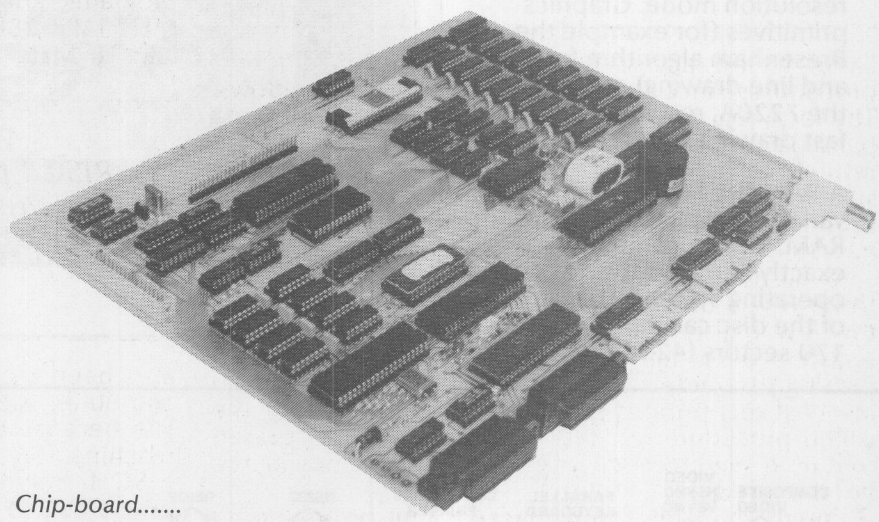
6809-BASED MICROCOMPUTER

In this, the first of a series of articles, G. Mills of Micro Concepts describes a new single-board microcomputer designed by Dave Rumball.

This article describes a single board, 6809-based microcomputer which incorporates a state-of-the-art graphics processor and other advanced features. It can be built at very low cost and is also available from Micro Concepts as a kit.

One of its features is the ability to appear as a Flex standard machine to the wide range of Flex software. This would be of interest to those who are involved in writing software for microprocessor controlled equipment, allowing the board to be used as an inexpensive but sophisticated software development system. In case you aren't aware, the Flex operating system has a wide range of cross assemblers and an elegant command set, and is widely used for this type of work. British companies currently using Flex based development systems for microprocessor software development include Dacom, Racal, and Westwood. Because of its advanced features, this board offers a more cogenial environment for software development than many more expensive systems. Companies currently using the Micro Concepts kit (known as the Microbox II) for software development include Thorn EMI and British Telecom.

The design should also be of interest to those who want a really useful computer for very little money. It runs serious wordprocessing and data base software, has beautiful graphics, superb resolution, a completely soft character set and the prototype cost around £450 to build including discs, video monitor, keyboard, power supply and operating system (and the price is coming down).



Chip-board......

By way of introduction, the following is a partial description of the hardware:

Central processor — Motorola 68B09E.

64K of dynamic RAM for the central processor. When running the board in the monitor mode, 8K of this is mapped out by the monitor EPROM. When running the Flex operating system, only 4K of the monitor EPROM is retained. This 4K contains driver routines for the discs, serial ports and parallel ports, as well as interface routines for the graphics chip and terminal emulator.

A floppy disc controller that will support up to two 3½ or 5¼ inch floppy disc drives, single or double density, single or double sided, 40 or 80 track.

One parallel keyboard port.

Two independent bi-directional RS232 ports with software programmable baud rates (50 to 19.2k baud), parity, stopbits, etc.

One Centronics standard parallel printer port.

A buffered, fifty pin expansion bus.

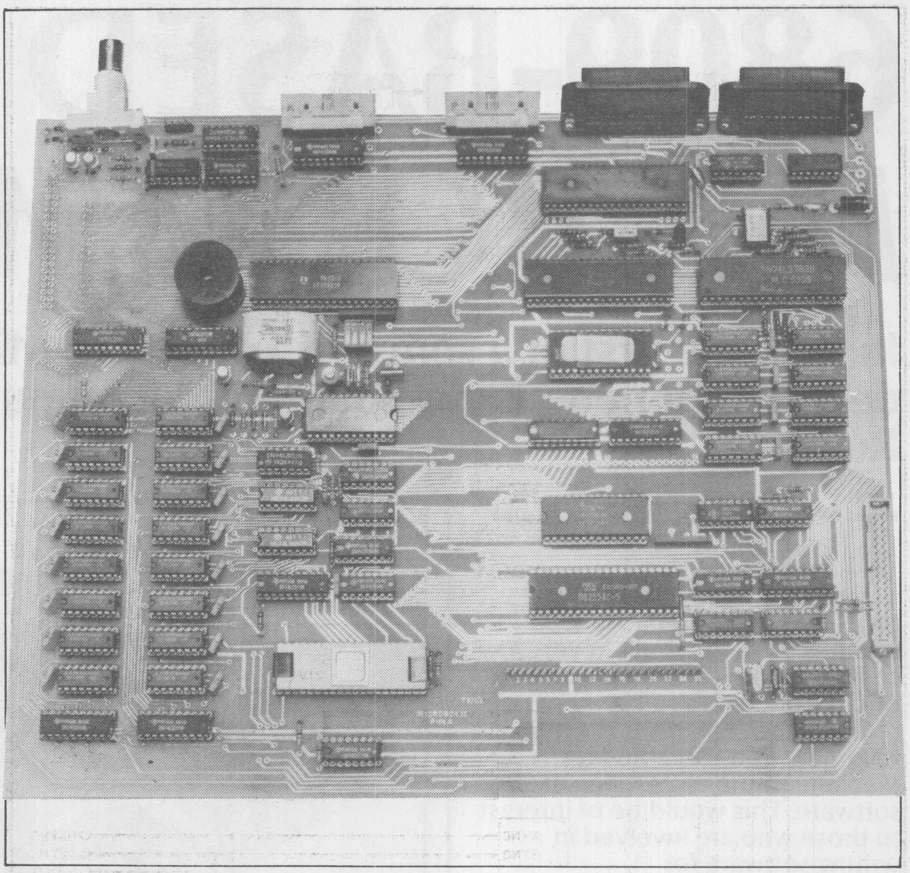
All of the above will be familiar to anyone who has experience with run-of-the-mill Flex machines available from a number of manufacturers. The following features are unique to this design:

