

There are many readers who would like to know more about home computers but who may not be technically minded or who consider them too complicated to understand. These two reasons, coupled with cost, tend to prevent many people from 'taking the plunge'. To help overcome these problems we have designed the Junior Computer (JC). Do not be misled by the term 'Junior' — this computer provides the first step to understanding large and powerful systems. Although small in size, the Junior Computer can be used with high level languages (PASCAL for instance). This is possible because it uses a simplified method of operation and has the advantage of various expansion possibilities.

junior computer

The cost and complexity of home computers is a serious deterrent to the newcomer to computer operating and programming. We know of many readers who would like to 'build their own' but who lack the necessary technical knowledge. The Junior Computer has been designed (for just this reason) as an attempt to 'open the door' to those readers who need a push in the right direction.

It should be emphasized that, although simple to construct, the Junior Computer is not a 'toy' but a fully workable computer system with the capability for future expansion. It has been designed for use by amateurs or experts, and software to be published will include a PASCAL compiler — the computer language of the future.

The purpose of this article is to give a general description of the operation and construction of the Junior Computer. It has been decided to publish a more detailed description in book form.

The arrival of 'The Junior Computer' Books 1 and 2 on the market will be announced shortly. This, however, is a preview intended to give the reader an idea of what the computer entails.

The heart of the JC occupies no more than a single printed circuit board which should dispel any fears produced by large and complicated systems. The intention of this article is to encourage readers to take the initial steps towards constructing and operating their own personal computer. Extensive and precise details will not be dealt with here but will be published in depth in book form — the Junior Computer Books 1 and 2. We can however whet the appetite and set the ball rolling. Specific data concerning the computer are given in Table 1, this is intended for readers who are already familiar with computers.

Block diagram

The fundamental features of the Junior Computer are shown in the simplified block diagram of figure 1. The heart of any computer system is the CPU, or central processing unit. In this particular case it is a 6502 microprocessor, a 40 pin chip that you can hold in the palm of your hand — but shouldn't! Its purpose is to control communications between the various units inside the computer in accordance with the instructions of the program. A clock generator (oscillator) serves as a 'pace-maker' for the processor.

A certain amount of memory is required by the microprocessor to store programs and data. In the JC it consists of two sections. The first one for storing permanent data and the monitor program. The monitor program contains a number of routines which perform such chores as program loading,

debugging and general housekeeping. The second section of memory is used for storing temporary data and program instructions.

The block marked I/O (input/output) maintains contact between the computer and the outside world including the keyboard and display. In the circuit the I/O appears as the PIA, or peripheral interface adapter. It takes care of the data transfer in two directions and can (temporarily) store data. The operator communicates with the computer via the keyboard and display.

Computers are not as 'intelligent' as some television programmes would have us believe. In fact, they merely carry out (programmed) instructions in a certain (programmable) order. There are three sets of parallel interconnections (called buses - not the Midland Red type!) which carry the various data and control signals. First of all there is the data bus to consider. It is made up of a number of lines along which data travels from block to block. The processor must also be able to indicate the memory location where data is to be stored or removed. This is performed by the second bus, the address bus. Last, but by no means least, is the control bus

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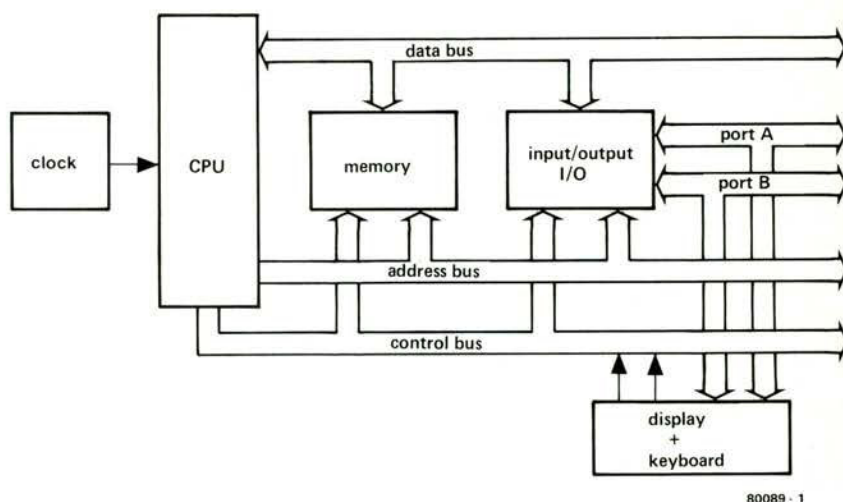


Figure 1. Block diagram of the Junior Computer.

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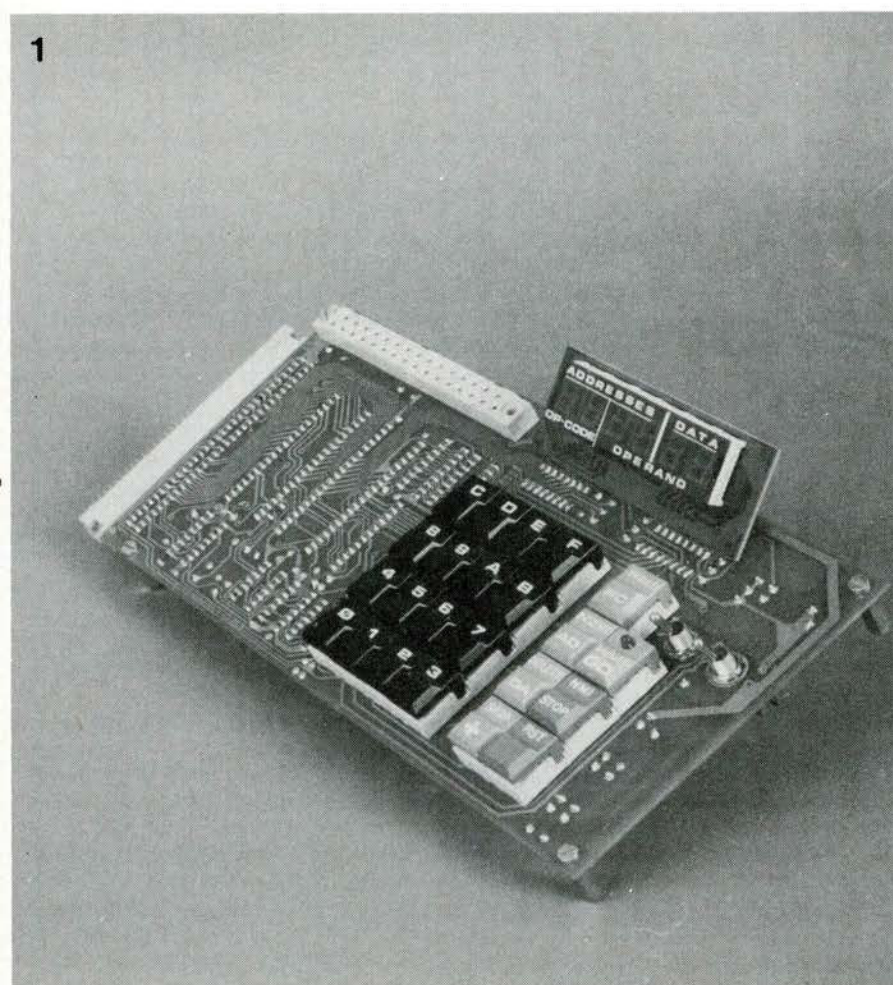


