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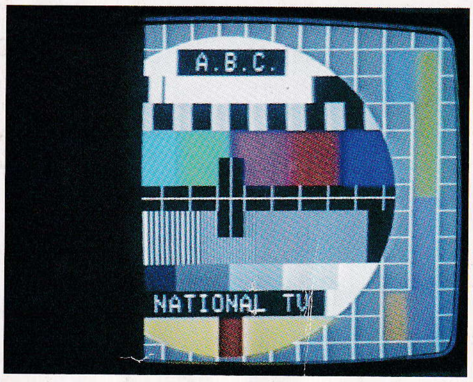
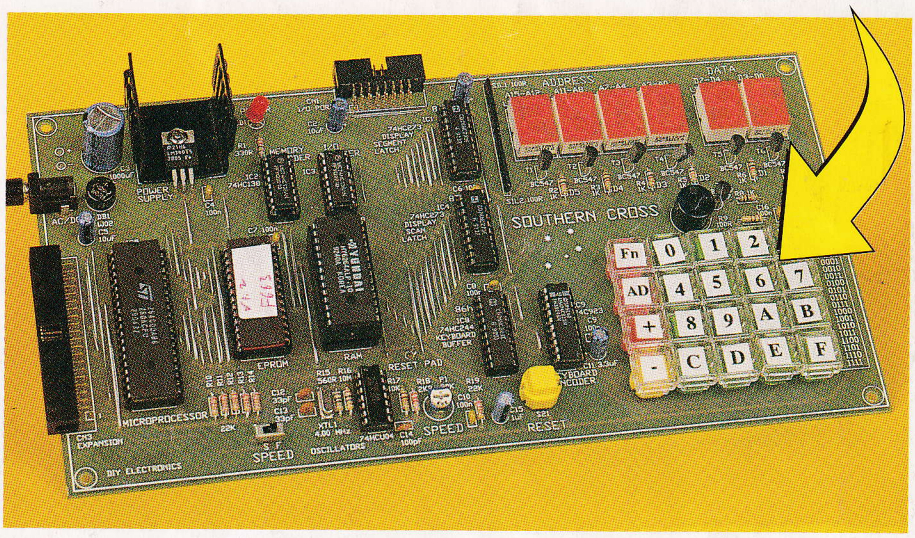


Z80-BASED SINGLE BOARD COMPUTER



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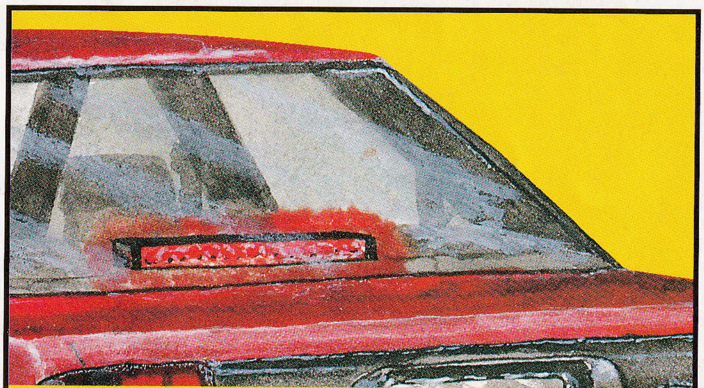

