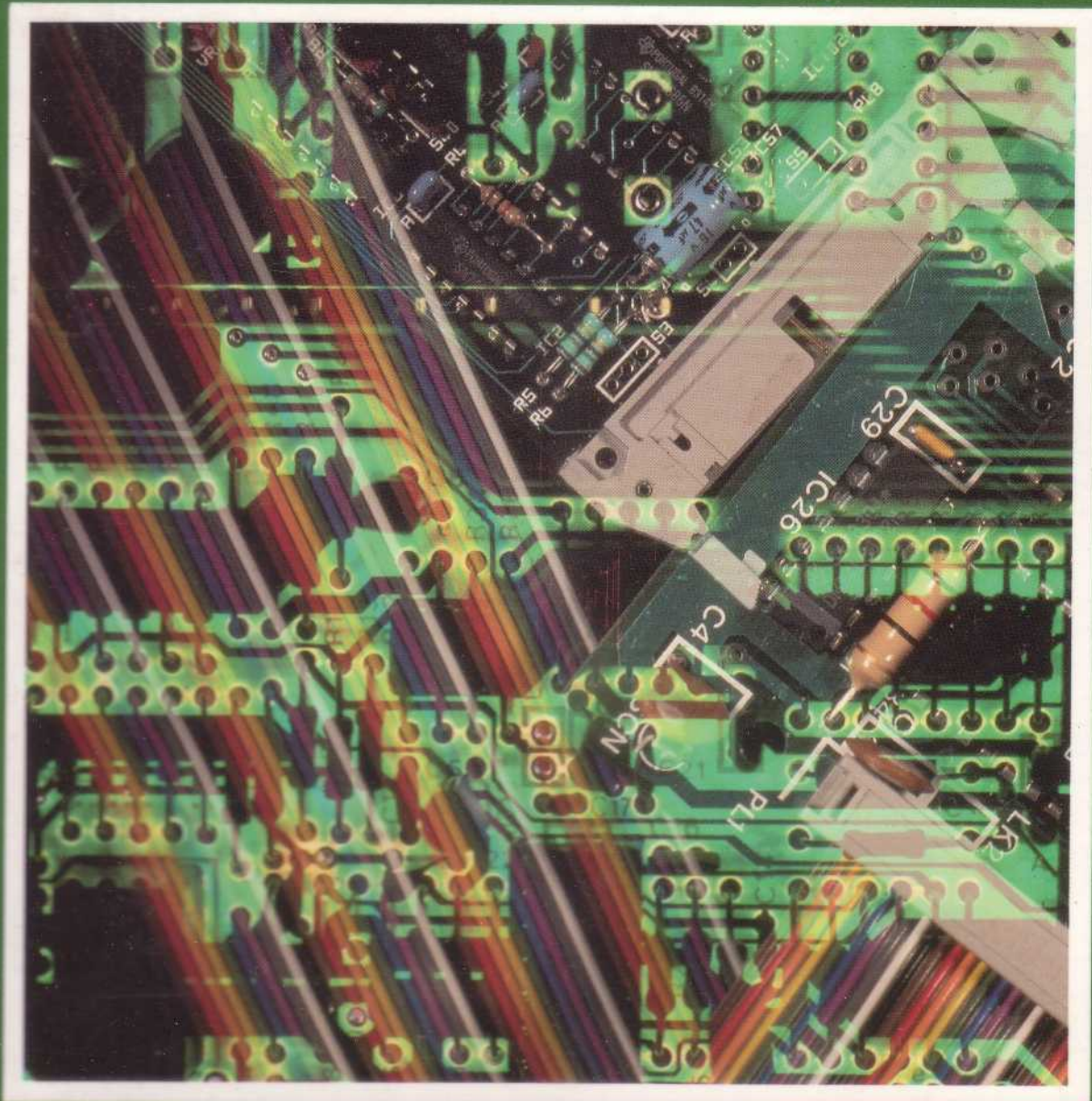


 ACORN COMPUTER

6502

second processor

Service Manual



6502 SECOND PROCESSOR SERVICE MANUAL

Part no 0408,003
Issue 1
May 1984

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First published 1984

Published by Acorn Computers Limited

6502 SECOND PROCESSOR SERVICE MANUAL

	page
Contents	
1 Introduction	1
2 Packaging and Installation	2
3 Specification	3
3.1 The 6502 Second Processor	3
3.2 Tube Operating System	3
3.3 BASIC	3
3.4 Power Supply	3
3.5 Environmental	4
3.6 Outside Dimensions	4
4 Disassembly and Assembly	5
5 Circuit Description	6
5.1 General	6
5.2 Power-Up	6
5.3 After Power-up	6
5.4 PCB Links	7
5.5 Tube Connector Pinout	8
6 The Tube	9
6.1 Tube Registers	9
6.2 Tube Pinout	12
6.3 Timing	14
7 Fault Finding on the 6502 Second Processor	15
7.1 General	15
7.2 Start-up Message Printed	15
7.3 Total Failure	15
7.3.1 Power Supply	16
7.3.2 Oscillator	17
7.4 Checking the Second Processor in Boot Mode	17
7.4.1 PHI Generation Circuit	18
7.4.2 Reset and ROM Enable Circuitry	18
7.4.3 CPU	18
7.5 Checking the Second Processor in Run Mode	19
7.5.1 PHI Generation Circuit	19
7.5.2 Refresh Circuitry	19
7.5.3 DRAMs	20
7.5.4 CPU	21
7.5.5 The Tube IC1	21
APPENDIX	23
IC Number and Function	25
General Assembly	27
Block Diagram	29
Main PCB Circuit Diagram	31
Assembly Drawing	33
Power Supply Board Circuit Diagram	35
Parts List	37

WARNING: THE COMPUTER MUST BE EARTHED

IMPORTANT: The wires in the mains lead for the second processor are coloured in accordance with the following code:

GREEN & YELLOW - EARTH
BLUE - NEUTRAL
BROWN - LIVE

As the colours of the wires may not correspond with the coloured markings identifying the terminals in your plug, proceed as follows:

The wire which is coloured green and yellow must be connected to the terminal in the plug which is marked by the letter E, or by the safety earth symbol , or coloured either green or green and yellow.

The wire which is coloured blue must be connected to the terminal which is marked by the letter N, or coloured black.

The wire which is coloured brown must be connected to the terminal which is marked by the letter L, or coloured red.

If the socket outlet available is not suitable for the plug supplied, the plug should be cut off and the appropriate plug fitted and wired as previously noted. The moulded plug which was cut off must be disposed of as it would be a potential shock hazard if it were to be plugged in with the cut off end of mains cord exposed.

The moulded plug must be used with the fuse and the fuse carrier firmly in place. The fuse carrier is of the same basic colour* as the coloured insert in the base of the plug. Different manufacturers' plugs and fuse carriers are not interchangeable. In the event of loss of the fuse carrier the moulded plug MUST NOT be used. Either replace the moulded plug with another conventional plug wired as previously described, or obtain a replacement fuse carrier from an authorised BBC Microcomputer dealer. In the event of the fuse blowing, it should be replaced, after clearing any faults, with a 3 amp fuse that is ASTA approved to BS 1362.

*Not necessarily the same shade of that colour.

1. Introduction

This manual is intended to provide the information required to diagnose and repair faults on the 6502 second processor (a part of the BBC Microcomputer system) which was designed by Acorn Computers Ltd of Cambridge, England.

The information contained in this manual is aimed at service engineers and Acorn dealers who will be servicing the 6502 second processor on behalf of Acorn Computers Ltd.

2. Packaging and Installation

The 6502 second processor is supplied in a two part moulded polystyrene packing which is further packaged within a cardboard sleeve. Supplied with the second processor is a User Guide, a ROM labelled DNFS, a ROM labelled HIBASIC, and a guarantee card.

The DNFS ROM must be plugged into one of the BBC Microcomputer's sideways ROM sockets, or the second processor system will not work, see 3.2.

The socket on the second processor ribbon cable should be plugged into the connector labelled TUBE under the BBC Microcomputer Keyboard.

A mains power switch is located at the rear of the second processor.

A T315mA fuse is located at the rear of the second processor. Before tampering with the fuse the second processor must be disconnected from the mains. Access to the fuse may be gained by undoing the round cover with the slot in it using a screwdriver. The mains must not be reconnected until the fuse is relocated correctly in its holder with the cover screwed shut.

Do not use the second processor in conditions of extreme heat, cold, humidity or dust or in places subject to vibration. Do not block ventilation under or behind the second processor. Ensure that no foreign objects are inserted through any openings in the second processor.

3. Specification

3.1 The 6502 second processor

A second processor for the BBC Microcomputer operating through THE TUBE giving faster processing speed, more user memory, faster BASIC. The second processor is contained in a rigid injection moulded thermoplastic case and contains the following:

A 3MHz 6502

64K of read/write Random Access Memory

4K Read Only Memory containing part (2 Kbytes) of the Tube Operating System (TOS)

The Tube - a fast asynchronous communication path connecting the second processor to the I/O processor (BBC Micro)

3.2 Tube operating system

The Tube operating system is divided between the second processor and the I/O processor. The 2K of code in the second processor is stored in a ROM labelled 6502 BR (boot ROM) and on power-up or BREAK is copied to RAM locations &F800 to &FFFF in the second processor. The 1K of code in the I/O processor is stored in a ROM labelled DNFS and on power-up or BREAK is copied to RAM locations &400 to &7FF in the I/O processor. All the usual BBC Microcomputer OS calls are available on the second processor.