Photo 1. The completed Junior Computer looks like this. The keyboard and display can be clearly seen, the microprocessor and other components being on the other side of the printed circuit board.

which ensures that the CPU is able to control the internal status, for instance the nature and direction of data transfer and the progress of successive program sections.

This then very briefly covers the various blocks, their functions and their interconnections. We can now move on to look at the circuit in greater detail.

Circuit diagram

The circuit diagram of the entire Junior Computer (except for the power supply) is shown in figure 2. Now that the block diagram has been examined, each section should be easily recognisable. The 6502 microprocessor is IC1. Below it is the clock generator formed by N1, R1, D1, C1 and the 1 MHz crystal. The system uses a two-phase clock, shown in the circuit diagram as signals 01 and 02. The memory is constituted by IC2, IC4, IC5 and part of IC3. The monitor program is stored in IC2, a 1024 byte EPROM (Erasable Programmable Read-Only-Memory). This is the basic program in the computer (not to be confused with BASIC - a high level computer language). The RAMs (Random Access Memory) IC4 and IC5 serve as user memory and together have a capacity of 1024 bytes.

In the PIA, IC3, there are another 128 bytes of RAM. The PIA constitutes a data buffer which controls all the data transfer passing in either direction between the computer and ports A and B. The port lines are fed out to a 31 pole connector. IC3 also contains a programmable interval timer.

The displays (Dp1...Dp6) and keys

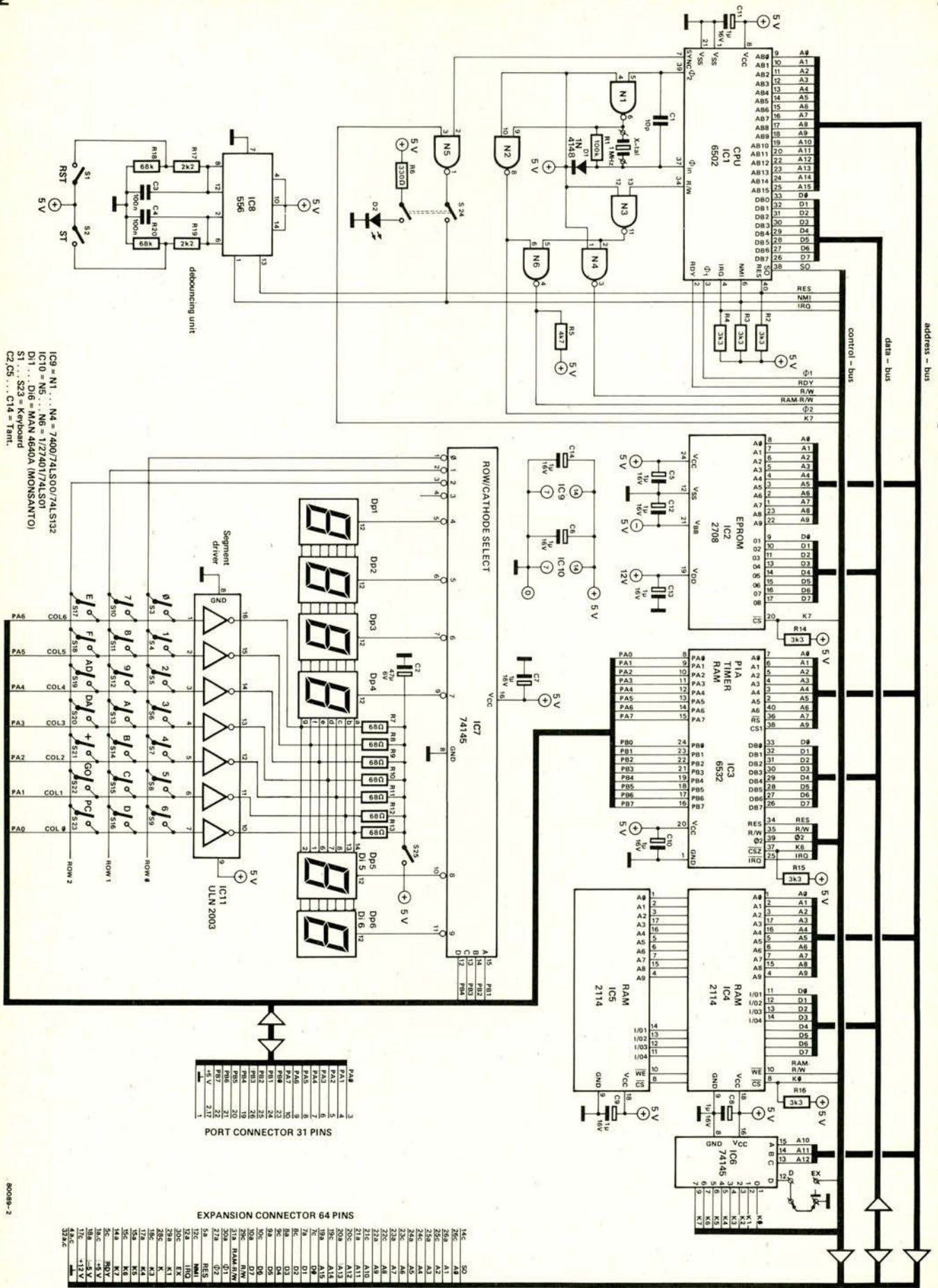


Figure 2. The circuit diagram of the Junior Computer.