An additional 128K of dynamic RAM partitioned into alphanumeric video RAM, graphic video RAM, and RAMdisk.

An alphanumeric display format of 108 columns by 24 lines when using the terminal emulator resident in the monitor EPROM. The terminal emulator and the associated character set are in software and therefore can be redefined if desired. Alternate memory resident emulators come with the kit. One gives a format of 84 by 24 and another 128 columns by 56 lines.

Exceptional monochrome graphics facilities generated by an NEC 7220A graphic display controller. The resolution of the display is 768 pixels by 576 pixels. By way of comparison, this is a resolution 2.7 times greater than the BBC Model B in its highest resolution mode. Graphics primitives (for example the Bresenham algorithm for arc and line drawing) are built into the 7220A, resulting in very fast drawing speeds.

A RAMdisc facility, using a variable amount of the 128K RAM. This RAMdisc looks exactly like a floppy disc to the operating system. The capacity of the disc can vary between 170 sectors (42.5K) when



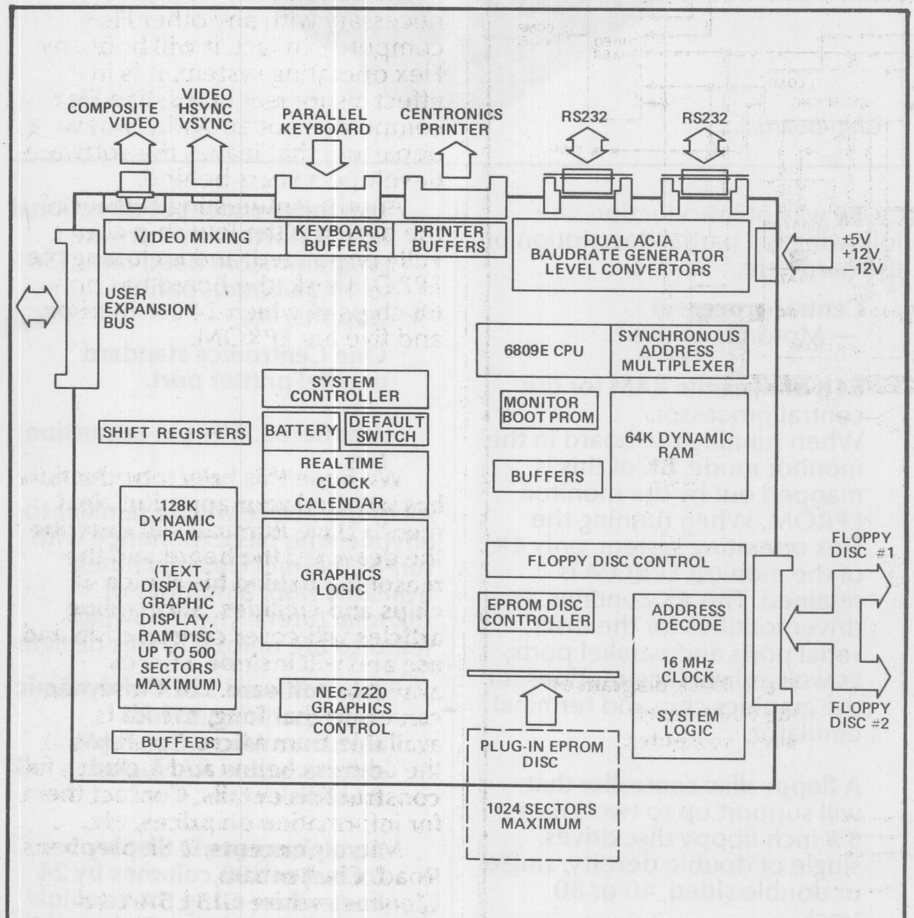


Fig. 1 Location of the principal components on the board.

using the full graphics capabilities of the machine, and 500 sectors (125K) when the machine is being used with a serial terminal and no graphics output. Its mid capacity, when using the terminal capacities of the 7220A, is exactly the size of a single density, single sided 40 track Flex disc. This enables the user to perform fast disc to disc copying with only one disc drive.