3.3 BASIC

On power-up, the rightmost language ROM in the I/O processor's sideways ROM sockets is copied across the Tube into the second processor's memory. Standard BBC BASIC (ROM identification number PB01 or P1305) is copied into locations &8000 to &BFFF. HI-BASIC, which is supplied with the second processor, may be copied into locations &B800 to &F7FF (allowing more user-RAM space for programs if required).

All of BBC BASIC's facilities are available on the second processor, and execution speed is up to twice as fast as the BBC Microcomputer alone.

3.4 Power supply

Max AC input 264V AC

Min ACinput 216V AC

Power rating 14 watts

Supply frequency 47-63 Hz

Max output current 1A at +5V

3.5 Environmental

Minimum operating temperature	+5 degrees C
Maximum operating temperature	+35 degrees C
Minimum storage temperature	-20 degrees C
Maximum storage temperature	+70 degrees C
Maximum operating humidity	95% RH at 35 degrees C
Maximum storage humidity	95% RH at 55 degrees C

3.6 Outside dimensions

Height	72mm
Width	207mm
Depth	346mm

4 Disassembly and assembly

To service the 6502 second processor, disconnect it from the mains and undo the three fixing screws, two at the top of the back panel and one underneath nearest the front equidistant between the two rubber feet. (The assembly diagram is given in the Appendix.) The lid can now be removed revealing the transformer and power supply board held in place by six screws, and the main PCB. It is recommended that the transformer and power supply board are not unscrewed from the case unless absolutely necessary.

To remove the main PCB from the case, pull off the two "fast on" tabs which connect the power supply (brown +5V and black 0V leads), and remove the four screws which hold the PCB in place.

5 Circuit Description

5.1 General

The microprocessor used in the 6502 second processor is a 6502C with clock signals provided by a 12MHz crystal oscillator (IC8) in conjunction with divider circuitry (IC12). The processor runs at 3MHz.

Random Access (Read/Write) Memory is provided by 8 64Kbit DRAMs (ICs 18 to 25), giving 64Kbytes in all. Thus the memory map for the second processor consists entirely of RAM.

5.2 Power-up

On power-up, the second processor runs for about 0.25 of a second in "boot mode", and the Tube Operating System code in the second processor ROM is copied into RAM at locations &F800 to &FFFF. The second processor is thereafter executing code from RAM only, and the ROM is not accessed again.

IC26 is a monostable which, on power-up, supplies a logic 0 to IC6 pin 10 and IC2 pin 40 (RST) for approximately 100µs. The D-type flip-flop contained in IC6, thus set, enables the divide by 16 counter (IC11 pin 9), the ROM chip select (IC3 pin 18), and the read/write ROM/RAM toggle circuit (NAND gate pins 4 5 and 6 of IC10). When RST goes high the CPU starts to operate and accesses the ROM.

PHI IN (the processor main clock input) to the second processor is supplied from IC12 pin 13 (divide by 4). In boot mode this counter (IC12) is enabled by the divide by 16 counter (IC11) and so the PHI IN frequency is $3/16\text{MHz} = 187.5 \text{ kHz}$.

When R/W is high (read), the NAND gate (pins 4 5 and 6) in IC10 applies a reset to pin 13 IC9 which disables the CAS input to the DRAMs. When R/W is low (write) then CAS is enabled. This means that in boot mode, read operations read from the ROM, and write operations write to the RAM, thus allowing the code to be copied across.

Boot mode is terminated by the software when it selects any one of the Tube addresses. The address is decoded by the NAND gate in IC4, which pulls pin 12 of IC6 low, thereby resetting the output. This deselects the ROM, and disables IC11 which allows IC12 to generate PHI IN at 3MHz.

5.3 After power-up

The second processor is now running at 3MHz and entirely in RAM. The NAND gate (pins 4 5 and 6 of IC10) now inhibits the action of the RAM by suppressing CAS only when the Tube chip itself (IC1) is being accessed, ie when IC4 pin 9 is logic 0.

The whole second processor is halted when the NOR gate (pins 8 9 and 10 of IC14) detects a collision. This happens when both the host (BBC Microcomputer) and parasite (second processor) select the Tube simultaneously, by pulling both HCS and PCS low.

Timing of the DRAM refresh is handled by counter 1C13, which requests a refresh by setting pin 55 high (which also pulls pin 7 low to stall the counter while the refresh is taking place). The NAND gate (pins 8 9 and 50 of 1C50) waits for SYNC to go high signalling the end of an instruction cycle and pulls the READY line low to stall the processor. It also pulls 1C57 pin 59 low and 1C55 pin 59 high which deselects the row address from the CPU and enables the refresh address from 1C7. 1C7 is an 8-bit counter which holds the address of the next row to be refreshed, and ICs 55 56 and 57 are address buffers. RAS, driven directly (but inverted) from PHI 1N, goes low to execute the refresh, and on its rising edge clocks pin 3 of the D-type flip-flop in 1C6, which clears the refresh request and reloads the timer (IC53). This in turn increments the refresh address held in 1C7.

For information on the operation of the Tube (IC13) see section 6.

5.4 PCB Links

The second processor PCB has 5 links numbered LK5 to LK5 and a Disable link. These links are hard-wired in the correct position for normal use. The action of these links is as follows:

LK2 when made powers the whole second processor from the BBC Microcomputer's power supply. The second processor power supply leads must be disconnected before LK5 is made. Running the second processor from the BBC's power supply may overload it and this practice is not recommended.

LK2 when made connects the H1RQ line. H1RQ is the interrupt request line from the second processor to the I/O processor, and is not used by standard software. If LK2 is made the BBC Microcomputer will not work when the second processor is powered down.

LK3 controls the source of the power supply to the BBC peripherals in the Tube chip. In its hard-wired position, LK3 selects power for the BBC half of the Tube chip from the BBC's power supply. LK3 must not be altered.

LK4 is included to replace the diode D1. (D1 and R6 are not fitted because the disable feature is not implemented). If the Disable link is made then LK4 must be broken.

LK5 ensures the correct refresh rate for use with a processor running at 4MHz. At 3MHz it must not be altered.

Disable is not implemented, but may be used if LK4 is broken (see LK4).

5.5 Tube connector pinout

The tube connector pinout is as shown below:

TOP	Pin	No	BOTTOM
0V	1	2	R/NW (read/not-write)
0V	3	4	2MHzE
0V	5	6	N1RQ (not-interrupt request)
0V	7	8	NTUBE
0V	9	10	NRST (not-reset)
0V	11	12	D0
0V	13	14	D1
0V	15	16	D2
0V	17	18	D3
0V	19	20	D4
0V	21	22	D5
0V	23	24	D6
0V	25	26	D7
0V	27	28	A0
0V	29	30	A1
+5V	31	32	A2
+5V	33	34	A3
+5V	35	36	A4
+5V	37	38	A5
+5V	39	40	A6

6 The Tube

The Tube (IC1) is a custom chip which provides parallel asynchronous communication between two processor systems, the BBC Microcomputer (host) and the second processor (parasite). To each processor system it resembles a conventional peripheral device, occupying 8 bytes of memory or I/O space.

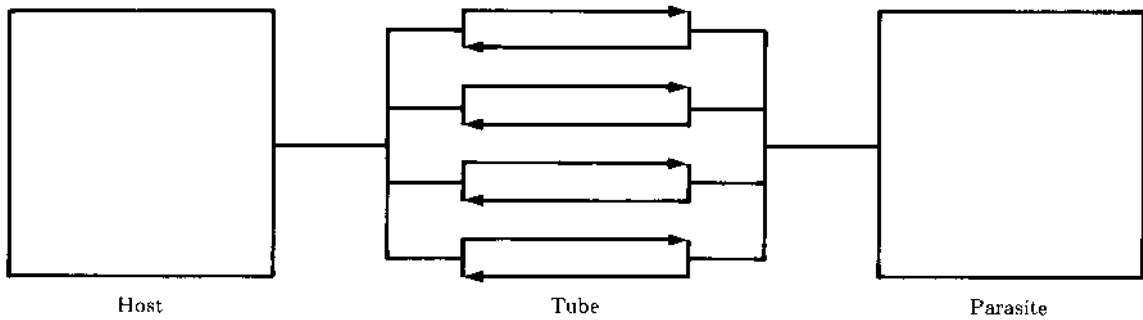


Figure 1 Tube concept

6.1 Tube Registers

As can be seen from Figure 1, each system (host or parasite) has access to 4 read only registers and 4 write only registers. In addition, each read only register has an associated status register, and the host system also has access to a single write only status register.