(S1...S23) are at the bottom of the circuit diagram. Of these keys, sixteen are for the purpose of entering data and addresses in hexadecimal form and the remaining seven have various control functions. Data to the displays and from the keyboard is transferred across seven lines from port A. The information on the displays is controlled by the software in the monitor program, which also ensures that key function signals are recognized. IC7 multiplexes the displays and periodically checks the state of the rows of keys to see which one, if any, is being depressed. With the aid of switch S24 the display may be switched off.

The display may be used in two different ways. Usually, the four left hand displays will indicate an address and the two right hand ones will indicate the data in the address location concerned. As a second possibility, the two left hand displays can show the (hexadecimal) code of an instruction while the others display the address of the data corresponding to this instruction. This makes program entry much easier.

The address decoder, IC6, provides chip select signals for each of the various memory blocks. These appear as K7, K6 and K0 for the EPROM, PIA and the RAMs respectively. The other five selection signals are available externally for memory expansion. The RAMs also require a R/W (read/write) signal. This is made available via gate N6 and is generated by a combination of the R/W signal in the 6502 and the $\phi 2$ clock pulse ($\phi 2$ = data bus enable). Another control signal is the reset signal RES, which places the microprocessor and the PIA in the correct initial condition for the monitor program. A reset is generated when key RST (S1) is pressed and half of a 556 timer (IC8) is used to suppress any contact bounce this key might produce.

There are two ways in which a program being run can be interrupted by means of the NMI (non-maskable interrupt). The first one is provided by the STOP key S2 (which uses the other half of IC8 for contact bounce suppression) and the second is provided by the STEP switch S24 when this is in the 'ON' position. When the output of N5 then changes from high to low, the IRQ (interrupt request) connection causes the program being run to be interrupted, for instance by programming the interval timer in IC3. Also present on the control bus are the two clock signals $\phi 1$ and $\phi 2$ which control the PIA and the RAM R/W signals. These determine the direction of data transfer. Finally, lines RDY, SO and EX provide possibilities for future expansion.

All the address, data and control signals are fed to a 64 pole expansion connector which, as its name suggests, is meant for the purpose of expanding the system further at a later stage. Figure 3 shows the power supply for the Junior Computer. This produces three voltages: +5 V for all the ICs and the displays,

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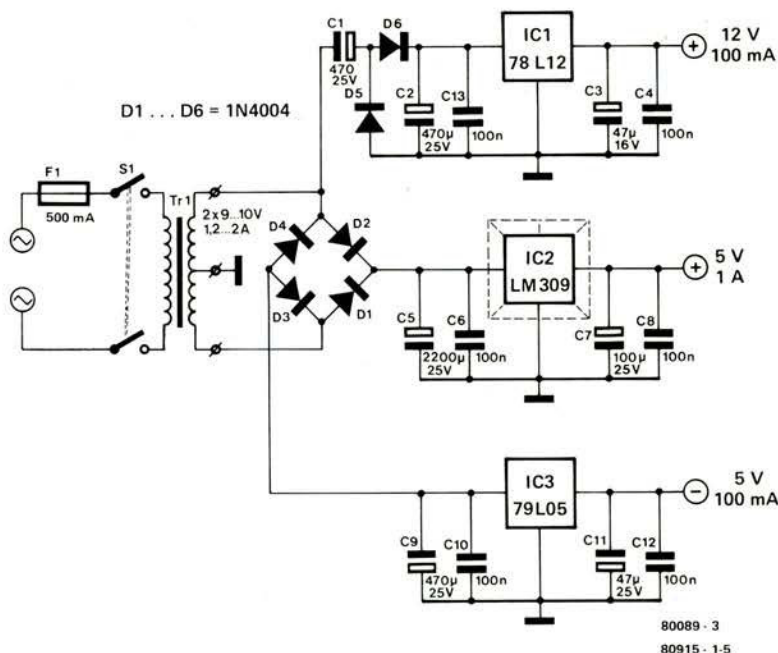


Figure 3. The power supply which produces the three voltage levels required by the Junior Computer.

and +12 V and -5 V for the EPROM (IC2). Capacitors C5...C14 ensure the necessary decoupling.

A few remarks

Before work is begun on the construction of the Junior Computer, two more aspects have yet to be considered. The entire system is built up on three printed circuit boards of which one is double sided with plated through holes. It is advisable to check all the through connections with an ohmmeter to make sure that both sides of the circuit are well connected. This will avoid problems later, for after soldering it is very difficult to trace any breaks.

Normally, of course, the 2709 EPROM will not have been programmed when it is bought. The monitor program (or 'hex dump') is given, so that the reader who has a PROM programmer at his disposal may program the IC himself. Alternatively, pre-programmed 2708s can be purchased from the retailers listed at the end of this article.

How to build the Junior Computer

Construction of the Junior Computer is not difficult by any standards. If it is assembled carefully (paying particular attention to solder connections) and the instructions are followed to the letter, very little can go wrong. The three sections of the JC are each constructed on a separate printed circuit board: the main board (including keyboard) the

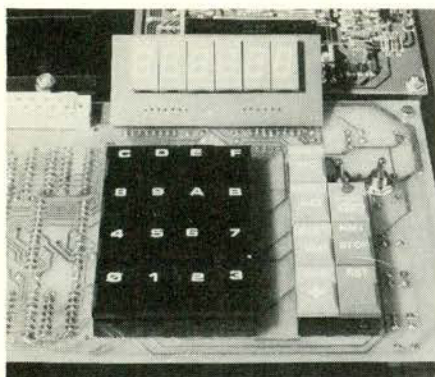
display board and the power supply.

The smallest of the printed circuit boards is the display board (figure 6). This is connected to the main board by means of thirteen wire links. The seven-segment displays can be soldered directly onto the printed circuit board.

