R		
R65-R69	10K			10K		
R70/R71	220R			220R		
R72	470K or 18K	10K	<u>2</u>	10K		
R73	-	1K	<u>4</u>	1K		
R74/R75	-			10K		
R76/R77	-			1K		
R78	-			470R		
VR1/VR2	2K2			-		

8.12 TRANSISTORS

Circuit Reference	Issue 2	Issue 2 Mod	Notes	Issue 3
TR1/TR2	ZTX313	-		ZTX313
TR3	ZTX313	-		ZTX313
TR4	ZTX650/TIPP31	-		ZTX313
TR5	ZTX213	-		ZTX213
TR6	ZTX313	-	<u>5</u>	ZTX313
TR7	-	-		ZTX450
TR8/TR9	-	-		BC184/BC549B

8.13 MISCELLANEOUS

Reference	Description	Manufacturer/Part Number
REG	5V Regulator	7805
MOD	UHF Modulator with E36 vision carrier (UK only)	Astec UM1233
Loudspeaker	40 ohm TV Type	
Modulator Screen Insulator		1740
Heatsink	Special (Issue 2 or 3)	
Regulator Fixings (1)	Screw, ch hd. 4BA x 15/16 in	
Regulator Fixings (2)	Washer, shk prf, 4BA	
Regulator Fixings (3)	Nut, hex, 4BA	
DIL SKT	16-way (10 off) for 48K expansion RAM (16K model only)	
DIL SKT	14-way (2 off) for 48K expansion RAM (16K model only)	
DIL SKT	28-way for IC1 (ULA)	

9 SUPPLEMENT NO. 1

Introduction

DC-DC Converter Modification

Issue 3B Board

Issue 4 Board

Issue 4A Board

Issue 4B Board

Issue 5 Board

Issue 6 Board

Issue 6A Board

Fault-Finding - Servicing Addenda

Warranty Seal

Parts Lists

Notes to parts lists

Capacitors

Coil

Connectors

Crystals

Resistors

Diodes

Integrated Circuits

Transistors

Miscellaneous

9.1 INTRODUCTION

In line with Sinclair's policy of continual product improvement a number of changes to the Spectrum Printed Circuit board have been implemented. Since the Service Manual was published the printed circuit board has been upgraded through Issues 4A, 4B, 5 and is currently at Issue 6A. This supplement details the modifications, board by board and also provides additional servicing information and spare parts lists.

A substantial change has been introduced in the area of the DC-DC converter and the method of implementing this modification is detailed under its own heading. It is recommended that this modification is embodied in units on which either TR4 or the 16k DRAM has blown. Some Issue 3B and 4A units, and all later issues have these modifications embodied.

9.2 DC-DC CONVERTER MODIFICATION

EDITOR'S NOTE: The following information is incorrect, but is left here in the spirit of being as faithful to the original service manual as possible. DO NOT attempt the modification using these instructions.

The following new materials are required:

Diodes

- D17 - BR157
- D18 - IN4148
- D19 - 5V1 Zener

Capacitors

- C78 - 1uF 25V WKG Electrolytic
- C79 - 1uF 16V WKG Electrolytic

Resistors

- R60 - 220R 5%, 0.25W
- R79 - 2k2 5%, 0.25W

Remove the following components from the printed circuit board:

- D12- IN4148 Diode
- D16 - 5V1 Zener
- C47 - 22uF Electrolytic
- R54 - 100k
- R55 - 56R
- R60 - 270R

Embodiment the modification as follows:

- Break the connection between D15 and C49

- Connect C78 between C49 and D15 (positive end of C78 to C49)
- Connect D17 between ground (positive end of D17) and the new connection of C78 to D15

Substitute components as follows:

Remove	Substitute
D12	R79
D16	C79 (positive to ground)
C47	Open circuit
R54	D19 (positive to ground)
R55	D18 (positive to C46)
R60	R60, 220R

9.2.1 Circuit Operation

The modification is confined to adding/changing protection components in the rectification circuit to improve reliability. Circuit function does not change.

9.3 ISSUE 3B BOARD - (ALREADY COVERED IN EXISTING MANUAL)

9.4 ISSUE 4 BOARD - NONE ISSUED

9.5 ISSUE 4A BOARD

This differs from the issue 3B follows:

- R32 deleted
- Two spare gates from IC24 have been used to improve ULA timing. It is important that ULA 6C001-7 or later issues (the issue number is designated by the number after the hyphen) are used in this circuit. The gates are fitted in series with the RASL output from the ULA and the input to the display RAM multiplexers.
- Provision is made for fitting interference suppression coils and a modulator channel switch, as required on VHF units.