Figure 2 shows the Tube registers in more detail

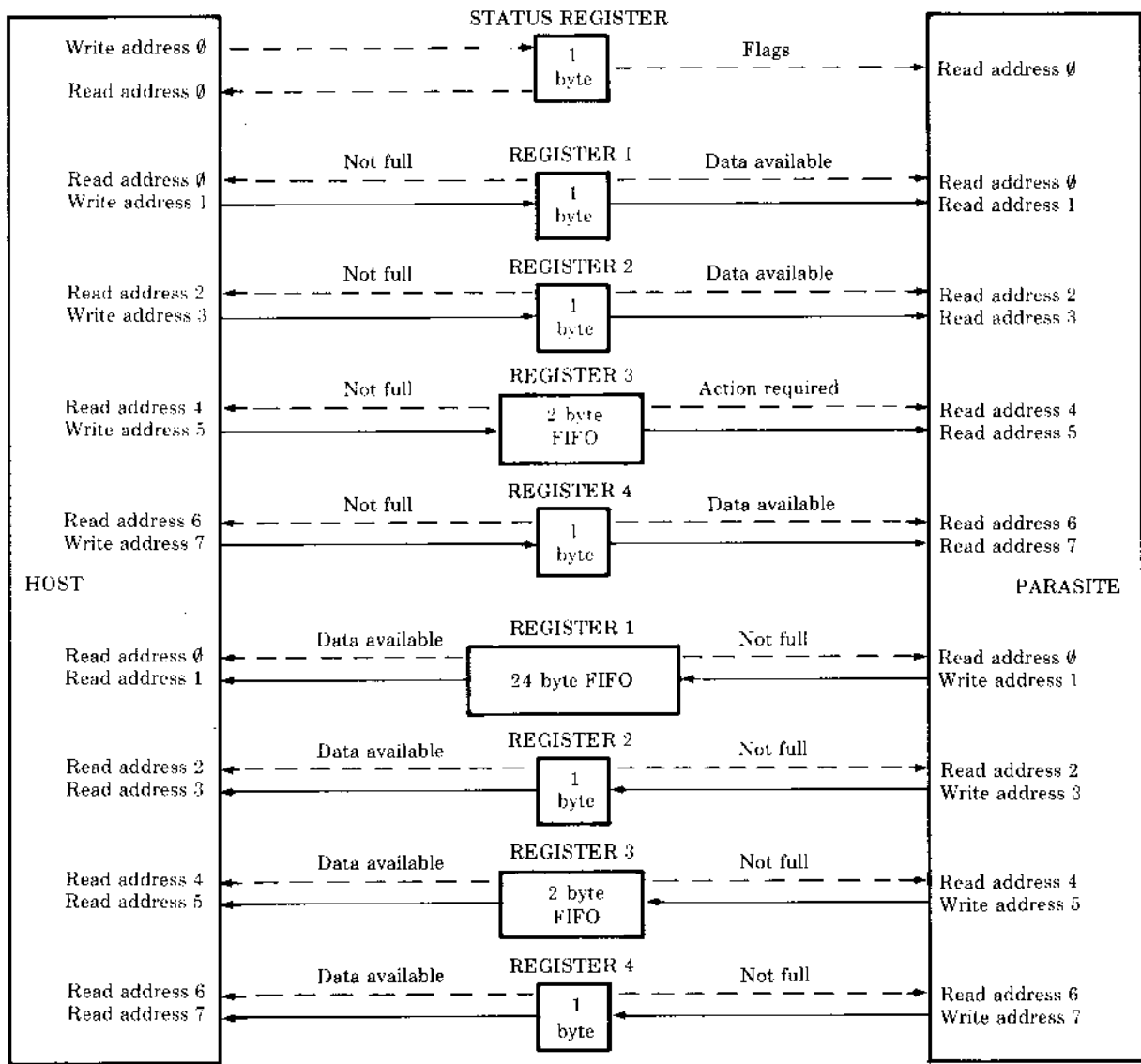


Figure 2 Schematic diagram of Tube registers

The following tables show the relative address and type of each register in the Tube, firstly for the host system, and secondly for the parasite system.

Table 1 Host system registers

Address	Read
000	Status flags and Register 1 flags
001	Register 1 (24 byte F1FO read only)
010	Register 2 flags
011	Register 2 (1 byte read only)
100	Register 3 flags
101	Register 3 (2 byte F1FO read only)
110	Register 4 flags
111	Register 4 (1 byte read only)

Address	Write
000	Status flags
001	Register 1 (1 byte write only)
010	
011	Register 2 (1 byte write only)
100	
101	Register 3 (2 byte F1FO write only)
110	
111	Register 4 (1 byte write only)

Table 2 Parasite system registers

Address	Read
000	Status flags and Register 1 flags
001	Register 1 (1 byte read only)
010	Register 2 flags
011	Register 2 (1 byte read only)
100	Register 3 flags
101	Register 3 (2 byte F1FO read only)
110	Register 4 flags
111	Register 4 (1 byte read only)

Address	Write
000	
001	Register 1 (24 byte F1FO write only)
010	
011	Register 2 (1 byte write only)
100	
101	Register 3 (2 byte F1FO write only)
110	
111	Register 4 (1 byte write only)

As can be seen from Figure 2 and Tables 1 and 2, each numbered register (eg register 1) is actually two registers, one for reading and one for writing. The register selected is determined by R/W on the host side, and by PNRDS/PNWDS on the parasite side (see 6.2).

Some of the registers are single byte latches, and others are FIFO buffers which store two or more bytes to be read out in the same order they were put in. Data is stored in the Tube until removed by the receiving processor, thus allowing completely asynchronous operation of the two systems. Messages and data are passed to and fro through the various registers according to carefully designed software protocols which allow both systems to operate with the minimum waiting time.

6.2 Tube Pinout

Figure 3 shows the pinout diagram for the Tube 1C.

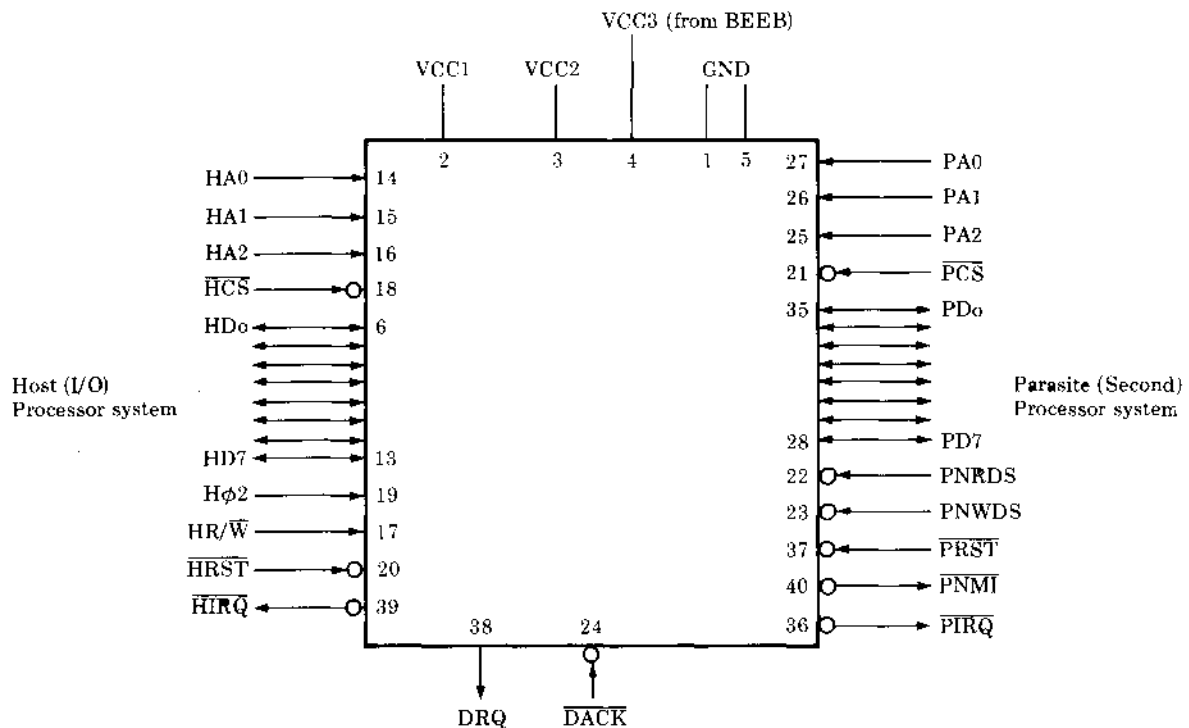


Figure 3 Pinout diagram for Tube 1C

Description of pins:

Power supply	GND	0V supply rail
	VCC1	Parasite main +5V supply
	VCC2	Parasite secondary supply
	VCC3	Host +5V supply
Data buses	HD0-7	8-bit data bus to host processor
	PD0-7	8-bit data bus to parasite processor
Address signals	HA0-2	3 register select lines from host
	PA0-2	3 register select lines from parasite
	HCS	Host chip select
	PCS	Parasite chip select
Timing signals	HPHI2	Host PHI2 - high level signifies valid address bus
	HR/W	Host read/write line - determines whether read or write register is selected on address specified by HA0-2, and direction data flow on HD0-7
	PNRDS	Parasite read strobe (active-low)
	PNWDS	Parasite write strobe (active-low)
Interrupt lines	HRST	Host reset (RST) - initialises Tube to known state and generates PRST
	PRST	Reset (RST) line to parasite processor
	P1RQ	Interrupt to parasite
	PNM1	Non-maskable interrupt to parasite
	H1RQ	Interrupt to host (not used by 6502 second processor)
DMA lines	DRQ	Request for DMA transfer
	DACK	DMA acknowledge from DMA controller
DMA facility is not used by the 6502 second processor		

6.3 Timing

Figure 4 gives the Tube timing diagram.