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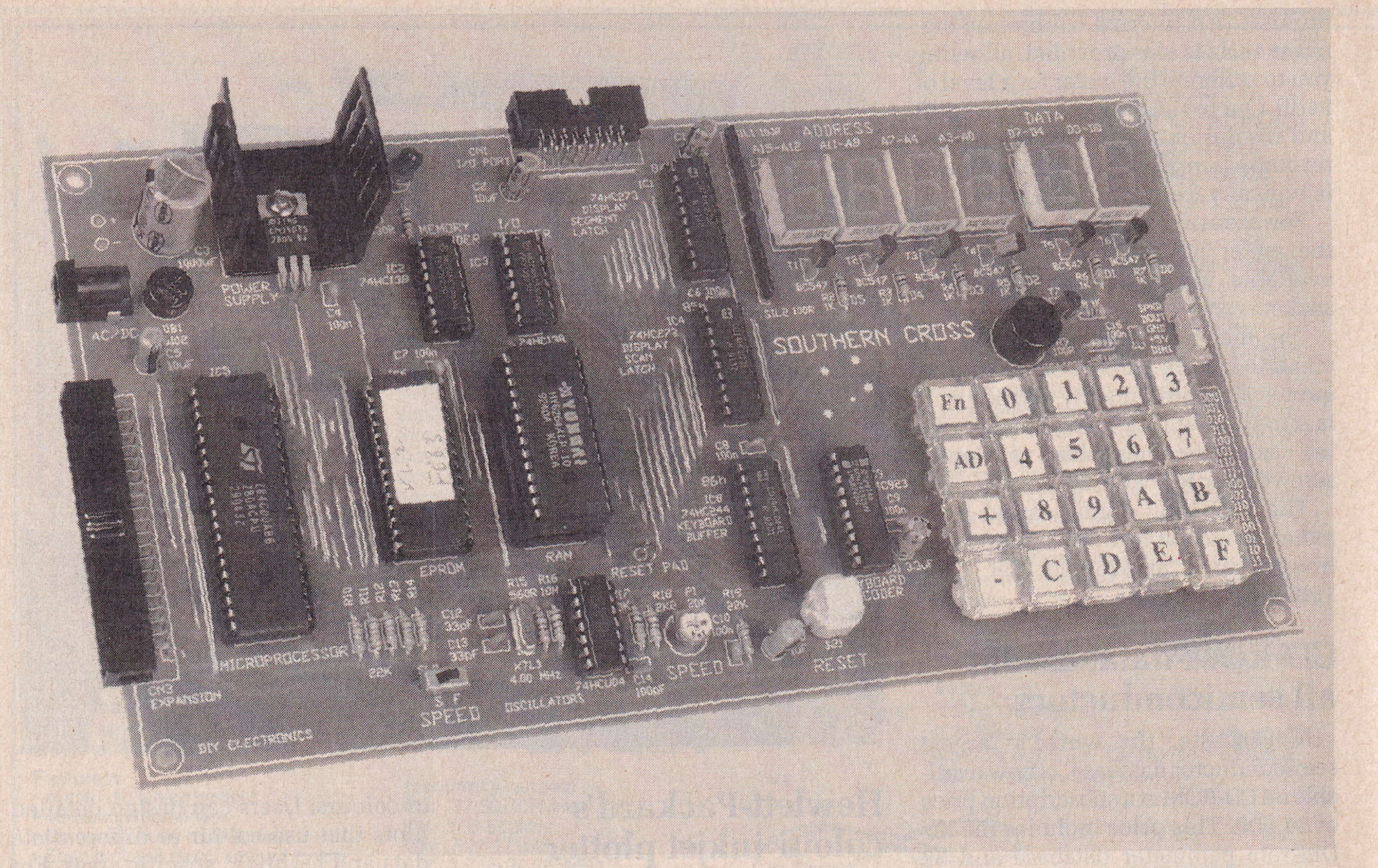


THE SOUTHERN

A single board Z80-based computer

Here is a single board computer designed especially for the 1990s generation of students. With a series of add-on boards, smart sockets, fully commented Monitor & an intelligent EPROM emulator, it can teach many aspects of microprocessor & microcontroller techniques of programming.

By PETER CROWCROFT & CRAIG JONES

CROSS

for the 1990s

ANYONE WHO USED a single board computer (SBC) in the early 80s will remember how quickly their limitations were met. The worst was that when you had written a program of about 60-80 lines of code, the calculation of forward and backward subroutine jumps and the actual data entry became a real chore. Second, there was no easy way to store your work when you turned off the power to the board. Third, some SBC suppliers did not publish their Monitor and so disregarded a whole area of teaching programming and worked against the very aim that the SBC was supposed to promote.

With the advances in electronics over the last few years there was an opportunity to launch a modern, updated SBC. It had to meet all the above objections. But it had to be more; it had to be able to introduce students to the real world of current day µP and µC programming techniques. We wanted to be able to take a student who had never programmed before and after a few hours (after the kit was constructed) have them writing programs using Monitor system calls and software and hardware interrupts, almost before they knew it.

In the first article of this series, we will introduce the Southern Cross SBC, its features, its circuit diagram and describe the construction.

In future articles we will look at how to connect it to a Personal Computer to aid in code development and introduce two add-on boards which give the Southern Cross SBC access to the outside world. Further on, we will introduce an EPROM emulator and look at how it can be used with a PC for program development. We will also look at how to use the routines in the Monitor for your own programs and how to do software and hardware single stepping to debug your own programs. Full documentation on programming the Southern Cross SBC is contained in the user manual which comes with the kit.

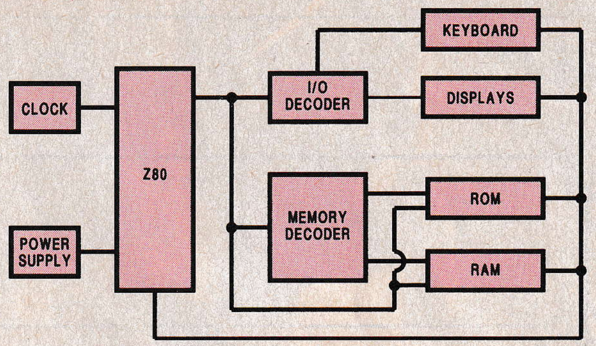


Fig.1: the concept of the Southern Cross is simple with a Z80, RAM, EPROM & decoding.