The main board is double sided and is shown in figures 4 and 5. With the aid of the component overlay it is possible to see on which side to mount the various components. First resistors R1...R20 and diode D1 are mounted, then capacitors C1...C13, followed by all the IC sockets. It is advisable to use IC sockets especially for IC1...IC3. Be sure to use a top quality type with gold contacts.

The other side of the board can now be assembled. Switches S1...S23 (Digitast) and LED D2 (remember the LEDs polarity) can now be mounted. Two holes remain free next to the keyboard for switches S24 and S25. These switches are connected to the main printed circuit board using short lengths of insulated wire. A single wire link is placed on the main board to connect the 'D' input of IC6 to the zero volt rail. The other connection indicated between D and EX is meant for future expansion. The 31 pole connector is mounted on the keyboard side, followed by the 64 pole connector which is positioned on the other side of the board.

The display printed circuit board can now be connected to the main board. The distance between the two boards



4a

should be about 5 mm. All that remains to complete the computer board is to solder the 1 MHz crystal in place, and finally, fit IC1...IC3 (the expensive ones) into their sockets. The main board is now complete.

The power supply has been left until last. The simple construction should not give anyone any headaches. All components are mounted according to figure 7, not forgetting the mica insulating plate (with a smear of heat-sink compound) under IC2. Connections between the power supply and the computer can be made using a four wire cable to the 64 pole connector as follows:

- +12 V to pin 17c
- +5 V to pins 1a, 1c
- 5 V to pin 18a
- 0 V to pins 4a, 4c

It would be wise to make absolutely sure that these connections are correct. An error here can be very costly. This completes the construction of the Junior Computer and now we approach the moment of truth.

Switch on

Just before you do that, one more check-over would not be a waste of time. Are all the chips the right way round? Are there any cut offs of wire lying on the boards? A final thorough inspection could save you money. Now switch on... and of course nothing happens, the display remains unlit. There is no reason for alarm yet, everything is exactly as it should be. Now press the RST key and random hexadecimal characters appear on the display. This is quite in order and as good a proof as any at this time that your JC is functioning correctly. It can now be fitted into the case of your choice.

Something wrong, after all?

Unfortunately, (due to Murphy's Law no doubt) there is a possibility that pressing the RST key will depress the operator rather than cause anything to appear on the displays. This will of course occur with an unprogrammed 2708 (IC2). A survey of the most common errors and how to deal with them are given below.

First verify that the supply voltages at the 64 pole connector are as follows:

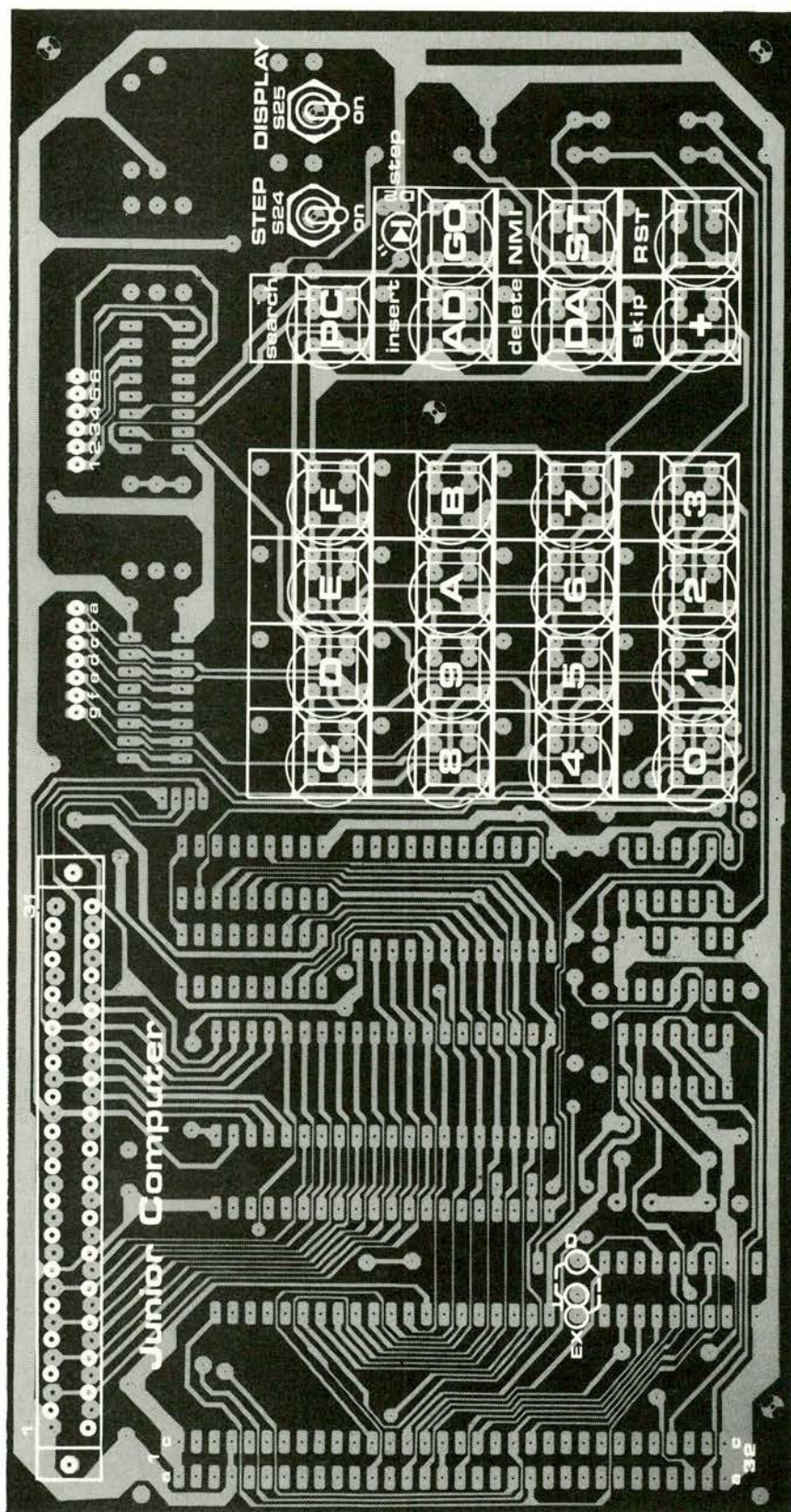


Figure 4. Component overlay of keyboard (a) and components (b) of the main printed circuit board (EPS 80089-1).