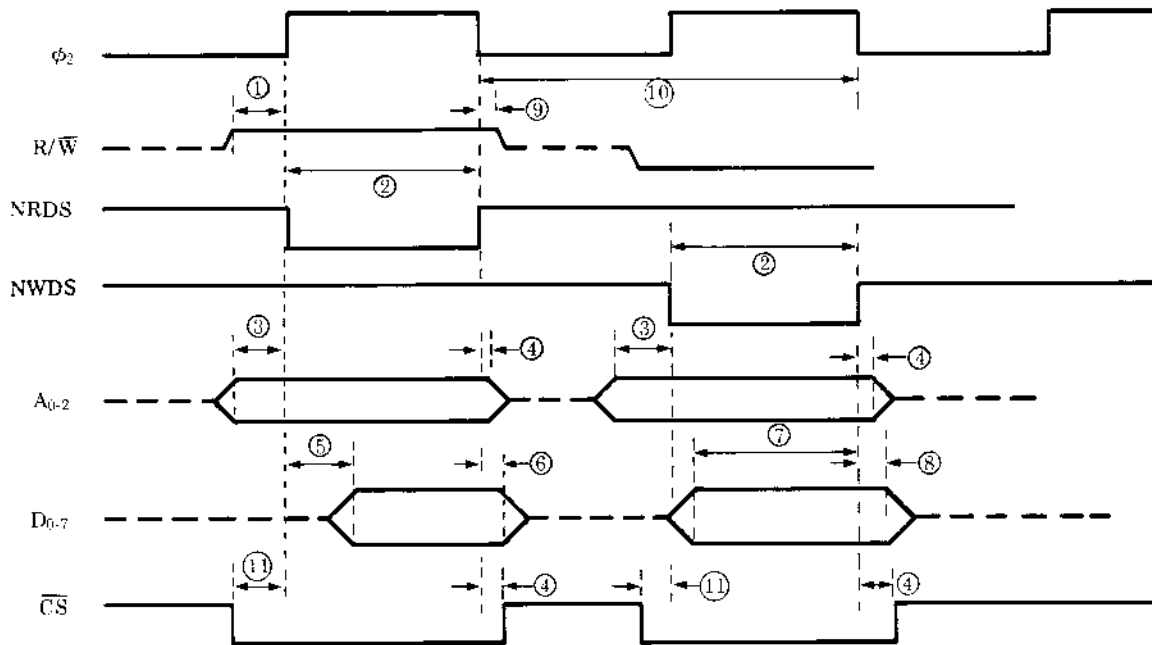


Figure 4 Tube timing diagram

1 - R/W set up to PHI 2 (host PH1 2)	35ns maximum
2 - timing strobe pulse width	110ns maximum
3 - address set up time	35ns maximum
4 - address and chip select hold times	10ns maximum
5 - data out delay time	70ns minimum
6 - data out hold time	10ns maximum
7 - data in set up time	50ns maximum
8 - data in hold time	20ns maximum
9 - R/W hold time	10ns maximum
10 - cycle time	250ns maximum
11 - CS set up time	20ns maximum

The timing reference for the host is PH1 2, and R/W gives the direction of transfer.

For the parasite, both timing and direction are given by PNRDS or PNWDS

7 Fault Finding on the 6502 Second Processor

7.1 General

- a) The 6502 second processor PCB has three socketed ICs (ICs 1 to 3), so these chips may easily be replaced if necessary.
- b) The second processor circuit is difficult to diagnose area by area because it contains only one subsystem which terminates, namely the 12MHz oscillator. A check on any other subsystem on the board requires earlier subsystems to be working, but this same argument also applies to each of them.
- c) The second processor system runs entirely in RAM, except for the first quarter second when the Tube Operating System ROM contents are copied across at a reduced clock speed of 187.5kHz. It is useful to bear this in mind when debugging.

7.2 Start-up message printed

Remember from 3.2 that the Tube Operating System software is copied from ROM to RAM on power-up or CTRL BREAK. If the start-up message

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Acorn TUBE 6502 64K
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is printed on the screen then the second processor has completed the boot phase, and the Tube chip (IC1) is operating.

The fault will lie in the DRAMs, see 7.5.3, or the refresh circuitry, see 7.5.2.

7.3 Total Failure

The usual result of plugging in a broken 6502 second processor is a blank screen with just the cursor flashing in the top left corner. Most faults manifest themselves in this way.

If by any chance the "BBC Microcomputer 32K" message is printed on the screen, then the host is not recognising the presence of the second processor. This means that the DNFS ROM has not been plugged into the BBC, or that there is no power supply to the second processor (see 7.3.1), or that the ribbon cable connection is faulty, or the Tube (I01) has failed (see 7.5.5).

Check IC8 pin 12 with an oscilloscope or frequency counter. If oscillating at 12MHz then the master clock is running, and therefore the power supply. Try replacing the Tube (IC1) with a known good one and see if the second processor now works. If not then carry on with the diagnosis below.

7.3.1 Power supply

Check the T315mA mains fuse which can be accessed via a cover at the rear of the second processor, see section 2.

Check for any loose, disconnected, or broken leads.

After making sure that the second processor is disconnected from the mains, check the mains switch at the rear of the unit.

Overload protection of the second processor is provided by a thyristor (TH1) and a fuse (FS1) on the second processor PCB itself. The fuse protects against overcurrent, and the thyristor protects against overvoltage by blowing the fuse. Hence, if the fuse is blown it could be due to either overvoltage or overcurrent, and there is likely to be either a short circuit somewhere or the power supply board is faulty (it is supplying too high a voltage).

Disconnect the two power supply leads, brown and black, from the second processor PCB and connect a 10 ohm 2.5W resistor between them. Measure the voltage across the brown lead (+5V) and the black lead (ground) which should be in the range 4.95 to 5.25V with a maximum of 50mV noise. If the voltage is out of spec then set it to 5V exactly using the trimmer which is accessible through a hole in the power supply board, see Figure 5.

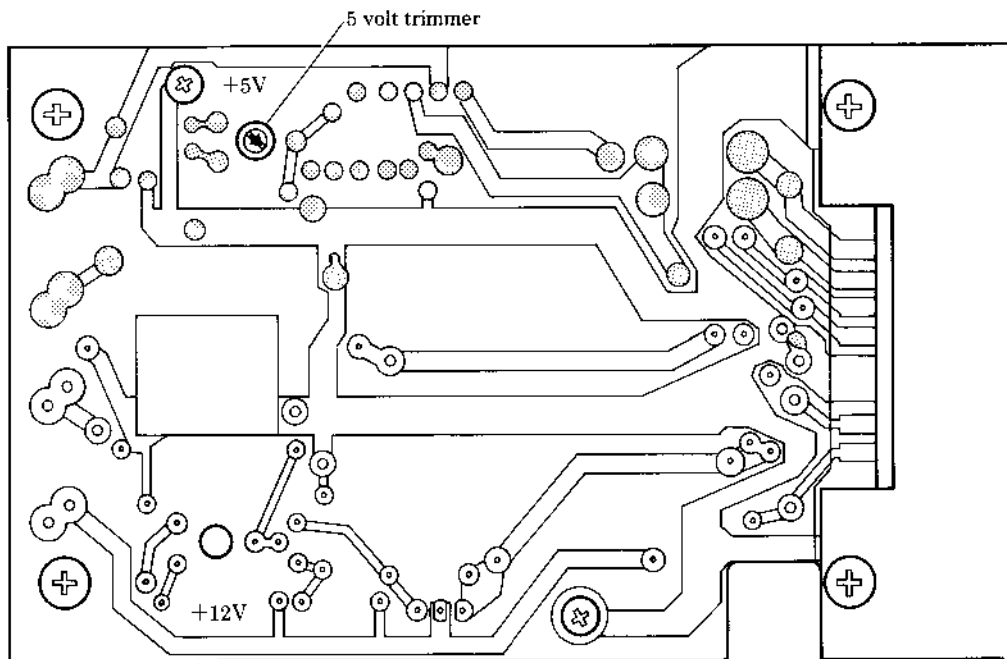


Figure 5 Position of voltage trimmer on PSB.

If the measurements obtained are incorrect then replace the power supply unit.

Now remove the resistor connected across the power supply leads and test the current drawn by the second processor PCB from the +5V supply. The board should draw between 800 and 1000mA from the power supply.

If the current is zero then the second processor PCB has gone open circuit so look at the fuse (FS1) and connectors and tracks.