Features

The Southern Cross comes on a large, single-sided PC board measuring 248 x 130 mm. It is designed around a Z80 microprocessor and nine CMOS ICs. The system runs at 4MHz but a speed control has been built into the board for those times that speed control is more efficiently carried out in hardware than in software.

All the circuit features of the Southern Cross are shown in the block diagram of Fig.1. The complete circuit is shown in Fig.2. In the bottom lefthand corner of the circuit is the 5 x 4 keypad and 74C923 keyboard encoder (IC9). The 74C923 continuously monitors the keypad matrix, looking for a keypress. When one is detected, it produces a 5-bit number and its pin 13 output (Data Available) is set high. Two capacitors are connected to the 74C923. C9 sets the speed at which the chip scans the keypad matrix while C11 provides keypad debouncing.

The 5-bit data from IC9 is buffered by IC8, a 74HC244 octal Tristate buffer, which feeds the data bus. The Z80 controls IC8 through the I/O address decoder chip IC3. The keyboard buffer chip (IC8) has two unused input lines. These have been taken to connector CN4 where they are available for other uses.

Output interface

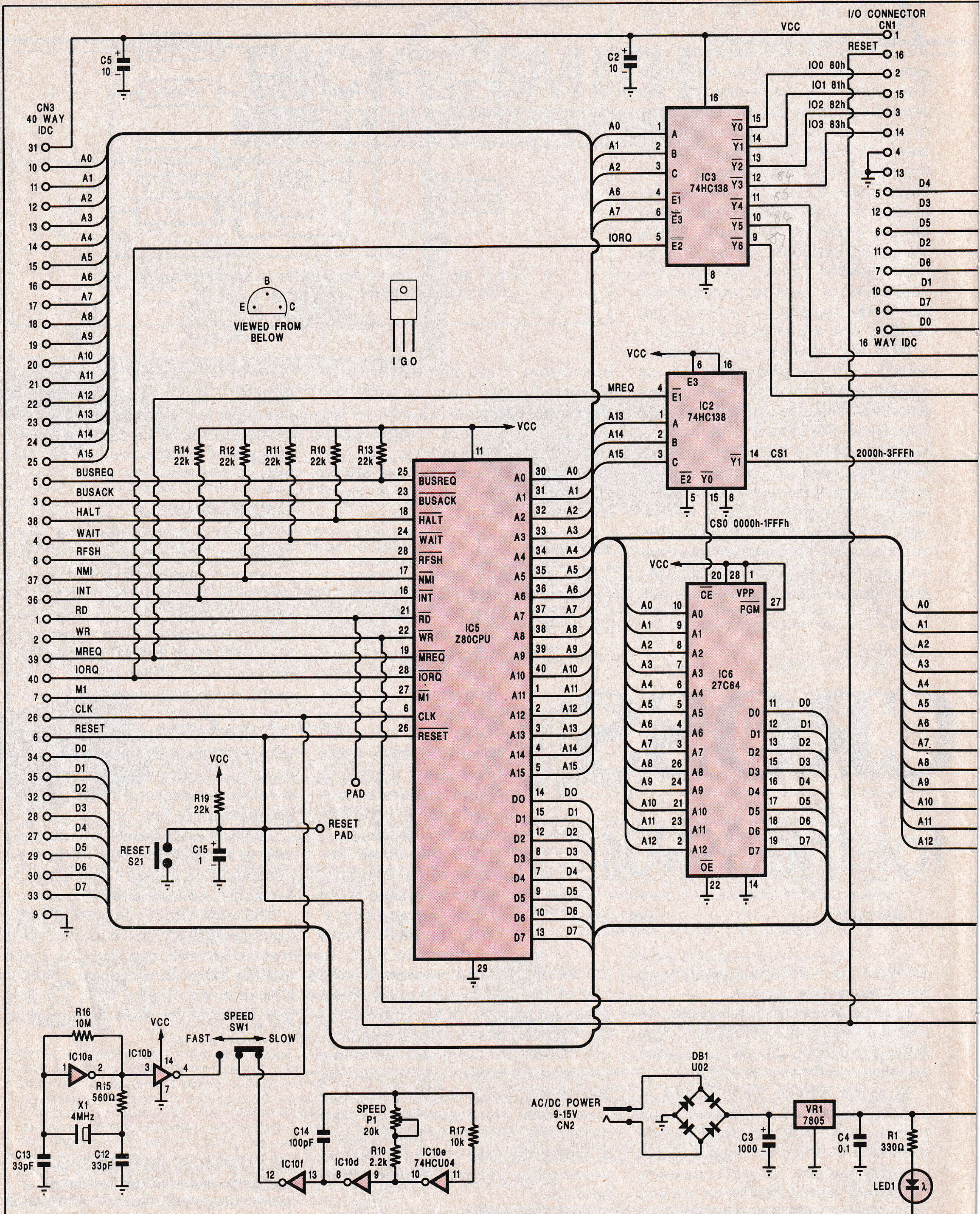
The output interface consists of six 7-segment common cathode LED displays and an 8-ohm loudspeaker driven by transistor Q7. Latch IC1 drives the display segments and decimal points via two resistor networks, SIL1 & SIL2. Latch IC4 drives the common cathodes of each display as well as the speaker via seven NPN transistors.