9.6 ISSUE 4B BOARD

The Issue 4B board is the same as that for the Issue 4A with the addition of the dc-dc converter modification. The board layout was changed at this stage as shown here. Due to lack of board space, C61 (22uF decoupler) was omitted. It is reinstated on subsequent board issues. The circuit diagram is shown here.

9.7 ISSUE 5 BOARD

1000 of these boards were supplied. They are restricted to the UK market only. A single ULA, IC27, (Mullard ZX 84/01) replaces the six 74LS chips. The circuit diagram is shown here. An inverter chip IC28 has been added and is used in the decoupling of the RAS/CAS function. Circuit functions do not change. Some discrete components were added/changed as reference to the parts list show. The board layout is shown here.

9.8 ISSUE 6 BOARD - NONE ISSUED

9.9 ISSUE 6A BOARD

This board is similar to Issue 5 but can be fitted with either a Ferranti or a Saga main ULA. The circuit diagram is shown here and the board layout is shown here.

9.10 FAULT FINDING – SERVICING ADDENDA

The following are additions to Section 4 of the servicing manual:

- Picture quality and possible RAM failures. Test at elevated temperature to show up faults.
- Interface 1 fault. Inspect the edge connector to check for damaged pins. Check the M1 signal from the CPU; this signal is only used with Interface 1 and so a failure is not evident when the Spectrum is used on its own.
- SAVE/LOAD failure. Inspect the jack sockets for deformation of contact springs.

9.11 WARRANTY SEAL

From August 1984, a new warranty seal label is fitted. The label is applied over the central screw hole at the rear of the base and has a four-digit code. Breaking of this seal invalidates the warranty.

9.12 PARTS LISTS

As alternatives to ZTX 213 in TR5 position, transistors BC213, BX214 or FRB925 may be used.

As alternatives to ZTX 313 in TR1, TR2, TR3 and TR6 positions, transistors MPD 2369 or MPS 2713 (both in TO-92 packages) can be used.

The parts lists follow. Some components on this table are not always fitted. Each is identified by reference to the note number in the NB column. The notes are explained below.

9.12.1 Notes

1. With Issue 5 boards, if R80-R86 are seen to be fitted, the value of R17-R23 is 470R. If R80-R86 are fitted, the values of R17-R23 are 330R.
2. With Issue 6 boards, this is not necessary with the SAGA version of IC1.
3. With Issue 6 boards, this is not necessary with the FERRANTI version of IC1.
4. With Issue 6 boards, this is only required on VHF models.
5. With Issue 6 boards, this is only required on the 48k model.
6. With all issues of Spectrum, if TR3 is type KSC839, resistor R24 should be 15k.
7. With all Issue Spectrums, if TR4 is to be replaced by type KTC2236A-Y, the pin connections differ to all other replacement types (Pin 1 is emitter, Pin 2 is collector and Pin 3 is base, i.e. the base and collectors are reversed).