An EPROM based silicon disc which again looks to the DOS exactly like a floppy disc, but this time write protected. The EPROM disc is fabricated on its own small PCB which plugs into the main board. This allows the user to keep a number of these discs programmed for different applications. The capacity of this board is 4 EPROMS which can be 27128's, 27256's, or 27512's. These will give 64K, 128K, or 256K bytes of disc space respectively.

An on-board EPROM programmer requiring only a programming power source (for 21V EPROMS three 9 volt batteries stablized by a zener diode can be used).

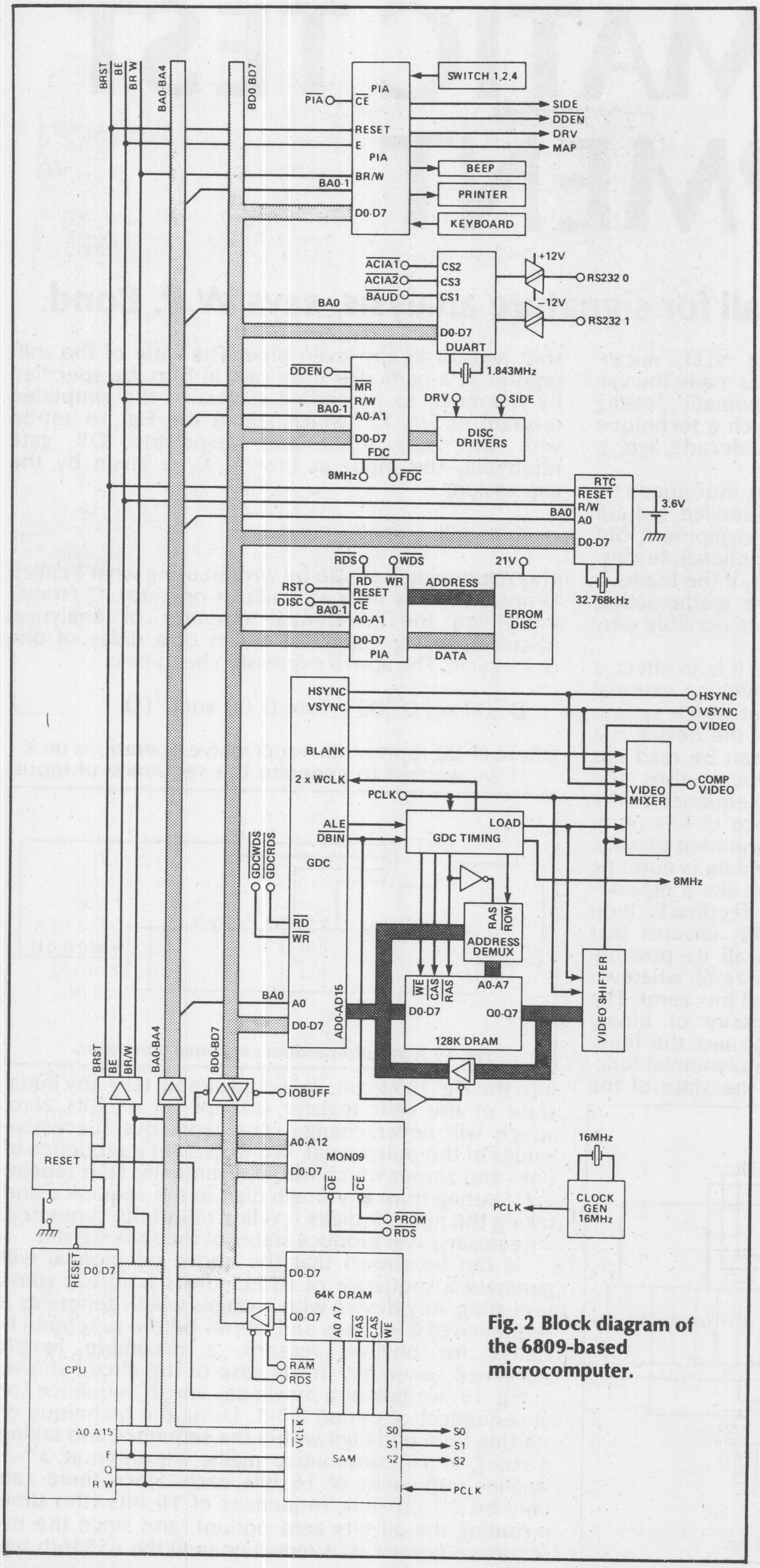


Fig. 2 Block diagram of the 6809-based microcomputer.