Both latches IC1 & IC4 are controlled by I/O decoder chip IC3. IC4 has one unused output line (pin 16) which is taken to connector CN4, as is the speaker output line.

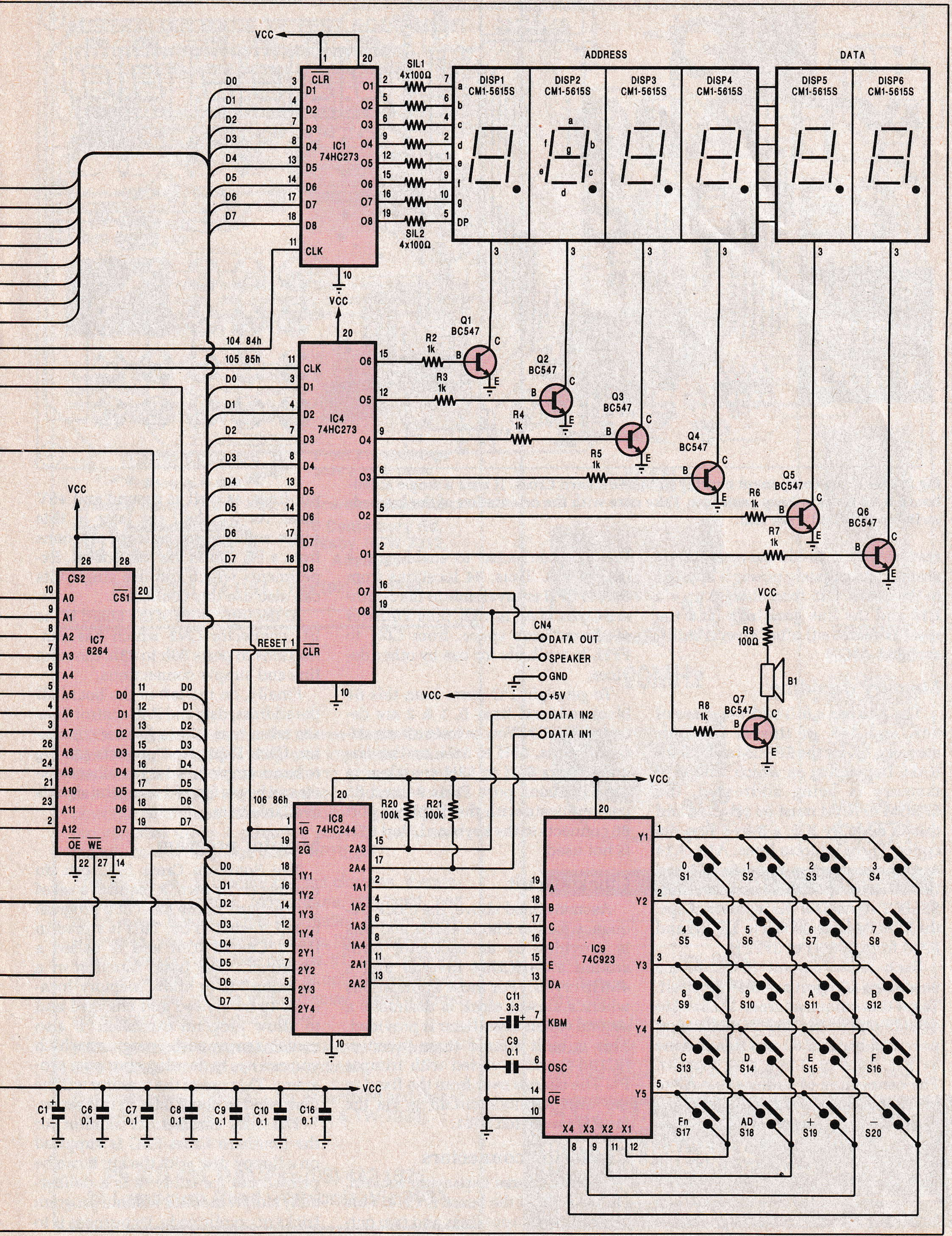
The core of the Southern Cross consists of the Z80 (IC6), the I/O address decoder (IC3), memory decoder (IC2), RAM (IC7) and EPROM (IC6).