9.13 CAPACITORS - UNLESS OTHERWISE STATED ALL ARE AXIAL TYPES

Circuit Ref	Issue 4A	Issue 4B	Issue 5	Issue 6A	Rating +/- Tol %	Type	NB
C1-C8	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C9-C24	NOT USED	NOT USED	NOT USED	NOT USED			
C25	22uf	22uf	22uf	22uf	10V, -10%+80%	Electrolytic	
C26	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C27	1uf	1uf	1uf	1uf	50V, 10%	Electrolytic	
C28	22uf	22uf	22uf	22uf	10V, -10%+80%	Electrolytic	
C29	47nf	47nf	44nf	22nf	25V, 10%	Ceramic	
C30	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	<u>2</u>
C31	100nf	100nf	100nf	100nf	25V, 10%	Ceramic	
C32	100nf	100nf	100nf	100nf	25V, 10%	Ceramic	<u>2</u>
C33	22nf	22nf	22nf	47nf	25V, 10%	Ceramic	
C34	22uf	22uf	22uf	22uf	10V, -10%+80%	Elect	
C35	10nf	10nf	10nf	10nf	25V, 10%	Ceramic	<u>2</u>
				100nf	25V, 10%	Ceramic	<u>3</u>
C36	NOT USED	NOT USED	NOT USED	NOT USED			
C37/C38	33pf	33pf	33pf	33pf	25V, 10%	Ceramic	
C39	10nf	10nf	10nf	10nf	25V, 10%	Ceramic	
C40/C42	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C43	100nf	100nf	100nf	100nf	25V, 10%	Ceramic	
C44/C45	100uf	100uf	NOT USED	100uf	16V, -10%+80%	Ceramic	
C46	1uf	1uf	1uf	1uf	50V, -10%+80%	Elect	
C47	22nf	22nf	NOT USED	NOT USED	10V, -10%+80%	Elect	
C48	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C49	560pf	560pf	560pf	560pf	25V, 10%	Ceramic	
C50	22uf	22uf	22uf	22uf	10V, -10%+80%	Elect	
C51	NOT USED	NOT USED	NOT USED	NOT USED			
C52/C53	150pf	150pf	150pf	150pf	25V, 10%	Ceramic	<u>2</u>
C54	NOT USED	NOT USED	NOT USED	NOT USED			
C55-C60	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C61	22nf	NOT USED	22nf	22nf	25V, 10%	Ceramic	
C62	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C63	47pf	47pf	NOT USED	NOT USED	25V, 10%	Ceramic	
C64	180pf	180pf	NOT USED	NOT USED	25V, 10%	Ceramic	
C65	22uf	22uf	22uf	22uf	20V, -10%+80%	Elect	
C66	22nf	22nf	22nf	22nf	25V, 10%	Ceramic	
C67	100pf	100pf	100pf	100pf	25V, 10%	Ceramic	<u>2</u>
C68-C71	100nf	100nf	100nf	100nf	25V, 10%	Ceramic	<u>2</u>
C72/C73	16pf	16pf	16pf	16pf	25V, 5%	Ceramic	
C74	4.7uf	4.7uf	4.7uf	4.7uf	5V min	Elect	
C75	100nf	100nf	100nf	100nf	25V, 10%	Ceramic	
C76	47nf	47nf	47nf	22nf	25V, 10%	Ceramic	<u>2</u>
C77	100nf	100nf	NOT USED	NOT USED	25V, 10%	Ceramic	
C78	NOT USED	NOT USED	22uf	NOT USED	25V, 10%	Elect	
C79	NOT USED	1uf	1uf	1uf	16V, 10%	Elect	
C80	NOT USED	22uf	NOT USED	22uf	25V, 10%	Elect	
C100	NOT USED	NOT USED	NOT USED	10nf	25V, 10%	Ceramic	<u>4</u>
C101	NOT USED	NOT USED	NOT USED	22nf	25V, 10%	Ceramic	<u>4</u>
C102	NOT USED	NOT USED	NOT USED	NOT USED			
C103	NOT USED	NOT USED	NOT USED	NOT USED			
C104	NOT USED	NOT USED	100nf	100nf	25V, 10%	Ceramic	
C105	NOT USED	NOT USED	180pf	180pf	25V, 10%	Ceramic	

9.14 COIL

Circuit Ref	Issue 4A/4B/5/6A	Manufacturer
Coil L1-L2	Spectrum TFR, 2 windings on toroidal former	N. Devon

9.15 CONNECTORS

Reference	Description	Manufacturer/Part Number
EAR	3.5mm jack socket	Tuda
MIC	3.5mm jack socket	Tuda
PWR	2.1mm co-axial socket	Hoseiden
KB1	5-way ribbon connector	Molex 5229-05CPB/Flexlock
KB2	8-way ribbon connector	Molex 5229-08CPB/Flexlock

9.16 CRYSTALS

Circuit Reference	Issue 4A	Issue 4B/5/6A
X1	14.000000MHz	Same all issues
X2	4.43361875MHz	Same all issues