If the fuse is blown then the fault is a short circuit on the PCB.

If the current is higher than it should be then measure the voltage. If the voltage is greater than 5.25V then adjust it to 5V using the trimmer, see Figure 4. If the voltage is in spec then one or more of the components on the second processor PCB is shorting. Switch off the power supply and feel which of the components is hot.

The Tube (IC1) is powered both from the BBC Microcomputer and from the second processor. If either of these supplies fails then the second processor will not work.

With the second processor switched off (ON/OFF switch down), switch on the BBC Microcomputer (ON/OFF switch up). Check that there is a potential of 5V between pin 4 (+ve) and pins 1 and 5 (ground) of IC1. If not then check the ribbon cable and connectors.

Now switch off the BBC Microcomputer (ON/OFF switch down) and switch on the second processor (ON/OFF switch up). Check that there is a potential of 5V between pins 2 and 3 (+ve) and pins 1 and 5 (ground) of IC1.

7.3.2 Oscillator

Check with the oscilloscope that a 12MHz clock pulse is generated at pin 12 of IC8. If not then check the power supply to IC8, 5V across pin 14 (+ve) and pin 7 (ground). If the oscillator is not working then it could be a faulty 74S04 (IC 8), the crystal, or any of the passive components around them.

7.4 Checking the Second Processor in Boot Mode

On power-up the second processor goes into "boot mode" where the software is copied from the ROM into RAM. This process lasts for approximately 0.25 of a second. The second processor can also be forced into boot mode by causing a reset, ie by pulling RST low (IC2 pin 40). This is easily accomplished by pressing the BREAK key on the host, so to test the second processor circuit in boot mode will require frequent use of the BREAK key.

A quick check that the boot phase of operation has probably completed successfully is to test IC6 pin 9. After releasing BREAK, this pin should be high for 0.25 of a second and then go low, and remain low. If this does not happen then either the address bus is shorting (check A15) or the reset pulse is not reaching the monostable (IC26).

7.4.1 PHI generation circuit

In boot mode PH1 is derived from the 12MHz clock by dividers 1C11 and 1C12, see 5.2. 1C11 and 1C12 are disabled by the NOR gate (pins 8 9 and 10 of 1C14) and 1C27 when a collision is detected, so the first thing to check is that 1C14 pin 10 is logic 0 and 1C27 pin 8 is logic 1. (Remember, it is the quarter second immediately after release of the BREAK key in which the second processor is operating in boot mode.) If these logic levels are incorrect then both host and parasite are attempting to access the Tube 1C (which should not be accessed by either processor in boot mode if operating correctly).

Test PH1 1N (IC2 pin 37) with an oscilloscope and check that clock pulses arrive at a frequency of 187.5kHz for the quarter second after the BREAK key is released. (After this period the frequency will jump to 3MHz.) If PH1 is not getting through to 1C2 then follow the track back to 1C12 pin 13 and test there. 1C12 is clocked from the 12MHz and PH1 is taken from pin 13 which gives a divide by 4. However, in boot mode 1C11 is enabled (a divide by 16 counter also clocked from the 12MHz) and this divided by 16 pulse is used to enable 1C12, thereby giving an overall divide by 64.

7.4.2 Reset and ROM enable circuitry.

Carry out the quick check given in 7.4.

Use an oscilloscope on 1C2 pin 40 and check that there is a logic 0 reset pulse when the BREAK key is pressed and released. On release of the BREAK key the RST line should go high after approximately 100 μ s. If it is stuck low then there is a fault in the monostable (IC26) or possibly the CPU (IC2).

Check that the ROM is receiving its chip enable signal (IC3 pin 18 should be low for 0.25 of a second after BREAK and then go high).

Use a scope on the ROM output enable (IC3 pin 20) and see that the data bus (IC2 pins 26 to 33) is not floating (3-state) when OE is low.

7.4.3 CPU

Use an oscilloscope on 1C2 pin 7 to look at the SYNC output from the CPU. Press BREAK and on releasing it see that SYNC pulses slowly for the 0.25 seconds of boot mode, and that it then starts pulsing faster when the processor runs at 3MHz. If SYNC stops at any time, either before or after the transition to 3MHz, then the CPU has stopped.

If SYNC doesn't run at all then look for bad connections, power supplies, and finally replace the CPU.

If SYNC stops in boot mode then the fault could be that the ROM is not being selected.

If SYNC stops after the transition then the fault is either in the DRAMs or the refresh circuitry, see 7.5.2 and 7.5.4.

If the above tests are satisfactory then we can proceed to fault finding in 3MHz normal running mode.

7.5 Checking the Second Processor in Run Mode

After all the software has been copied from ROM to RAM the second processor executes an instruction which accesses one of the Tube addresses, see section 6. This address is decoded by 1C4 which deselecteds the ROM and prevents counter 1C11 from slowing PHI. Thus PH1 IN jumps to 3MHz and the processor runs entirely in RAM (except when the Tube is accessed in which case the RAM is disabled by holding CAS high).

7.5.1 PHI generation circuit

In run mode PH1 is derived from the 12MHz clock by divider 1C12. PH1 is taken from 1C12 pin 13 which divides the clock by 4 giving a frequency of 3MHz. 1C12 is disabled by the NOR gate (pins 8 9 and 10 of 1C14) and 1C27 when a collision is detected, so PH1 will stop when this happens. However, this will not occur very often if the processor is running correctly.

During a write cycle (R/W=0) PH1 is stretched slightly in its high state by the action of R/W on 1C12 via 1C9 pin 2 and 1C11. This is for RAM timing purposes, see figure 6.

Use an oscilloscope or frequency counter on 1C2 pin 37 and check that the processor is receiving a 3MHz clock pulse. If not then either 1C12 is faulty or there is a broken track.

7.5.2 Refresh circuitry

1C13 is wired as a divide by 11 counter, and is clocked direct from the 12MHz. It is enabled from 1C12 pin 15 which is running at 12/16MHz, so the refresh request signal from 1C13 pin 15 should have a frequency of 68kHz. Check that this signal is reaching IC7 pin 1 and that 1C7 is counting.

If there is no signal on 1C13 pin 5 then check that pin 9 or pin 7 is not held low.

If the refresh request is working correctly then check 1C10 pin 6 which should be operating at the same frequency, but inverted. Also check that SYNC is coming from the CPU by testing 1C10 pin 5. If SYNC is stuck at one logic level then the CPU is not running. Test SYNC as described in 7.4.3 and see whether it stopped in boot mode or run mode. The fault is most likely to be in the DRAMS.

Check that 1C17 pin 19 is pulsing low at 68kHz.

7.5.3 DRAMs

RAS (pin 4 of each DRAM 1C) is driven through an inverter direct from PHI, and should therefore be oscillating at a frequency of 3MHz. In practice, during a write cycle (R/W=0) RAS is stretched slightly by the action of R/W on the PHI generation circuit, see 7.5.1. If RAS is stopped then check PHI, see 7.5.1. Note that if RAS is stuck low then the DRAMs may be destroyed.

CAS (pin 15 of each DRAM 1C) is driven from 1C9 pin 8, and runs at 3MHz except when the Tube is accessed in which case CAS is disabled, and during a write cycle when CAS is stretched slightly. On read cycles CAS is triggered from the processor R/W line (IC2 pin 34) gated with PH1 2 (IC2 pin 39) via 1C5 and the asynchronous set input 1C9 pin 10. On write cycles CAS is clocked from 1C12 pin 14 (PH1 1N times 2), and the clock is stretched by the action of R/W on 1C12, see 7.5.1. If CAS has stopped then check 1C9 pins 10 and 13 which should be high. If either is stuck low then check whether the processor has stopped by seeing whether PH1 2 is oscillating (IC2 pin 39). If PH1 2 is stuck then press BREAK and see at what time this happens. Also check RAS and CAS after pressing BREAK during boot mode. If the processor stalls when RAS and CAS are working then there is a fault in selecting the ROM (see 7.4.2), or one of the DRAM chips is dead.