The reset circuit consists of pushbutton switch S21 in conjunction with resistor R19 and capacitor C15. Pressing the reset button resets the Z80 CPU and the display latch IC4. R19 and C15 also provide the power-on

Fig.2 (following page): this is the complete circuit of the Southern Cross computer. It has a 5 x 4 keypad for data entry & program execution & a 6-digit display as the major output interface. ▶



SOUTHERN CROSS MICROPROCESSOR



ADDRESS
DATA
DISP1 CM1-5615S
DISP2 CM1-5615S
DISP3 CM1-5615S
DISP4 CM1-5615S
DISP5 CM1-5615S
DISP6 CM1-5615S
SIL1 4x100Ω
SIL2 4x100Ω
IC1 74HC273
IC4 74HC273
IC7 6264
IC8 74HC244
IC9 74C923
Q1 BC547
Q2 BC547
Q3 BC547
Q4 BC547
Q5 BC547
Q6 BC547
Q7 BC547
R2 1k
R3 1k
R4 1k
R5 1k
R6 1k
R7 1k
R8 1k
R9 100Ω
B1
R20 100k
R21 100k
CN4
DATA OUT
SPEAKER
GND
+5V
DATA IN2
DATA IN1
RESET 1
104 84h
105 85h
106 86h
C11 3.3
C9 0.1
KBM
OSC
C1 1
C6 0.1
C7 0.1
C8 0.1
C9 0.1
C10 0.1
C16 0.1
VCC
0 S1
1 S2
2 S3
3 S4
4 S5
5 S6
6 S7
7 S8
8 S9
9 S10
A S11
B S12
C S13
D S14
E S15
F S16
Fn S17
AD S18
+ S19
– S20

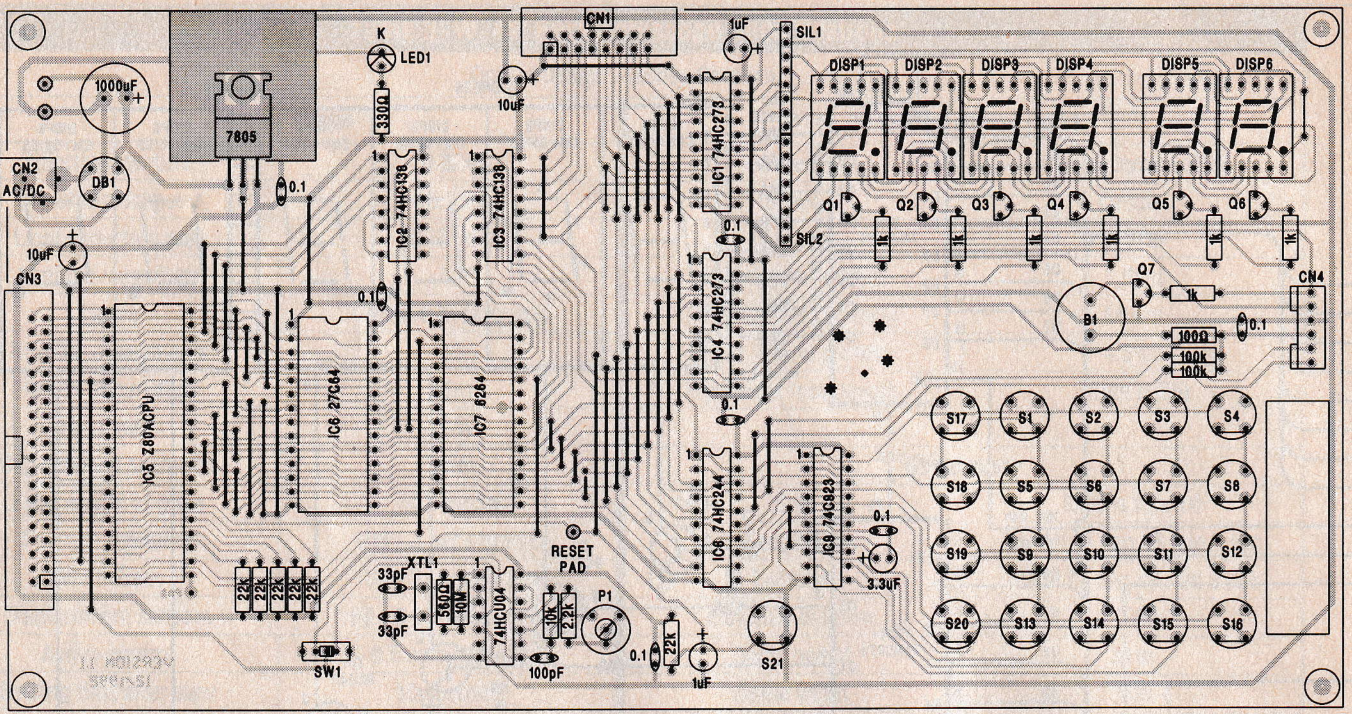


Fig.3: this is the component overlay of the Southern Cross. It uses a single sided board & 54 links to keep costs low. Take care with the orientation of the keypad switches (S1-S20) – see text.

reset circuit. It holds the reset line at ground immediately power is applied to the board. C15 then charges up via R19 and the line goes high (and the reset is removed) after several milliseconds.