A battery backed-up real time clock and calendar. This is used by Flex to date stamp files. The clock chip also contains 50 bytes of non-volatile RAM, some of which is used to maintain system parameters such as baud rates, floppy disc step rates, physical to logical mapping of disc drives and start-up parameters for the graphics device.

It should be apparent by now that the board has been designed with some thought. The combination of EPROM disc and RAM disk makes it very fast indeed and in most cases disc access time is not even noticeable.

The effect of the silicon discs and the fast graphics hardware is to make the machine compare favourably with the graphics on much larger machines (in one incarnation it was used by Imperial College as a graphics terminal for a VAX). Further, the terminal emulation software and the handling of the ROM and RAM discs so that they look like floppy discs enables the system to run Flex software with no more modification than would be necessary with any other Flex computer. In fact, it will boot any Flex operating system. It is in effect a superset of existing Flex computers, not an entirely new departure that leaves the software developers years behind.

Another interesting feature of the design is the low chip count. Fully populated, and including the EPROM disk, the board has only 68 chips of which 24 are memory and five are EPROM.

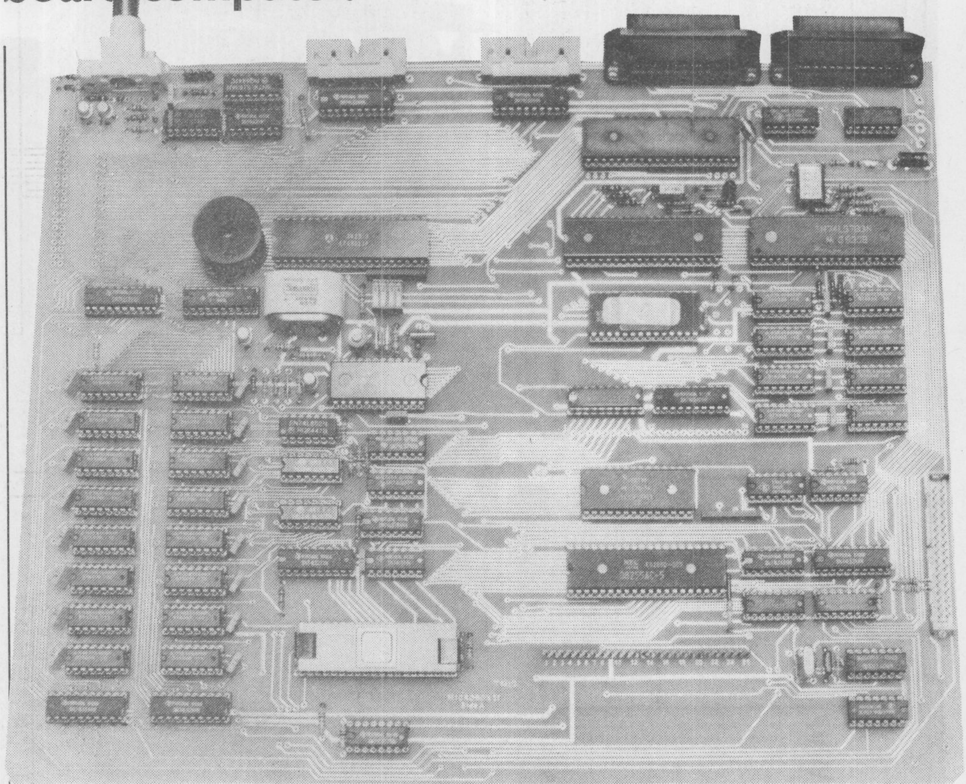
We hope this brief introduction has whetted your appetite! Next month Dave Rumball will describe the design of the board and the reasoning behind his choice of chips and facilities. Succeeding articles will cover construction and use and will include a list of available software. For those who can't wait that long, the kit is available from Micro Concepts at the address below and includes full construction details. Contact them for information on prices, etc.

Micro Concepts, 2 St. Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel 0242 - 510 525.

ETI

6809-BASED MICROCOMPUTER

Designer Dave Rumball takes us chip-by-chip through the circuitry of his single board computer.



This is the second in a series of articles which describe the design, construction and use of a powerful, 8-bit, single-board microcomputer based upon the 6809 microprocessor. The board uses the Flex operating system, giving access to a wide range of cross-assemblers and making it particularly suited to software development work. As well as having all the features usually found on a Flex standard machine, this design also offers very high resolution monochrome graphics, 128K of graphics RAM, a RAMdisc system which uses a variable amount of the 128K graphic RAM and appears to an operating system exactly as though it were a floppy disc, and an EPROMdisc system which consists of a small, plug-in board and again appears to the operating system as a floppy disc. Other features include a battery backed-up real time clock and an on-board EPROM programmer, and the complete package is available in kit form from Micro Concepts.

In this article we will look at the workings of the microcomputer section by section. In subsequent articles we will be describing the construction of the board and how to use it.