Figure 6 shows the DRAM timing

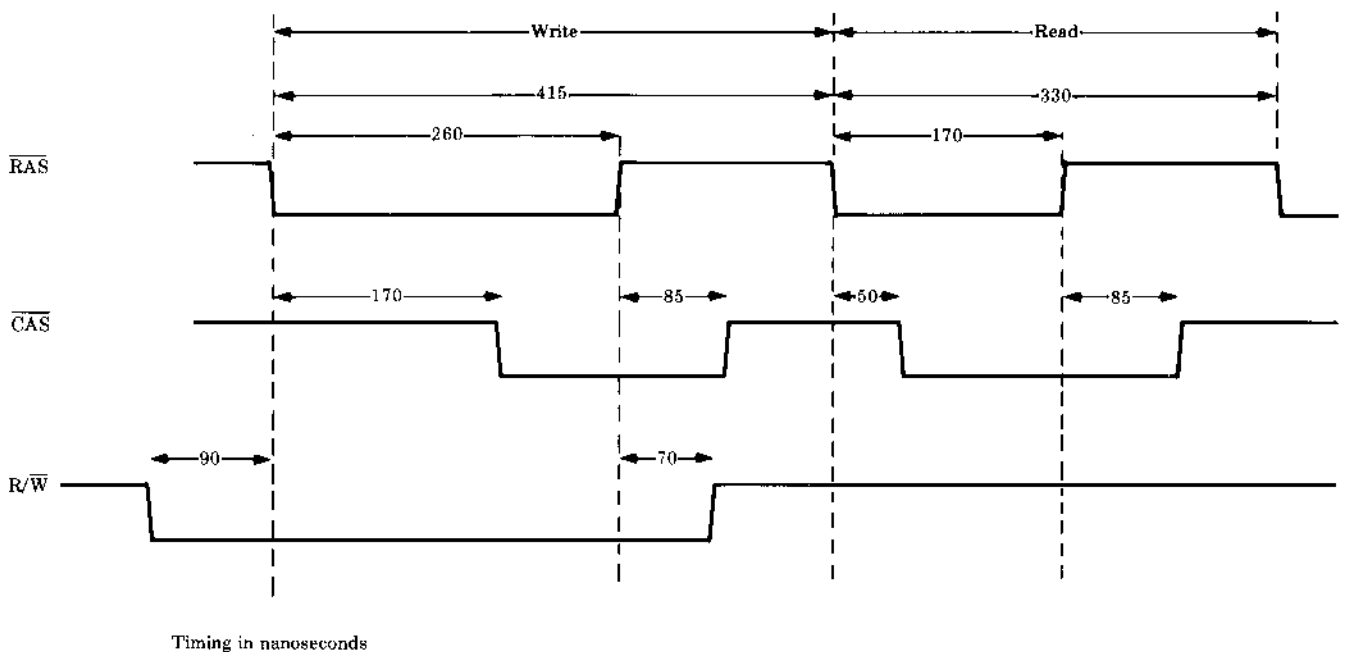


Figure 6 DRAM timing

7.5.4 CPU

Looking at SYNC (IC2 pin 7) with an oscilloscope will show whether the CPU keeps running or whether it has stalled (SYNC stuck at one logic level). If the processor does stall then determine when this happens after releasing BREAK.

If SYNC does not oscillate at all from the time of releasing BREAK then look for bad connections, check power supply (7.3.1). After this swap the CPU itself for a good one.

If SYNC stops in boot mode then check that the ROM is being selected, see 7.4.2.

If SYNC stops on the transition to 3MHz running or after, then there is probably a DRAM (7.5.3) or refresh (7.5.2) fault.

7.5.5 The Tube IC1

After checking for short circuits and loose connections check the power supply to the Tube IC.

The Tube (IC1) is powered both from the BBC Microcomputer and from the second processor. If either of these supplies fails then the second processor will not work.

With the second processor switched off (ON/OFF switch down), switch on the BBC Microcomputer (ON/OFF switch up). Check that there is a potential of 5V between pin 4 (+ve) and pins 1 and 5 (ground) of IC1. If not then check the ribbon cable and connectors.

Now switch off the BBC Microcomputer (ON/OFF switch down) and switch on the second processor (ON/OFF switch up). Check that there is a potential of 5V between pins 2 and 3 (+ve) and pins 1 and 5 (ground) of IC1.

If the power supplies are good then replace the Tube IC with a known good one.

Appendix

1C Number and Function

1C1 Tube 1C - fast asynchronous parallel interface between two processors

1C2 6502C microprocessor - 4MHz spec 6502

1C3 2732 ROM - contains the Tube Operating System which is copied into RAM on power-up and reset

1C4 74LS133 - multi-input NAND gate to decode Tube select addresses

1C5 74LS00 - general gating

1C6 74LS74 - one D-type used for boot mode, the other to reset the refresh timer

1C7 74LS393 - 8-bit counter to provide refresh address

1C8 74S04 - oscillator and general gating

1C9 74LS74 - one D-type to generate CAS, the other to stretch PH1 during a write cycle