Resistors:

R1 = 100 k
R2,R3,R4,R14,R15,R16 = 3k3
R5 = 4k7
R6 = 330 Ω
R7 ... R13 = 68 Ω
R17,R19 = 2k2
R18,R20 = 68 k

Capacitors:

C1 = 10 p ceramic
C2 = 47 μ /6 V tantalum
C3,C4 = 100 n MKH
C5 . . . C14 = 1 μ /35 V tantalum

Semiconductors:

IC1 = 6502 (Rockwell)
IC2 = 2708
IC3 = 6532 (Rockwell)
IC4, IC5 = 2114
IC6, IC7 = 74145
IC8 = 556
IC9 = 74LS00, 7400, 74LS132
IC10 = 74LS01, 7401
IC11 = ULN2003 (Sprague)
D1 = 1N4148

Miscellaneous:

S1 . . . S21,S23 = digitast
(Shadow)
S22 = digitast + LED
S24 = double pole switch
S25 = single pole switch
Dp1 . . . Dp6 = MAN 4640A
common cathode (Monsanto)
connector 64-pole male
perpendicular solder to
DIN 41612
connector 31-pole female
perpendicular solder to
DIN 41617
1 MHz-crystal
1 24-pin IC sockets
2 40-pin IC sockets

Capacitors:

C1,C2,C10 = 470 μ /25 V
C3,C11 = 47 μ /25 V
C4,C5,C8,C9,C12,
C13 = 100 n MKH
C6 = 2200 μ /25 V
C7 = 100 μ /25 V

Semiconductors:

IC1 = 78L12ACP (5%)
IC2 = LM 309K
IC3 = 79L05ACP (5%)
D1 ... D6 = 1N4004

Miscellaneous:

Tr1 = transformer prim. 220 V
sec. $2 \times 9 \dots 10 \text{ V}/1.2 \dots 2 \text{ A}$
S1 = double pole switch
F1 = fuse 500 mA, with fuse
holder

Table 1

General information on the Junior Computer

- single board computer
- programmable in machine language (hexadecimal)
- microprocessor type 6502
- 1 MHz crystal
- 1024 bytes of monitor in EPROM
- 1024 bytes of RAM
- PIA type 6532 with two I/O ports, 128 bytes of RAM and a programmable interval timer
- six digit seven segment display
- hexadecimal keyboard with 23 keys: 16 'alpha' keys and 7 double function control keys

Control keys (normal mode)

- + : increment address on display by one
- DA : enter data
- AD : enter address
- PC : call up contents of current program counter position
- GO : start program from address on display
- ST : interrupt program by way of NMI
- RST : call up monitor
- STEP : step by step run through program

Control keys (editor mode via ST)

- insert : insert program step before address shown on display
- input : insert program step after address shown on display
- skip : jump to next op-code
- search : search for a certain label
- delete : delete row of characters on display

Possibilities

- debugging : all internal registers may be shown on display
- hex editor : label identification with hexadecimal figures JMP, JSR, branch instructions operate with label
- hex assembler : conversion of label numbers into displacement values for real address
- branch : calculate address offset for jump instructions

Applications

- compatible with SC/MP bus
- can be used as a basis for many expansions
- can be used as a 6502 CPU card
- educational computer for beginners
- can be expanded with:
 - elektterminal
 - cassette interface
 - video interface
 - BASIC and PASCAL
 - matrix printer
 - assembler
 - disassembler
 - editor