9.17 RESISTORS - 0.25W, 5% TOLERANCE UNLESS OTHERWISE STATED

Circuit Ref	Issue 4A	Issue 4B	Issue 5	Issue 6A	Rating +/- Tol%	NB
R1-R8	470R	470R	470R	470R		
R9-R16	8k2	8k2	8k2	8k2		
R17-R23	330R	330R	470R	470R		<u>1</u>
R24	1k	1k	1k	1k		<u>6</u>
R25	180R	180R	180R	180R		
R26/R27	470R	470R	470R	470R		
R28	10k	10k	10k	10k		
R29	10k	10k	10k	10k		
R30	10k	10k	10k	10k		
R31	220k	220k	220k	220k		
R32	NOT USED	NOT USED	NOT USED	NOT USED		
R33	680R	680R	680R	680R		<u>2</u>
				560R		<u>3</u>
R34	15R	15R		15R	0.5 or 1W	<u>2</u>
R35	10k	10k	10k	10k		
R36	680R	680R	680R	680R		
R37	1k	1k	1k	1k		
R38-R41	NOT USED	NOT USED	NOT USED	NOT USED		
R42	1k	1k	1k	1k		
R43	3k	3k	3k	3k	2%	
R44	5k1	5k1	5k1	5k1	2%	
R45/R46	1k	1k	1k	1k		
R47	1k	1k	1k	1k		
R48	2k2	2k2	2k2	2k2		<u>2</u>
R49	10k	10k	10k	10k		<u>2</u>
R50	4k7	4k7	4k7	4k7		<u>2</u>
R51	2k2	2k2	2k2	2k2		<u>2</u>
				1k2		<u>3</u>
R52	2k2	2k2	2k2	2k2		
R53	390R	390R	390R	390R		
R54-R55	NOT USED	NOT USED	NOT USED	NOT USED		
R56	1k	1k	1k	1k		<u>2</u>
R57	NOT USED	NOT USED	NOT USED	NOT USED		
R58	1k	1k	1k	1k	2%	
R59	1k8	1k8	1k8	1k8	2%	
R60	220R	220R	220R	220R		
R61/R62	15R	15R	15R	15R		
R63	1k	1k	1k	1k		<u>2</u>
R64	15R	15R	15R	15R		
R65-R67	10k	10k	10k	10k		<u>2</u>
R68	10k	10k	10k	6k8		<u>2</u>
R69	10k	10k	10k	10k		<u>2</u>
R70/R71	220R	220R	NOT USED	NOT USED		
R72	10k	10k	10k	10k		
R73	1k	1k	1k	1k		<u>2</u>
R74/R75	10k	10k	10k	10k		<u>2</u>
R76/R77	1k	1k	1k	1k		<u>2</u>
R78	470R	470R	470R	470R		
R79	NOT USED	NOT USED	2k2	2k2		
R80-R86	NOT USED	NOT USED	1k	1k		<u>1</u>
R87	NOT USED	NOT USED	LINK	0		
R88	NOT USED	NOT USED	1k	1k0		
R89	NOT USED	NOT USED	8k2	8k2		
R90	NOT USED	NOT USED	NOT USED	2k7		

9.18 DIODES

Circuit Reference	Issue 4a	Issue 4b	Issue 5	Issue 6a	Type
D1-D9	1N4148	1N4148	1N4148	1N4148	Signal
D10	NOT USED	NOT USED	NOT USED	NOT USED	
D11/D13	1N4148	1N4148	1N4148	1N4148	Signal
D12	NOT USED	NOT USED	NOT USED	NOT USED	
D14	NOT USED	NOT USED	NOT USED	NOT USED	
D15	BA157	BA157	BA157	BA157	Rectifier
D16	5V1	NOT USED	NOT USED	NOT USED	Zener
D17	-	BA157	BA157	BA157	Rectifier
D18	-	1N4148	1N4148	1N4148	Signal
D19	-	5V1	BZY88C	BZY88C	Zener

9.19 INTEGRATED CIRCUITS

Circuit Reference	Issue 4a, Issue 4b	Issue 5	Issue 6a	Manufacture/Type
IC1(ULA)	6C001-7 (6C011) 6C001E-7	6C001E-7		Ferranti
	NOT USED	NOT USED		or SAGA
IC2(CPU)	Z80A/u780		Z80A	NEC/ZILOG
IC3/IC4	74LS157N (MUX)			NOT National
IC5(ROM)	SPECTRUM			NEC/Hitachi
IC6-IC13	4116/416- 3/MN5290-2		4116	150ns
IC14	LM1889		LM1889	National
IC15-IC22	T14532/MSM3732 (48k only)		4532	Texas/OKI
IC23	74LS32N/74AL532 (48k only)	NOT USED		
IC24	74LS00N/74AL500 (48k only)	NOT USED		
IC25, IC26	74LS157N/74157 (48k only)	NOT USED		NOT National
IC27	NOT USED	ZX84/01	ZX84/01	Mullard
IC28	NOT USED	74LS04	74LS04	Texas