1C10 74LS00 - general gating

1C11 74LS161 - boot mode divide by 16

1C12 74LS163 - divide by 4 for PH1 generation

1C13 74LS163 - refresh timer

1C14 74LS02 - general gating

1C15 81LS95 -

1C16 81LS95 - 3-state address buffers

1C17 81LS95 -

1C18 64Kbit DRAM -

1C19 64Kbit DRAM -

1C20 64Kbit DRAM -

1C21 64Kbit DRAM - 64Kbytes of random access read/write memory

1C22 64Kbit DRAM -

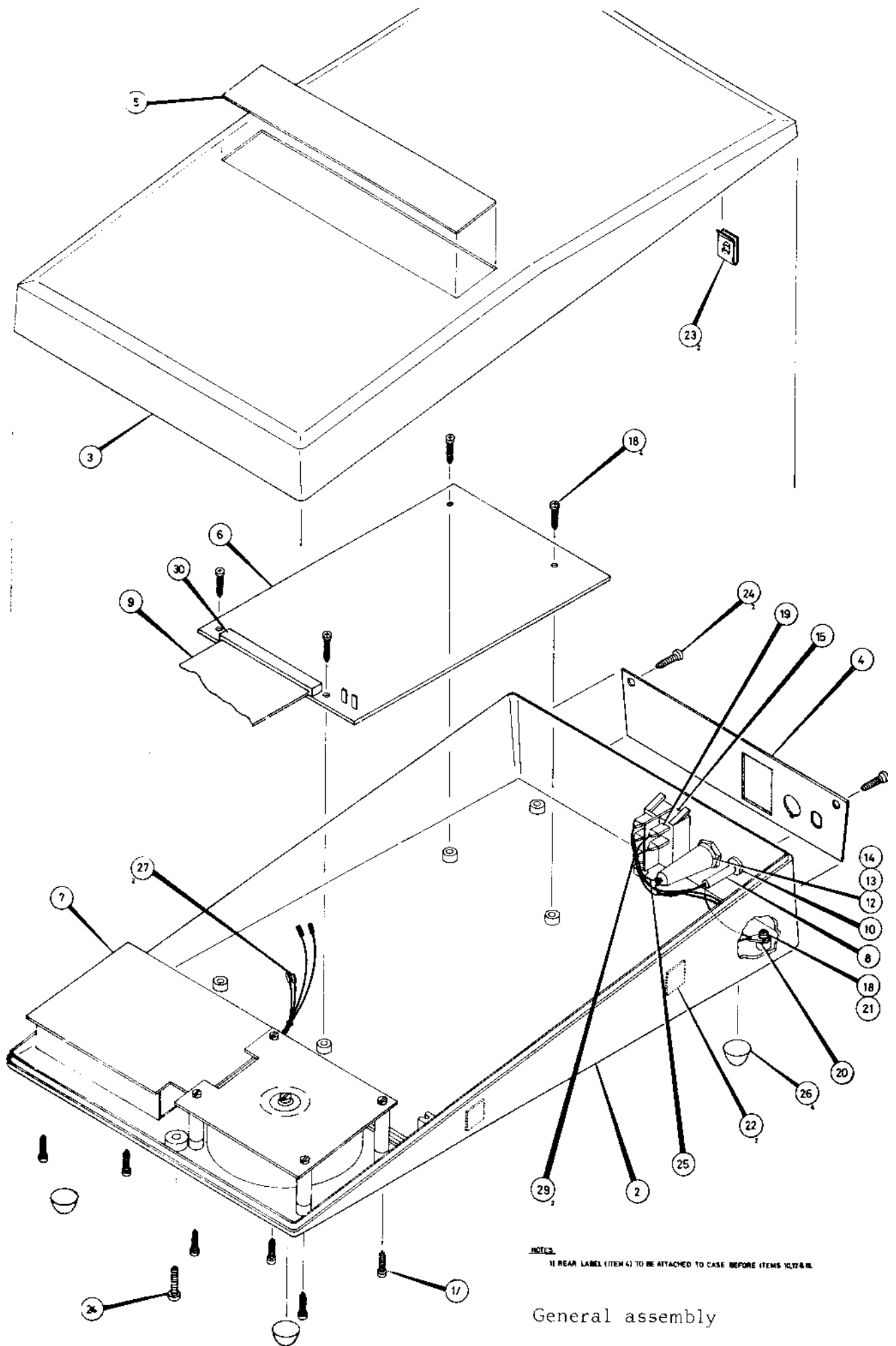
1C23 64Kbit DRAM -

1C24 64Kbit DRAM -

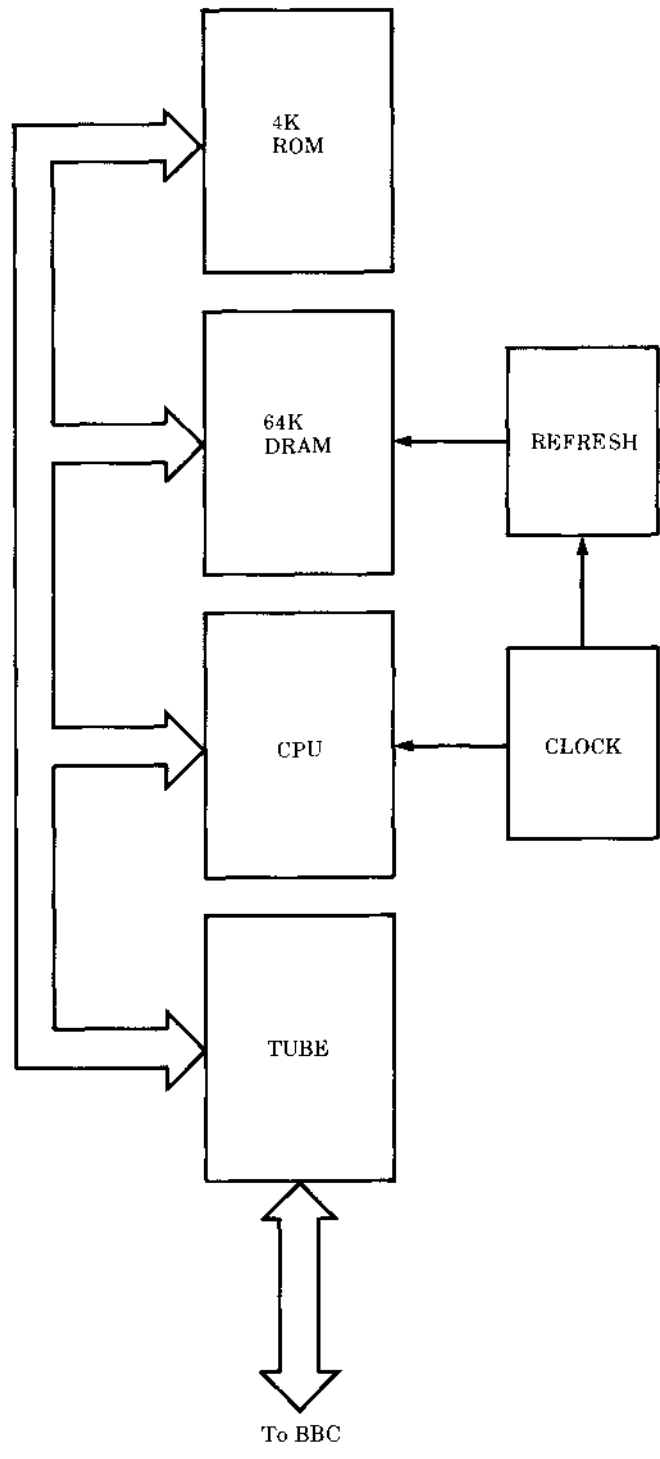
1C25 64Kbit DRAM -

1C26 74LS122 - monostable to supply reset pulse on release of BREAK key

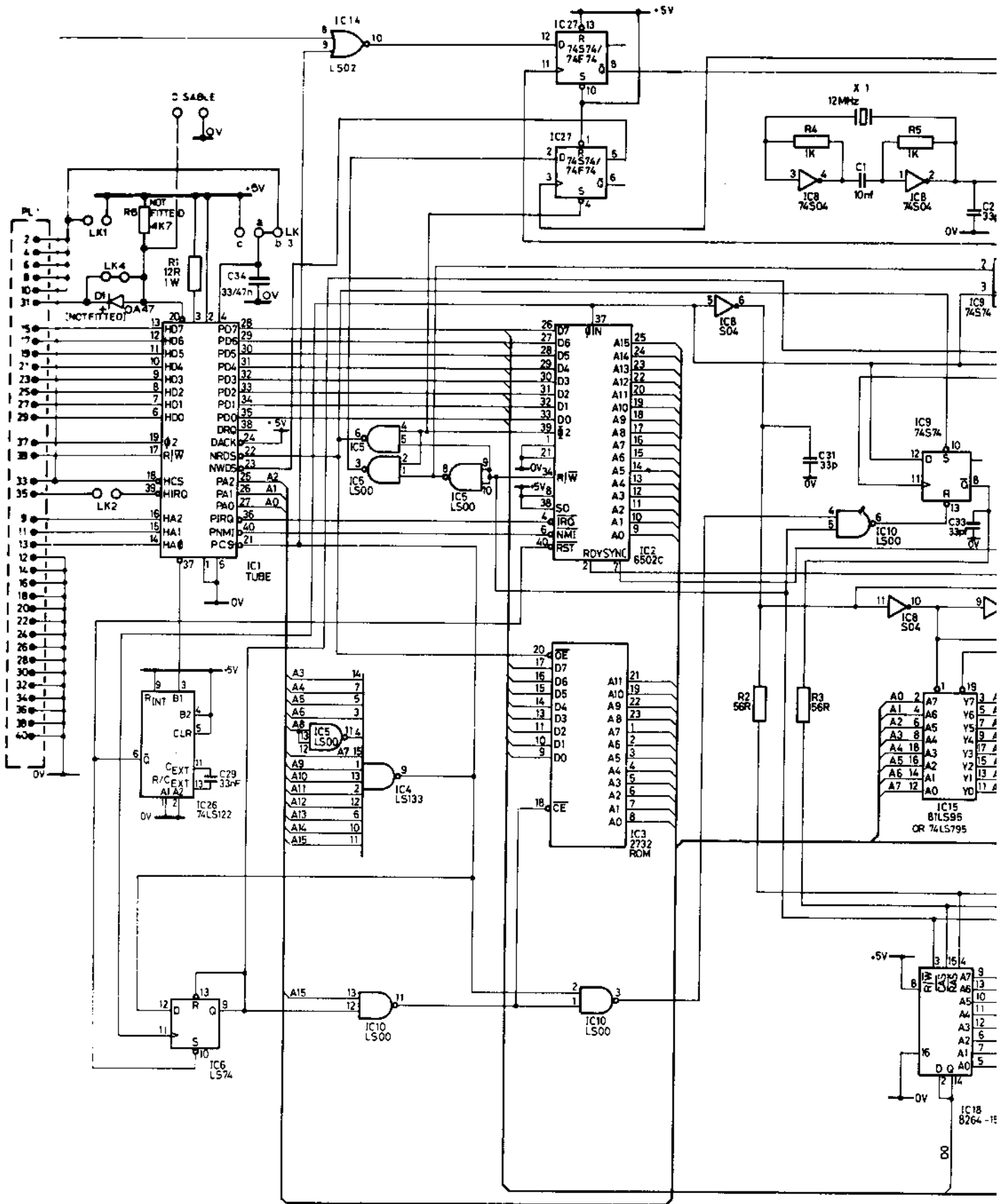
1C27 74F74 - D-type used in collision detection circuitry