5a

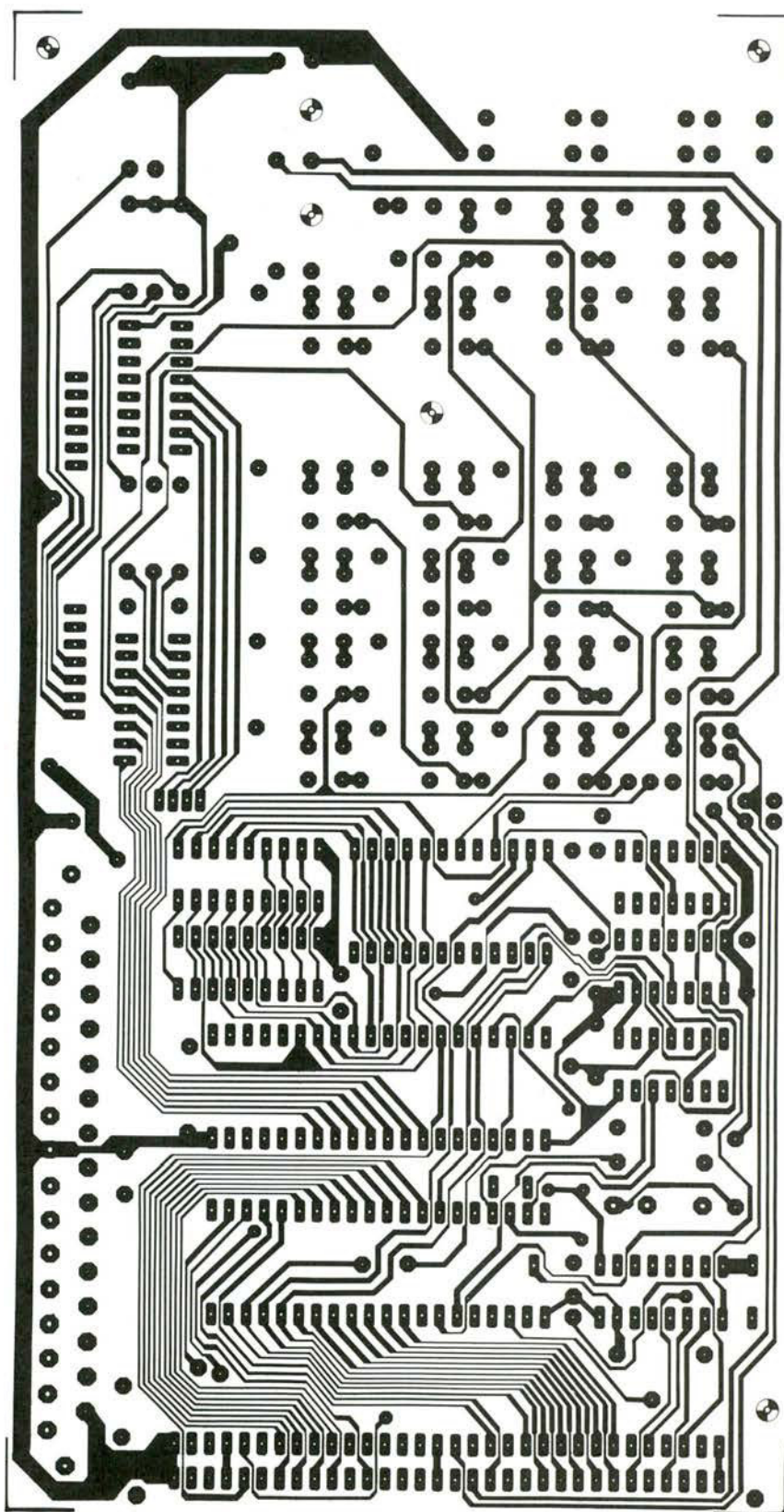
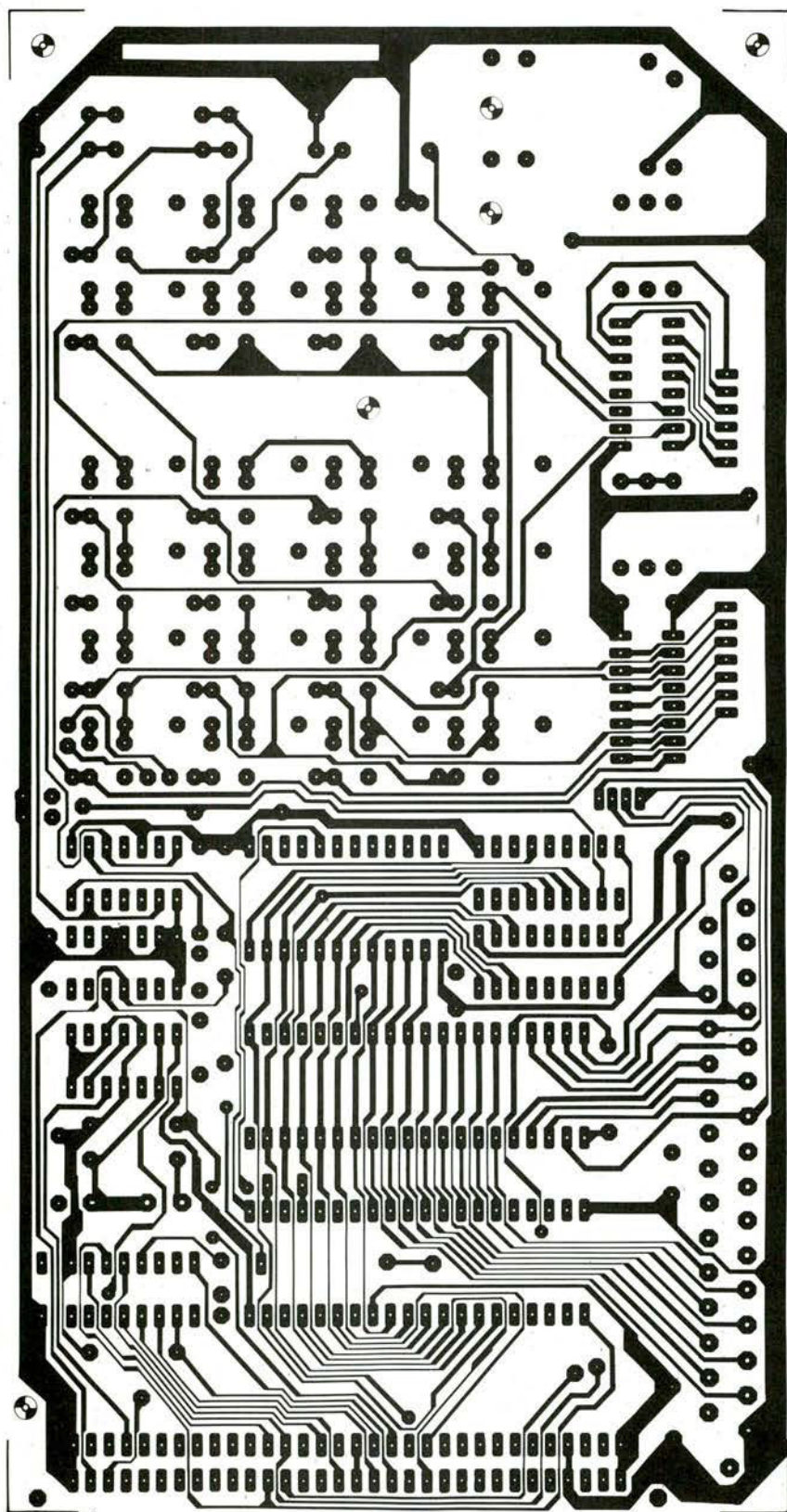


Figure 5. The track pattern for both sides (a and b) of the main board.

5b



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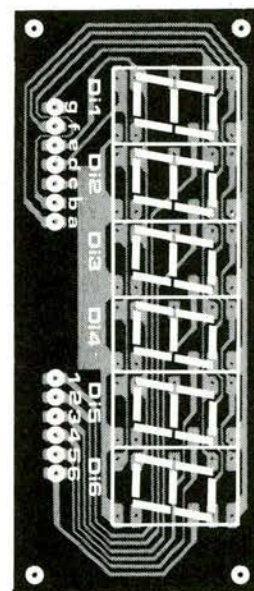
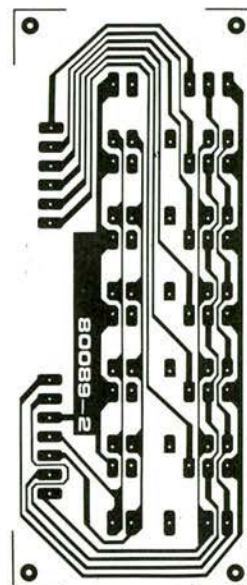