Memory decoding

The Z80 has a full address space of 64K and 16K of this is used for memory, 8K for the EPROM and 8K for RAM. Depending on which section of memory is being addressed, the EPROM or RAM must be selected and this is done by IC2, a 3-to-8 line decoder. Three address lines, A13, A14 & A15, are used as input to IC2 and two of its output lines become CHIP SELECT signals for the memory chips; the EPROM from 0000H to 1FFFH and RAM from 2000H to 3FFFH.

Each input/output (I/O) device needs one I/O port address for itself. To get this unique address, we need to decode one of the 256 I/O addresses provided by the Z80 and this is done by IC3, another 3-to-8 line decoder. The connection of address line A7 to the enable (E3) pin 6 of IC3 effectively divides the memory map into two halves. If A7 is low, the decoder is disabled and no I/O ports on the Southern Cross are selected.

The upper half of this memory map is further divided in half by address line A6, connected to enable pin 4 (E1) of IC3. Thus, 64 locations from 80H to BFH are available to the Southern Cross. If A6 is high, then a quarter of the address space, from C0H to FFH, is available for use by other devices.

To get eight I/O ports from this 64 block, address lines 0, 1 & 2 are decoded by IC3. You can see seven decoded ports, 80H to 86H, on the diagram. Ports 80H to 83H are taken to the expansion port. Ports 84 and 85 communicate with the displays; port 86 connects to the keyboard. Port 87H is not used.

Clock circuit

As mentioned above, the clock frequency for the Z80 is 4MHz and this is provided by an oscillator built around a 74HCU04 inverter and a 4MHz crystal. For those applications where a slower clock is desirable, a second variable oscillator is provided. This is built around three inverters (IC10d-f) and is varied with trimpot P1. The change over from the fixed to the variable clock circuit is via the Fast/Slow switch SW1.

Expansion connectors

There are three expansion sockets. On the right of the board is CN4. This contains two input lines and two output lines, as well as ground and +5V lines. As we shall see later in this series, serial downloading of programs from a PC comes via this socket. Experiments which can use single bits can also use this connector.

At the top centre of the board is the I/O connector CN1 which has connections to ports 80h to 83h, the reset line and supply connections.

Finally, on the left of the board all the address, data and Z80 control lines are taken to a 40-pin header connector, CN3. Expansion projects too big to be accommodated at the other sockets can be performed using the signals available here.

Monitor program

The Southern Cross SBC can do nothing on its own. It requires a set of instructions in the form of a program to tell it what to do. This is stored in the 27C64 EPROM and is called a "monitor". The basic function of a "monitor" is to allow memory locations to be viewed and changed and to allow program execution. It also contains many useful programs which you can use to develop your own programs. This use of the monitor will be discussed in detail later in this series.

The fully commented monitor for the Southern Cross SBC is supplied on a floppy disc with the kit. It can be printed out for study. It is a deliberately simple monitor without program tricks or cryptic code. Its purpose is to teach, not to impress or confuse the beginner.

Programming of the Southern Cross begins with the simple examples listed in the User Manual which comes with the kit. First, one LED segment in one of the six segment displays is turned on. Gradually, the student is shown how to assemble code and enter it into the Southern Cross.

Several demonstration programs are built into the monitor. Function 8 (pressing the 'Fn' function key then the '8' key) will play a tune. You can then enter your own tune, press Function A and the tune you entered will play.

Function C brings up a random 4-digit hex number which you must be find within 20 tries (9 tries is our best).

Other Function key assignments include:

- Function 0 – start program execution.
- Function 1 – ready to receive Intel hex file in serial download.
- Function 4 – move a block of memory defined by Function 2 (begin block) and Function 3 (end block) to the address displayed.
- Function 5 – calculate a check sum on the block of memory defined by Function 2 (start) & Function 3 (end).
- Function 6 – relative branch calculator.
- Function B – toggle the speaker off/on. If you get tired of the speaker beeping when you press a key, you can turn it off and have a variable off period of the displays instead.
- Function D – test the Relay Board if attached.
- Function E – test the 8 x 8 LED dot matrix board if attached.
- Function F – brings up the time/day/date in the Smartwatch socket if attached.