The CPU, Memory, Buffers And Decoding

The 'core' of the Microbox II is formed by the processor IC1, the SAM chip IC2 and the memory IC3-IC12. IC2 has several functions. First, it takes the master 16MHz clock from IC15 and generates the 1-2MHz processor clocks. The processor address is converted to the multiplexed eight-bit buss and control strobes necessary for the eight 64K DRAMs, IC5-IC12. 22 ohm resistors in these lines damp any signal reflections or undershoots which would disturb the DRAM operation. It also defines a three-bit decoding buss which is used by the decoding logic. An 8K EPROM, IC3 holds the monitor program and system service. IC4 buffers the DRAM read data onto the processor data buss, whilst IC13 is a bi-directional buffer between the processor and the peripheral data busses.

The low order address lines, the control strobes E and R/W, and the reset signal are buffered by IC18, which has its two enable signals grounded. The reset signal from SW2 triggers two time constants, the shorter of which resets the SAM chip by pulling VCLK low, whilst the longer resets the processor so that the SAM chip comes out of reset before the processor. Note that no use is made of the SAM chip's video capabilities in this design.

The HS pin is tied low on the SAM chip. This frees up an extra RAM cycle per CPU cycle allowing operation at 2MHz. However the SAM chip stops refreshing the DRAM at 2MHz, so operation at this speed can only be for periods of less than 2ms, or longer if the operation itself refreshes the memory as would a transfer of 256 bytes during a disc operation.

The memory system map is defined by IC65 and parts of IC14 and IC16. The memory map is filled with the 64K RAM, except for the top 8K section which is the monitor EPROM. This 8K section is split into two, and the bottom 4K may be switched between EPROM and RAM with the MAP signal from the system PIA. This is used in the current software to

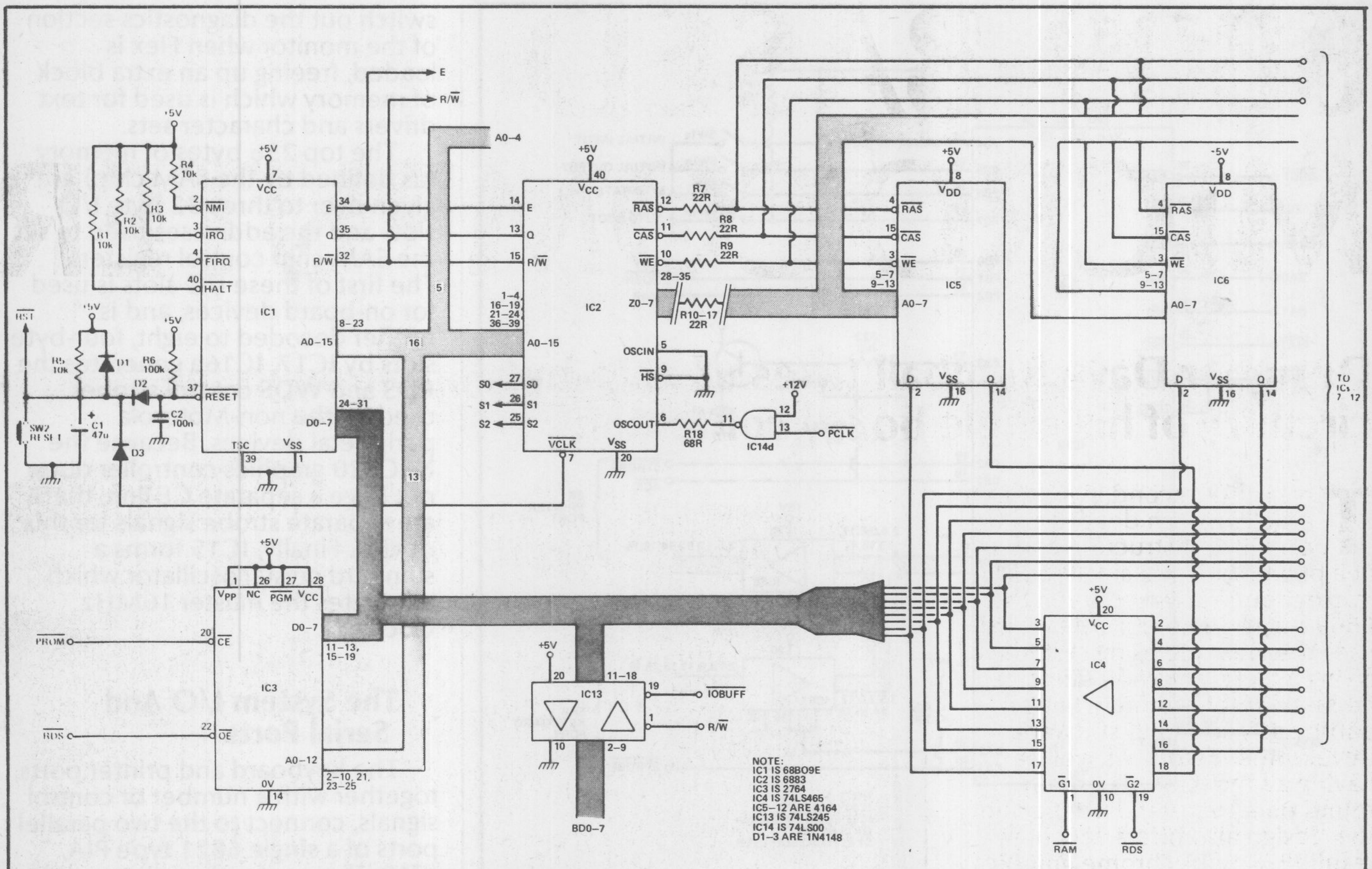


Fig. 1 Circuit diagram of the CPU and memory stages.