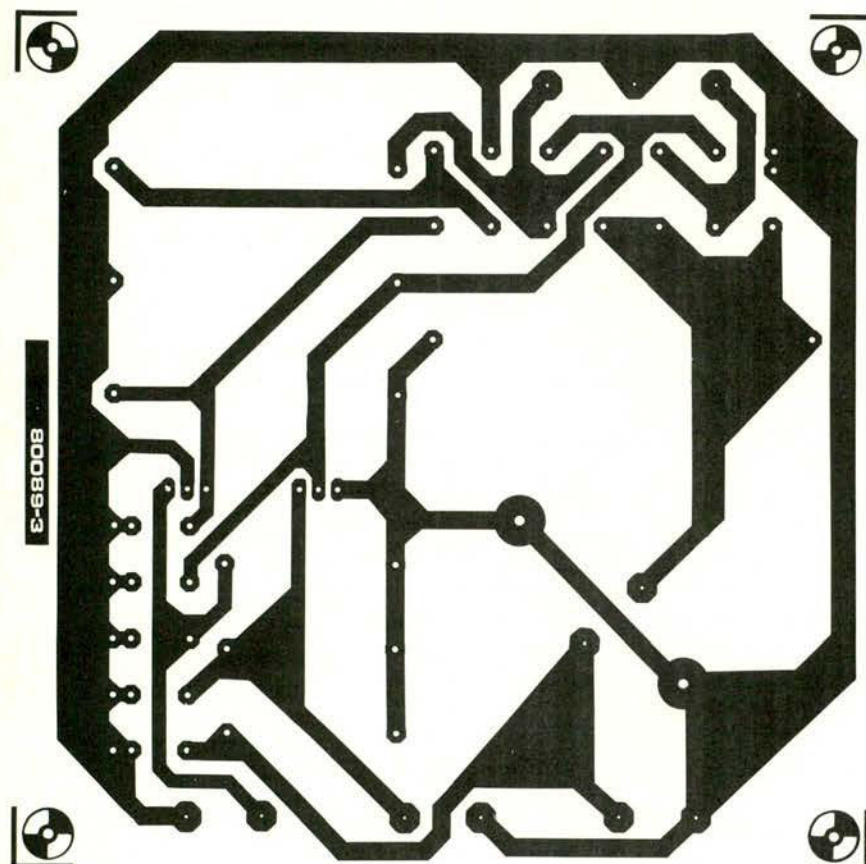
Figure 6. The display printed circuit board (EPS 80089-2).

- between pins 1a and 4a: $+5\text{ V} \pm 5\%$
- between pins 17c and 4a: $+12\text{ V} \pm 5\%$
- between pins 18a and 4a: $-5\text{ V} \pm 5\%$

If one of the voltages measured is not within the above tolerance, connections between the supply and computer should be removed and the supply checked separately.

If the supply voltages are in order, but the computer refuses to react to the RST key, further measurements will have to be carried out. The voltage between pin 13 and pin 17 of IC8 should be less than 0.5 V when RST is

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pressed. If this is not the case, the error will be in:

- the timer IC8
- the pull-up resistor R2
- the RST key S1.

With the supply switched off, the resistance between pin 12 of IC6 and 0 V (connector pin 4a) can be measured. If there is no 'short' between these two points the wire link will have been placed in the wrong position on the main board.

The last check to carry out involves the clock generator and for this an oscilloscope will be required. The CPU produces two clock signals which are fed to the expansion connector: 01 on pin 30a and 02 on pin 27a. With the aid of the 'scope it can be seen whether a 1 MHz square wave is present at both points (minimum RMS value 3 V). In the event of the oscillator not operating or showing a defect, this will probably be due to capacitor C1, diode D1 or IC9. Of course, other faults are possible, but the above checks should clear most problems.

For readers who have facilities for programming their own EPROM (IC2) the monitor dump is given here (figure 8). There are 64 rows of 16 bytes each, a total of 1024 bytes. The first column gives the hexadecimal address for the byte in col 0.

Your Junior Computer is now rearing to go and it is possible to begin your programming lessons. Each section of the Junior Computer Book is clearly illustrated with examples that can be put into practice on your very own computer. As mentioned earlier, there are plans afoot for the publication of a number of programs and a PASCAL compiler for the JC. Look out for further details.

Figure 7. The printed circuit board and layout of the power supply (EPS 80089-3).