9.20 TRANSISTORS

Circuit Reference	Issue 4a, 4b, 5, 6a	NB
TR1-TR2	ZTX313/MPS2369/MPS2713/KSC945-Y	
TR3	ZTX313/MPS2369/MPS2713/KSC839-0	<u>2 and 6</u>
TR4	ZTX650/TIPP31/KTC2236A-7	<u>7</u>
TR5	ZTX231/BC213/BX214/FRB925	
TR6	ZTX313/MPS2369/MPS2713	
TR7	ZTX450	
TR8/TR9	BC184/BC549B	<u>2</u>

9.21 MISCELLANEOUS

Reference	Description	Manufacturer/Part Number
REG	5V regulator	7805
MOD	UHF modulator with E36 vision carrier (UK only)	Astec UM1233 (UM16--- for VHF versions)
Loudspeaker	40 ohm TV type	G. English (Merry)
Modulator Screen Insulator	-	Stafford Rubber SRC090
Heatsink	Special (Issue 2 or 3)	
Regulator Fixings (1)	Screw, ch hd. 4BA x 15/16 in.	
Regulator Fixings (2)	Washer, shk prf, 4BA	
Regulator Fixings (3)	Nut, hex. 4BA	
DIL SKT	16-way (10 off) for 48k expansion RAM (16K model only)	DIL SKT
DIL SKT	14-way (2 off) for 48k expansion RAM (16K model only)	DIL SKT
DIL SKT	28-way for IC1 (ULA)	

10 SUPPLEMENT NO 2

Introduction

Conversion Procedure - Spectrum to Spectrum+

Assembly of the Keyboard for the Spectrum+

Keyboard Operation

Spectrum+ Keyboard - Top Membrane Diagram

Spectrum+ Keyboard - Lower Membrane Diagram

10.1 INTRODUCTION

The ZX Spectrum+ is basically the same as the 48k ZX Spectrum with a different keyboard and case, and a reset button. The board circuitry is similar apart from the reset button and the fitment of an extra resistor.

The layout of the keyboard is different, which because of its complexity now needs a five-layer membrane. The spring action of the keys is provided by a bubble mat.

10.2 CONVERSION PROCEDURE – SPECTRUM TO SPECTRUM+

1. Remove board from the early version case.
2. Change heatsink (on Issue 1 and Issue 2 boards only), retaining the triangular insulator, if originally fitted.
3. Connect the reset switch across C27 on the top side of the board.
4. Test keyboard, especially STOP.
5. If STOP does not work, connect a 22k resistor across R68. (On the Issue 1 board, connect a 22k resistor between pins 1 and 5 of RP1, on the reverse side of the board).
6. Fit four rubber feet to the underside of the case.
7. Fit board to case bottom.
8. Press the reset switch into the recess in the side wall (ensure that the leads are not trapped).
9. Fit foam pads: one to the top of the modulator; and on Issue 3 (and higher issue boards), two on the top of the heatsink. These are to protect the membrane tails from chafing.
10. Drop folding legs into slots. Sit the springs on top of the legs.
11. Connect the keyboard flextails.
12. Fit the top cover, taking care not to crease the tails.
13. Test.
14. Fit warranty seal, if applicable.

For details, see the ZX Spectrum+ upgrade instructions, which accompany the upgrade kits.

10.3 ASSEMBLY OF THE KEYBOARD FOR THE SPECTRUM+

The flextails running from the keyboard to the clamps should lie in an S shape, to prevent tension in the membrane. This is achieved by ensuring that the end of the tracks on the middle layer protrude by 1mm past the clamps. This is easily seen on the wider tail, but not so clear on the narrow one. Visible markers are provided on future membranes.

When clamping the flextails, ensure that an extra packing piece is included under the tails at the clamp position. (These are fitted to current production models). These should be approximately 0.75mm thick, and as wide as the tail. Paxolin is a suitable material. This section does not apply to any Spectrum+ which has S as the first digit in the serial number.

When assembling the keyboard, it is advisable to tighten the screws in the following order:

- Centre line of 3 screws first
- Screws adjacent to tail clamps last

The screws should be tightened to the minimum to give a firm fit, (e.g. a quarter-turn back from full tightness).