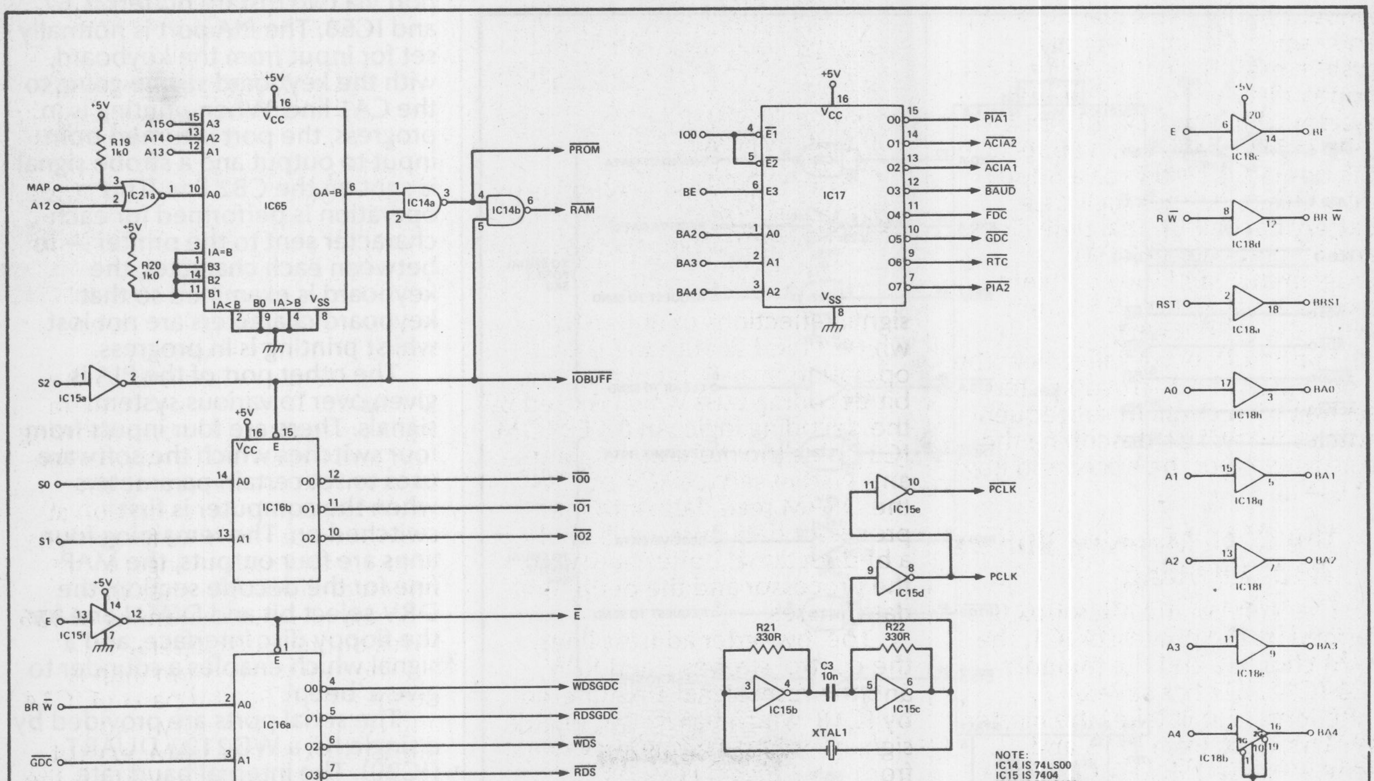


Fig. 2 Circuit diagram of the decoding, buffers and master clock.

The Floppy Disc Interface and PROMdisc

The floppy disc controller is refreshingly simple: it consists of just three ICs, two of which are SSI buffers! The work is done by IC24, a WD1770 floppy disc controller, which connects directly to the peripheral data buss. Input signals from the drives are buffered by IC25, whilst output signals are buffered by IC26. The two drive select lines are derived from a single signal. This means that one drive or the other will be selected all of the time, and its drive select light will be on. This causes no harm if the drive is set up to load its head with the MOTOR ON signal. The drive motor timing is set by the 1770 by counting index pulses. It will stop the drive nine index pulses after the last operation, and will delay any operation until six index pulses have occurred.