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	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
1C00:	85	F3	68	85	F1	68	85	EF	85	FA	68	85	F0	85	FB	84
1C10:	F4	86	F5	BA	86	F2	A2	01	86	FF	4C	33	1C	A9	1E	8D
1C20:	83	1A	A9	04	85	F1	A9	03	85	FF	85	F6	A2	FF	9A	86
1C30:	F2	D8	78	20	88	1D	D0	FB	20	88	1D	F0	FB	20	88	1D
1C40:	F0	F6	20	F9	1D	C9	13	D0	13	A6	F2	9A	A5	FB	48	A5
1C50:	FA	48	A5	F1	48	A6	F5	A4	F4	A5	F3	40	C9	10	D0	06
1C60:	A9	03	85	FF	D0	14	C9	11	D0	06	A9	00	85	FF	F0	0A
1C70:	C9	12	D0	09	E6	FA	D0	02	E6	FB	4C	33	1C	C9	14	D0
1C80:	0B	A5	EF	85	FA	A5	F0	85	FB	4C	7A	1C	C9	15	10	EA
1C90:	85	E1	A4	FF	D0	0D	B1	FA	0A	0A	0A	0A	05	E1	91	FA
1CA0:	4C	7A	1C	A2	04	06	FA	26	FB	CA	D0	F9	A5	FA	05	E1
1CB0:	85	FA	4C	7A	1C	20	D3	1E	A4	E3	A6	E2	E8	D0	01	C8
1CC0:	86	E8	84	E9	A9	77	A0	00	91	E6	20	4D	1D	C9	14	D0
1CD0:	2A	20	6F	1D	10	F7	85	FB	20	6F	1D	10	F0	85	FA	20
1CE0:	D3	1E	A0	00	B1	E6	C5	FB	D0	07	C8	B1	E6	C5	FA	F0
1CF0:	D9	20	5C	1E	20	F8	1E	30	E9	10	3E	C9	10	D0	0A	20
1D00:	20	1E	10	C9	20	47	1E	F0	C1	C9	13	D0	14	20	20	1E
1D10:	10	BB	20	5C	1E	20	F8	1E	A5	FD	85	F6	20	47	1E	F0
1D20:	A9	C9	12	D0	07	20	F8	1E	30	A0	10	0D	C9	11	D0	09
1D30:	20	83	1E	20	EA	1E	4C	CA	1C	A9	EE	85	FB	85	FA	85
1D40:	F9	A9	03	85	F6	20	8E	1D	D0	FB	4C	CA	1C	A2	02	A0
1D50:	00	B1	E6	95	F9	C8	CA	10	F8	20	5C	1E	20	8E	1D	D0
1D60:	FB	20	8E	1D	F0	FB	20	8E	1D	F0	F6	20	F9	1D	60	20
1D70:	5C	1D	C9	10	10	11	0A	0A	0A	0A	85	FE	20	5C	1D	C9
1D80:	10	10	04	05	FE	A2	FF	60	A0	00	B1	FA	85	F9	A9	7F
1D90:	8D	81	1A	A2	08	A4	F6	A5	FB	20	CC	1D	88	F0	0D	A5
1DA0:	FA	20	CC	1D	88	F0	05	A5	F9	20	CC	1D	A9	00	8D	81
1DB0:	1A	A0	03	A2	00	A9	FF	8E	82	1A	E8	E8	2D	80	1A	88
1DC0:	D0	F5	A0	06	8C	82	1A	09	80	49	FF	60	48	84	FC	4A
1DD0:	4A	4A	4A	20	DF	1D	68	29	0F	20	DF	1D	A4	FC	60	A8
1DE0:	B9	0F	1F	8D	80	1A	8E	82	1A	A0	7F	88	10	FD	8C	80
1DF0:	1A	A0	06	8C	82	1A	E8	E8	60	A2	21	A0	01	20	B5	1D
1E00:	D0	07	E0	27	D0	F5	A9	15	60	A0	FF	0A	B0	03	C8	10
1E10:	FA	8A	29	0F	4A	AA	98	10	03	18	69	07	CA	D0	FA	60
1E20:	20	6F	1D	10	21	85	FB	20	60	1E	84	F7	84	FD	C6	F7
1E30:	F0	12	20	6F	1D	10	0F	85	FA	C6	F7	F0	07	20	6F	1D
1E40:	10	04	85	F9	A2	FF	60	20	A6	1E	20	DC	1E	A2	02	A0
1E50:	00	B5	F9	91	E6	CA	C8	C4	F6	D0	F6	60	A0	00	B1	E6
1E60:	A0	01	C9	00	F0	1A	C9	40	F0	16	C9	60	F0	12	A0	03
1E70:	C9	20	F0	0C	29	1F	C9	19	F0	06	29	0F	AA	BC	1F	1F
1E80:	84	F6	60	A5	E6	85	EA	A5	E7	85	EB	A4	F6	B1	EA	A0
1E90:	00	91	EA	E6	EA	D0	02	E6	EB	A5	EA	C5	E8	D0	EC	A5
1EA0:	EB	C5	E9	D0	E6	60	A5	E8	85	EA	A5	E9	85	EB	A0	00
1EB0:	B1	EA	A4	F6	91	EA	A5	EA	C5	E6	D0	06	A5	EB	C5	E7
1EC0:	F0	10	38	A5	EA	E9	01	85	EA	A5	EB	E9	00	85	EB	4C
1ED0:	AE	1E	60	A5	E2	85	E6	A5	E3	85	E7	60	18	A5	E8	65
1EE0:	F6	85	E8	A5	E9	69	00	85	E9	60	38	A5	E8	E5	F6	85
1EF0:	E8	A5	E9	E9	00	85	E9	60	18	A5	E6	65	F6	85	E6	A5
1F00:	E7	69	00	85	E7	38	A5	E6	E5	E8	A5	E7	E5	E9	60	40
1F10:	79	24	30	19	12	02	78	00	10	08	03	46	21	06	0E	02
1F20:	02	02	01	02	02	02	01	01	02	01	01	03	03	03	03	6C
1F30:	7A	1A	6C	7E	1A	B1	E6	A0	FF	C4	EE	F0	0D	D1	EC	D0
1F40:	0A	88	B1	EC	AA	88	B1	EC	A0	01	60	88	88	88	D0	E9
1F50:	60	38	A5	E4	E9	FF	85	EC	A5	E5	E9	00	85	ED	A9	FF
1F60:	85	EE	20	D3	1E	20	5C	1E	A0	00	B1	E6	C9	FF	D0	1D
1F70:	C8	B1	E6	A4	EE	91	EC	88	A5	E7	91	EC	88	A5	E6	91
1F80:	EC	88	84	EE	20	83	1E	20	EA	1E	4C	65	1F	20	F8	1E
1F90:	30	D3	20	D3	1E	20	5C	1E	A0	00	B1	E6	C9	4C	F0	16
1FA0:	C9	20	F0	12	29	1F	C9	10	F0	1A	20	F8	1E	30	E6	A9
1FB0:	03	85	F6	4C	33	1C	C8	20	35	1F	F0	EE	91	E6	8A	C8
1FC0:	91	E6	D0	E6	C8	20	35	1F	F0	E0	38	E5	E6	38	E9	02
1FD0:	91	E6	4C	AA	1F	D8	A9	00	85	FB	85	FA	85	F9	20	6F
1FE0:	1D	10	F2	85	FB	20	6F	1D	10	EB	85	FA	18	A5	FA	E5
1FF0:	FB	85	F9	C6	F9	4C	DE	1F	FF	FF	2F	1F	1D	1C	32	1F

Figure 8. The JC's hexadecimal monitor dump.

coming soon

Pest Pester

Perpetually plagued by mosquitos? This summer, protect your person with the 'Pest Pester'.



Disco Lights

Brighten up your parties to the beat of the disco greats. Not Travolta, but the next best thing – Disco Lights.



8K RAM + 8K EPROM

SC/MP and Junior Computer owners who are short on memory may extend their systems with an 8K RAM + 8K EPROM board.



Summer Circuits 80

As usual the July/August issue will have more than 100 circuits to keep you busy over the summer.