Ensure that on each membrane tail the 2 tail surfaces are stuck together, to avoid short circuits on the board. This is best achieved by using a piece of double-sided tape, or a pair of tabs around the edges, near the connector end. This is current practice in production.

Both metal and plastic reaction plates are possible. The metal plate has to be accompanied by a plastic insulator. The plastic reaction plate is similar and cheaper. The metal plate needs 6.5mm fixing screws and the plastic plate needs 8mm.

It is advisable to check the operation of all the keys on newly assembled keyboards.

10.4 KEYBOARD OPERATION

The Spectrum+ keyboard is in effect two switching membranes in parallel, a 'top' membrane and a 'lower' membrane.

The top membrane is similar to that for the Spectrum 48k, except that pressing any one of the following keys also makes contact between row 1 and column 6 on the top membrane in addition to their dedicated row/column positions:

TRUE VIDEO	EXTEND MODE	CURSOR RIGHT
INV VIDEO	EDIT	CURSOR LEFT
BREAK	CAPS LOCK	CURSOR UP
DELETE		CURSOR DOWN
GRAPH		

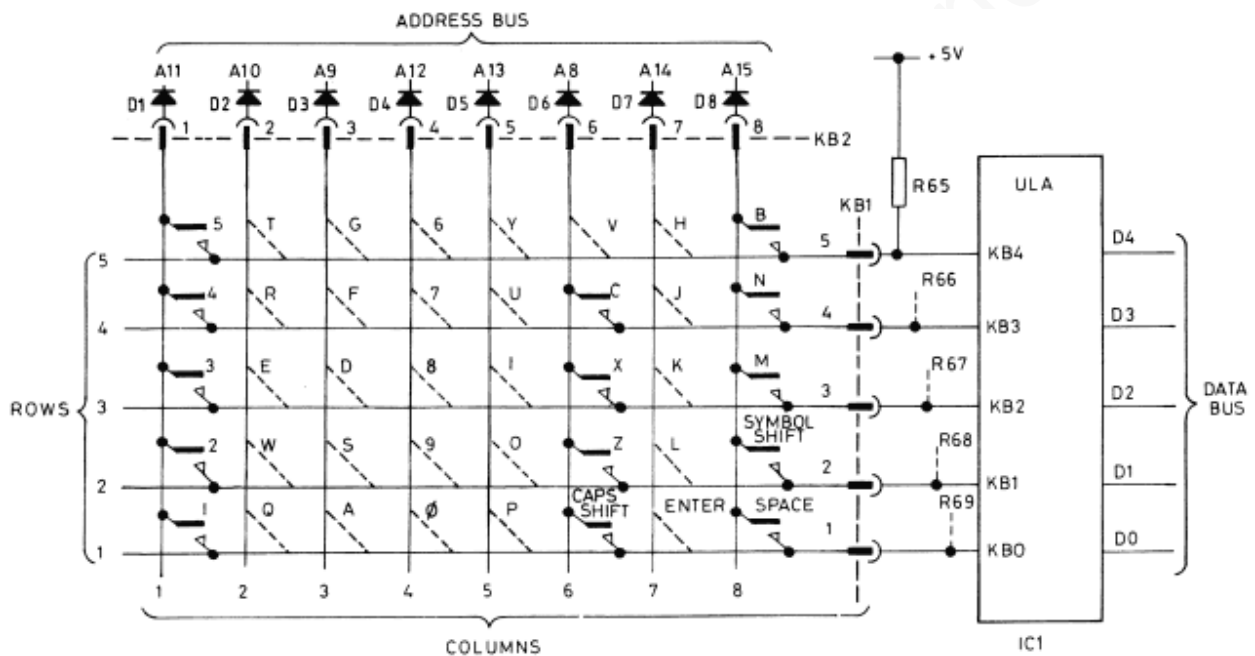
For example, pressing TRUE VIDEO connects row 1/column 6 on the top membrane as well as row 3/column 1 on the lower membrane.

Also pressing any one of the following keys also makes contact between row 2 and column 8 on the top membrane in addition to their dedicated row/column positions.

- . (full stop)
- ; (semi-colon)
- " (inverted commas)
- , (comma)

For example, pressing the full stop key connects row 2/column 8 on the top membrane as well as row 3/column 8 on the lower membrane.

10.5 SPECTRUM + KEYBOARD – TOP MEMBRANE



10.6 SPECTRUM+ KEYBOARD — LOWER MEMBRANE