The EPROM disc is formed from an 8255 PIA, four EPROMs and an eight bit counter. The data lines from the EPROMs are connected to one of the ports of the PIA, IC28, and the high eight address lines for the EPROMs to another. Chip enables for the four EPROMs, the program line for one of them, and clear and count lines for the counter are connected to the last port. Because Flex only reads data from discs in chunks of 256 bytes, not every address line is needed and the low eight address lines can come from an eight bit counter. To read a 'sector', the processor selects the correct EPROM as a function of the 'track' and 'sector' numbers, then clears the counter and clocks it 256 times, moving each byte for the port to RAM as it goes.

EPROMS may be programmed by applying 21V to the VPP pin, setting the address lines and data, and then pulsing the program line for 50ms.

The operation of the remainder of the board will be described next month, when we also hope to bring you complete constructional details including board overlay and parts list. If you'd rather not wait that long, a kit of parts complete with full constructional details is available from Micro Concepts, 2 St. Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel 0242-510 525.

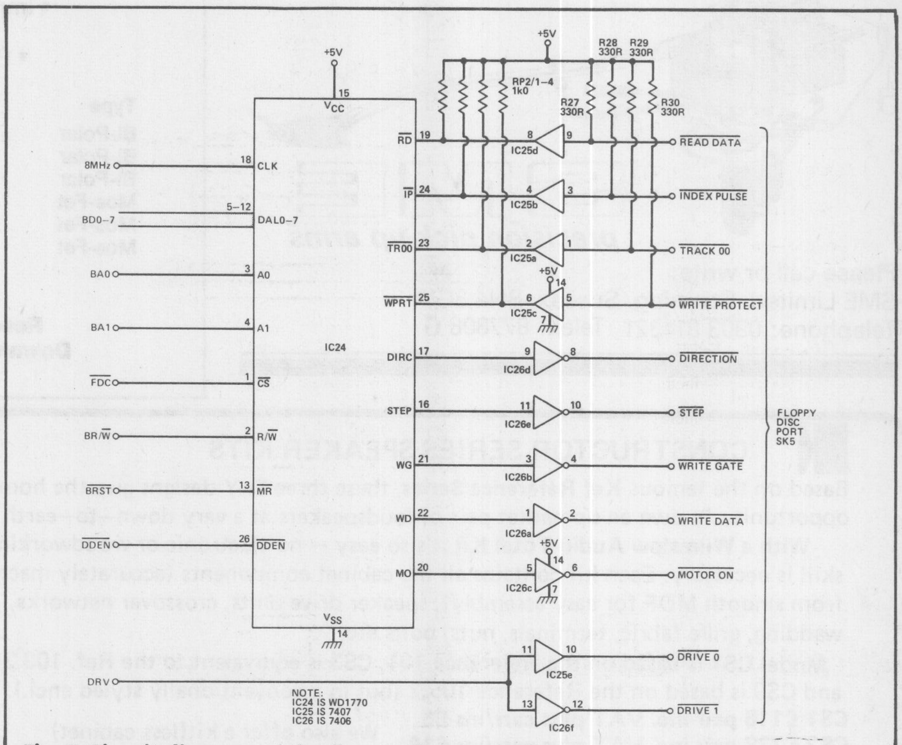


Fig. 5 Circuit diagram of the floppy disc controller.

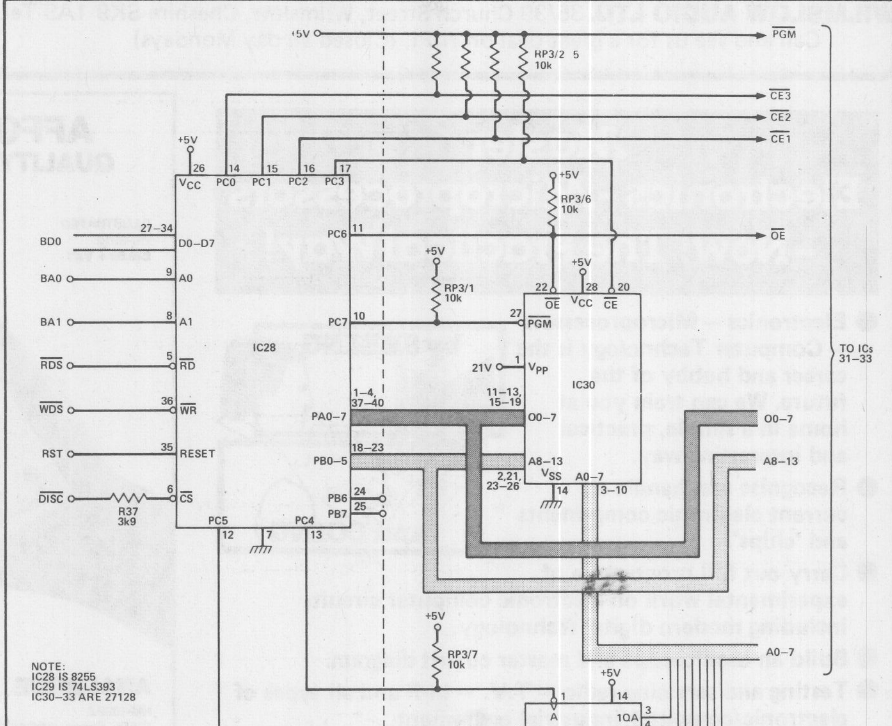


Fig. 6 Circuit diagram of the EPROM disc interface and board.