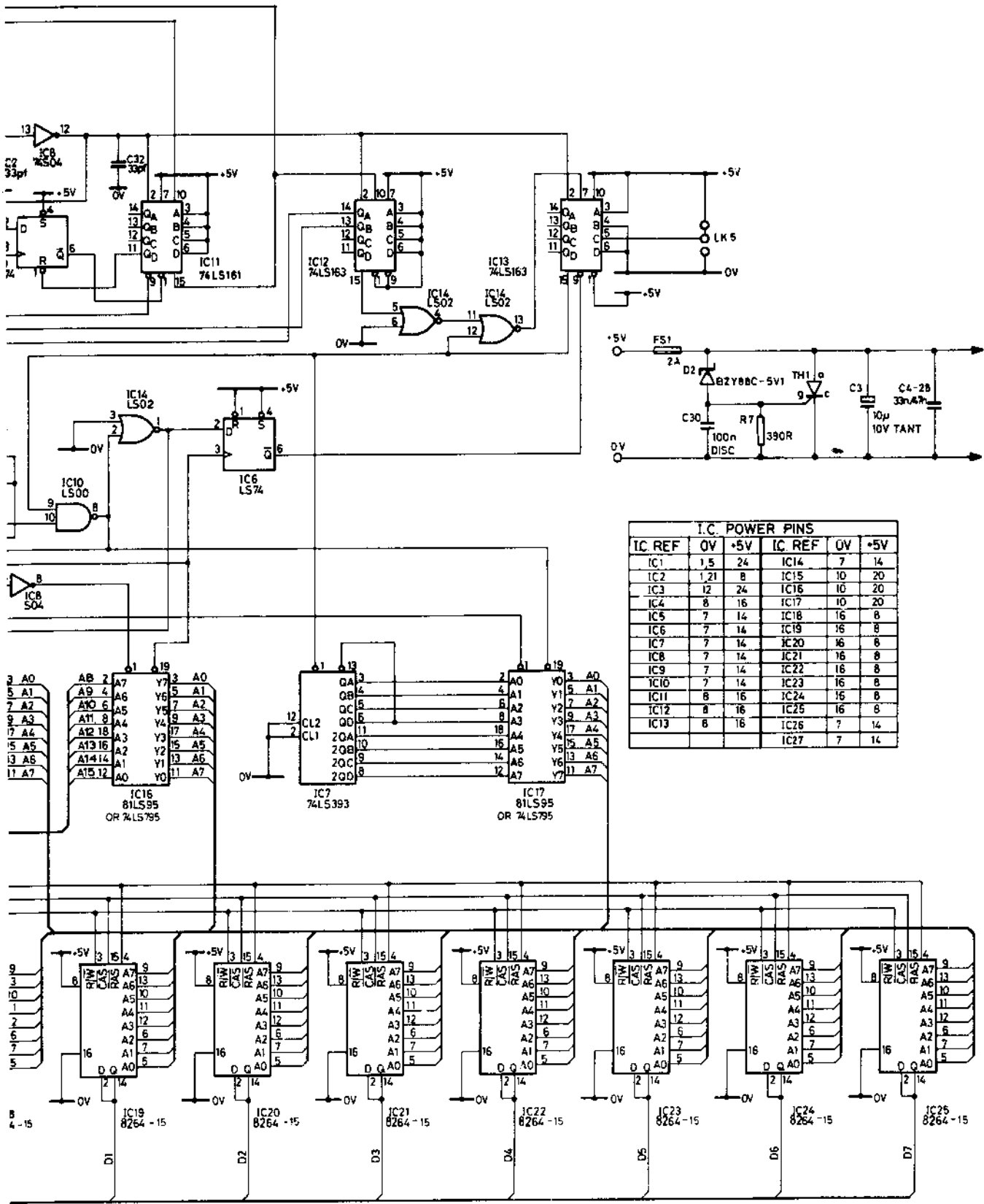
General assembly



Block diagram

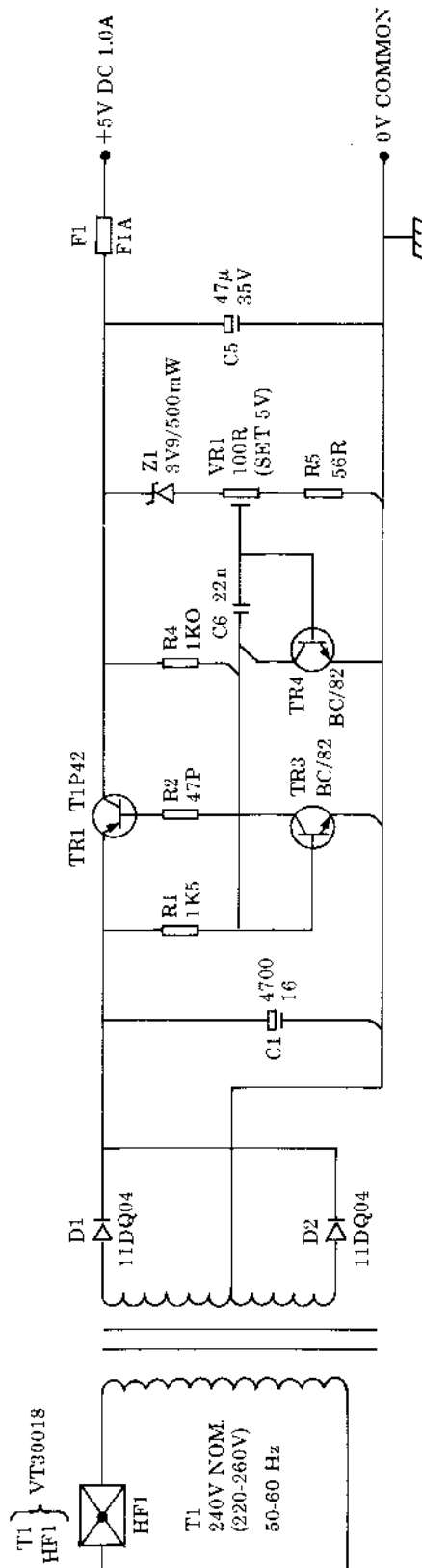


Main PCB circuit



I.C. POWER PINS					
IC REF	0V	+5V	IC REF	0V	+5V
IC1	1,5	24	IC14	7	14
IC2	1,21	8	IC15	10	20
IC3	12	24	IC16	10	20
IC4	8	16	IC17	10	20
IC5	7	14	IC18	16	8
IC6	7	14	IC19	16	8
IC7	7	14	IC20	16	8
IC8	7	14	IC21	16	8
IC9	7	14	IC22	16	8
IC10	7	14	IC23	16	8
IC11	8	16	IC24	16	8
IC12	8	16	IC25	16	8
IC13	8	16	IC26	7	14
			IC27	7	14

diagram



Power supply board circuit diagram

6502 2ND PROCESSOR PARTS LIST

Item	Part no	Description	Qty	Notes
1	208,000	BARE PCB	1	
2				
3				
4	520,120	RESISTOR 12 ohm 1W 10%	1	R1
5	502,560	RESISTOR 56ohm 1/4W 5%	2	R2,3
6	502,102	RESISTOR 1K 1/4W 5%	2	R4,5
7	502,391	RESISTOR 390 ohm 1/4W 5%	1	R7
8	628,101	CAPACITOR 100n DISC CERAMIC	1	C30
9	610,010	CAPACITOR 10µF 10V TANTALUM	1	C3
10	629,010	CAPACITOR 10nF PLATE CERAMIC	1	C1
11	631,033	CAPACITOR 33pF PLATE CERAMIC	4	C2,31,32,33
12	680,002	CAPACITOR DECOUPLER	27	C4-28,34
13	637,333	CAPACITOR 33pF MULTILAYER CERAMIC	1	C29
14				
15	742,000	INTEGRATED CIRCUIT 74LS00	2	1C5,10
16	742,002	INTEGRATED CIRCUIT 74LS02	1	1C14
17	741,004	INTEGRATED CIRCUIT 74S04	1	1C8
18	741,074	INTEGRATED CIRCUIT 74S74	2	1C9,27
19	742,074	INTEGRATED CIRCUIT 74LS74	1	1C6
20	742,133	INTEGRATED CIRCUIT 74LS133	1	1C4
21	741,161	INTEGRATED CIRCUIT 74S161	1	1C11
22	742,163	INTEGRATED CIRCUIT 74LS163	2	1C12,13
23	742,393	INTEGRATED CIRCUIT 74LS393	1	1C7
24	742,122	INTEGRATED CIRCUIT 74LS122	1	1C26
25	738,095	INTEGRATED CIRCUIT 81LS95	3	1C15-17
26	704,164	INTEGRATED CIRCUIT 4164-15	8	1C18-25
27	706,503	INTEGRATED CIRCUIT 6502C	1	1C2
28	201,606	INTEGRATED CIRCUIT 2732	1	1C3 BOOT ROM
29	201,605	INTEGRATED CIRCUIT TUBE U.L.A.	1	1C1
30				
31	820,120	CRYSTAL 12MHZ	1	X1
32				
33				
34	795,006	ZENER DIODE BZY88 5.1V	1	D2
35				
36	800,124	I.C. SOCKET DIL 24 WAY	1	
37	800,140	I.C. SOCKET DIL 40 WAY	2	
38				
39	815,010	FUSE 2 AMP 20mm x 5mm	1	FS1
40	791,000	THYRISTOR	1	TH1
41				
42				
43	800,037	S.H.E. CONNECTOR	1	PL1 (bottom half)
44				
45	800,200	FASTON TAB	2	
46				
47	815,910	FUSE CL1P P.C.B. 20mm x 5mm	2	
48				
49				
50	882,122	M3 x 8mm LG. PAN HD. SCREW	1	
51	882,902	M3 NUT FULL	1	
52	882,962	M3 WASHER PLAIN	1	
53	882,972	M3 WASHER SHAKEPROOF	1	
54				

6502 2ND PROCESSOR PARTS LIST (cont'd)

Item	Part no	Description	Qty	Notes
1				
2	201,110	CASE LOWER MOULDING	1	
3	201,109	CASE UPPER MOULDING	1	
4	201,106	CASE LABEL REAR	1	
5	201,103	CASE LABEL UPPER	1	
6	108,000	6502 PCB ASSEMBLY	1	
7	104,001	POWER SUPPLY ASSEMBLY	1	
8	201,084	MA1NS CABLE ASSEMBLY	1	
9	201,146	RIBBON CABLE ASSEMBLY	1	
10	800,024	CABLE GROMMET	1	
11				
12	815,900	FUSE HOLDER	1	
13	815,901	FUSE HOLDER SHROUD	1	
14	815,007	FUSE 20mm x 5mm 1 AMP RATING	1	
15	805,003	MAINS SWITCH	1	
16				
17	882,654	SELF TAPPING PAN HD SCREW No 6 x 9.5mm	6	SUPERDRIVE
18	882,652	SELF TAPPING PAN HD SCREW No 6 x 6.5mm	5	SUPERDRIVE
19	800,210	1/4" CRIMP CONN. SHROUDED RECEPTACLE	2	
20	800,702	SOLDER TAG M4	1	
21				
22	880,030	CABLE CLIP	2	
23	882,946	SPIRE CLIP No 6	2	
24	882,665	SELF TAPPING PAN HD SCREW No 6 x 13mm	3	SUPERDRIVE
25	870,111	WIRE 16/0.2 BROWN	1	CUT TO 70mm
26	890,000	BUMP-ON FEET	4	
27				
28	008,000/PG	PACKAGING ASSEMBLY		
29				
30	800,037	S.H.E. CONNECTOR	1	TOP HALF



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