Saving programs

One of the big problems with SBCs in the 1980s was that when you turned off the power, your programs in RAM were lost. The solution in those days was to build a battery-backed RAM board but these days Dallas Semiconductor has neatly solved the problem with their Smartsocket DS1213B. This can be fitted in the RAM socket underneath the 6264 RAM IC. It has a battery life of 10 years. When power is turned off, the Smartsocket senses this and the built-in battery takes over and all your programs are safely kept in the RAM.

Time & date option

Dallas Semiconductor also has a Smartsocket of the same physical size which incorporates a time and date function. This is the DS1216B. You can set the time and the date and it is permanently saved in the chip until you alter it.

Two simple changes to the board allow the DS1216B to be used. Function F then brings up the time and date on the displays. The date comes up in the standard DD/MM/YY format or you can change a single bit in

PARTS LIST

1 PC board, 247 x 130mm
21 keypad switches
1 miniature slide switch (SW1)
1 4MHz crystal
1 5V buzzer

Semiconductors
2 74HC273 8-bit latches (IC1,IC4)
2 74HC138 3-to-8 line decoders (IC2,IC3)
1 Z80A microprocessor (IC5)
1 27C64 8K EPROM (IC6)
1 6264 8K static RAM (IC7)
1 74HC244 octal Tristate buffer (IC8)
1 74HC923 keypad encoder (IC9)
1 74HCU04 hex inverter (IC10)
7 BC547 NPN transistors (Q1-Q7)
1 5mm red LED (LED1)
1 7805 5V regulator (REG1)
1 bridge rectifier (DB1)
6 CM1-5615S red 7-segment common cathode displays (DISP1-6)

Sockets & connectors
1 40-pin socket
2 28-pin sockets
4 20-pin sockets
2 16-pin sockets
1 14-pin socket
1 16-way rightangle socket (CN1)
1 2.5mm DC socket (CN2)
1 40-way rightangle socket (CN3)
1 6-way header & socket (CN4)

Capacitors
1 1000μF 35VW electrolytic
2 10μF 16VW electrolytic
1 3.3μF 16VW electrolytic
2 1μF 16VW electrolytic
7 0.1μF monolithic
1 100pF ceramic
2 33pF ceramic

Resistors (0.25W, 5%)

1 10MΩ	7 1kΩ
1 100kΩ	1 560Ω
6 22kΩ	1 330Ω
1 10kΩ	1 100Ω
1 2.2kΩ	

2 4 x 100Ω SIL resistor arrays (SIL1, SIL2)
1 20kΩ trimpot (P1)

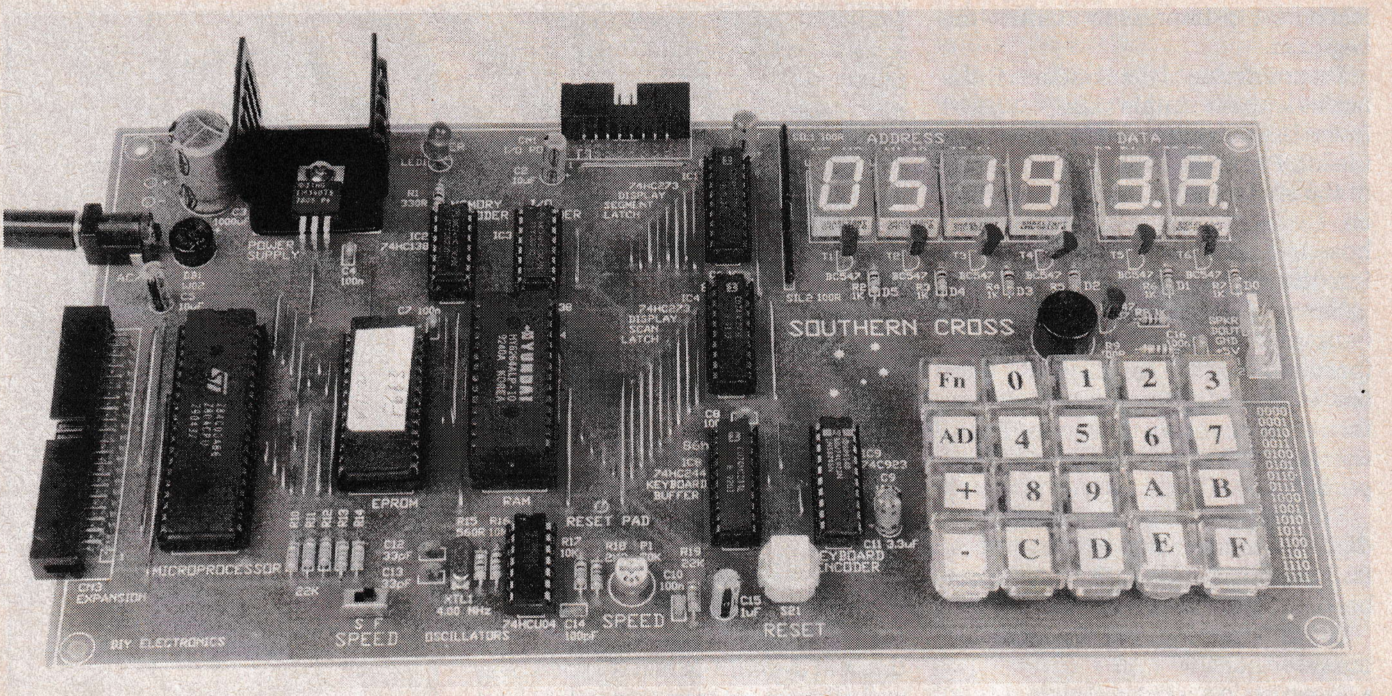
Miscellaneous
Heatsink for regulator, tinned copper wire, rubber feet.

Where to buy the kit

The Southern Cross computer kit was designed in Australia for DIY Electronics, GPO Box 904, Hong Kong. The kit containing all the components, documentation and floppy disc with the monitor program may be ordered in Australia from Alpine Technology, PO Box 934, Mt. Waverley, Vic 3149. Phone or fax (03) 751 1989. You may pay by Bankcard, Mastercard, cheque or money order. Buyers outside Australia should contact DIY Electronics in Hong Kong. Phone (852) 725 0610. The kit costs are as follows:

Southern Cross Computer	$172.00
Dallas DS1213B SmartSocket	$55.00
Dallas DS1216B SmartSocket	$74.00
Technical manual of IC data sheets	$10.00

The kit will be sent to buyers from Hong Kong by registered airmail and this is included in the purchase price. Note that there is no copyright on the PC artwork, program code or documentation and buyers are encouraged to copy and modify the software provided.



The Southern Cross single board computer is intended as a learning tool for those who want to know more about microprocessors. It uses the Z80 8-bit microprocessor & all the other parts are readily available.

the Monitor program to use the American MM/DD/YY format if you wish. The day of the week can also be indicated using the decimal points.

Construction

The Southern Cross computer is built on a single-sided PC board. The top is screen printed with the component overlay diagram while the copper pattern on the underside has a solder mask which covers all the board except around the solder pads. This makes soldering easier and reduces the risk of solder shorts on the copper pattern.

The first thing to do is to place all the components into a container and then check them off against the parts list. The component overlay shows where all the parts go. First, there are 54 links to be inserted. Next, insert the resistors and we suggest you check each one for correct value with your multimeter. Your can also insert the two resistor packages, SIL1 and SIL2, at this stage.

Sockets are used for all the ICs and they all oriented the same way, with the end notch pointing to the top of the board. Watch the polarity of the electrolytic capacitors, C1, C2, C3, C5, C11 & C15. The buzzer B1 must also be correctly oriented.

There are seven BC547 transistors to be inserted and their case orientation should match the shapes shown on the board overlay.

The six LED displays are oriented with their decimal points adjacent to the driver transistors. For LED1, the cathode lead is the shorter of the two and should be at the top of the PC board. The bridge rectifier, DB1, should be inserted so that the "+" symbol on the package is adjacent to the "+" on the PC overlay. The 7805 voltage regulator's leads should be bent with pliers before it is soldered in place. It is assembled on the board together with its heatsink, as shown in the photograph.

Each keypad switch has a flat part on one of its sides. This faces towards the bottom of the PC board as shown in Fig.2. All 21 key switches are identical. Sixteen of the same colour are supplied for the hex numbers 1-F.

Now insert all the miscellaneous components such as the Speed and Reset switches, the 20kΩ trimpot P1, the various connectors and the 4MHz crystal. Lastly, insert the integrated circuits in their sockets, making sure that they are oriented correctly.

When all the components have been installed on the board, check your work very carefully. In particular, check the following points: electrolytic capacitors around the correct way; ICs in their sockets the right way around; and all the links on the board.

We also suggest that you fit four rubber feet to the corners of the Southern Cross PC board. This will prevent the component leads on the underside from damaging your bench or desk surface and will prevent any shorts if you place the board on a metal surface.

Now set the Speed switch to the F (fast) position and connect a 9V or 12V AC or DC plugpack. The Southern Cross should then beep, the power LED should light and the numbers '2000' should appear in the group of four Address displays.

If the board does not work when you turn it on, remember that the problem is almost certainly a mistake you made during construction. The most common cause of kit failure is bad soldering or forgetting to solder a pad. Also common is incorrect insertion of components or solder shorting across two pads.

Use your multimeter to check that +5V is present at the respective pins of the ICs, as shown on the circuit diagram of Fig.2.

If the Southern Cross is completely dead when the power is connected (and LED1 does not come on), then clearly the place to look for faults is around the bridge rectifier and the 7805 regulator. Similarly, if some of the board is active and some parts are not, then this will indicate where to direct your attention. **SC**