ETI

6809-BASED MICROCOMPUTER

Dave Rumball and Gary Mills conclude their description of the workings of the computer before going on to consider the choices facing constructors and the assembly of the two boards.

The real time clock, IC27, is a 146818. This part is designed for a multiplexed processor address/data bus, but here is used with a non-multiplexed processor by means of a separate address decode for the address and data strobes. The CE line is grounded by a transistor which is held on by the main +5V rail. When the system power fails, the chip is disabled in order to prevent corruption of the data. The clock has its own internal oscillator which is driven by a 32.768 kHz crystal to reduce power consumption. Power for the clock is provided by a trickle-charged NiCad battery when the main power is off.

The 146818 also contains 64 bytes of CMOS RAM which are used to hold various system parameters, such as the serial baud rates, video timing parameters etc. An RC network on the PS input gives an indication of battery failure. The software checks for this condition on power up and loads a default set of system parameters if the battery power has failed.

The Display Section

The display section consists of three parts, the NEC7220A graphics controller IC34, a 128K bank of DRAM, ICs47–62 (not part of the processor address space), and some control logic. The NEC7220A does 98% of the work in producing the video. It generates the correct display address for the RAM, master timing strobes for reading and writing to the RAM, and display blanking and synchrony signals. The sixteen bit display address is multiplexed onto the eight bit RAM address by

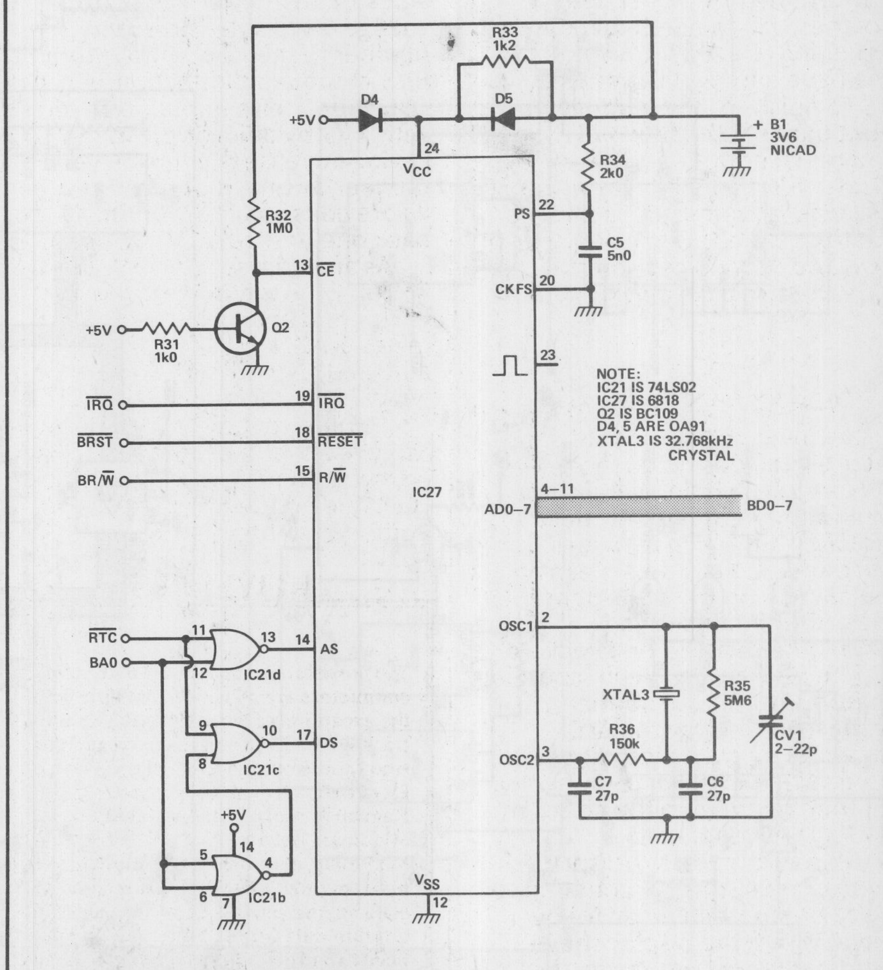


Fig. 1 Circuit diagram of the real time clock.

OOPS!

A capacitor should be added to the serial interface controller oscillator circuit shown in Fig. 4 on page 38 of last month's issue. The capacitor is C30, a 27p polystyrene type, and should be connected between pin 32 of IC20 and the 0V line. It has been included in the overlay diagram and the parts list in this article.

In Fig. 2 on page 37 of the January issue, XTAL1 is listed as a 10MHz crystal. It should be a 16.000MHz crystal, as stated in the parts list in this article.

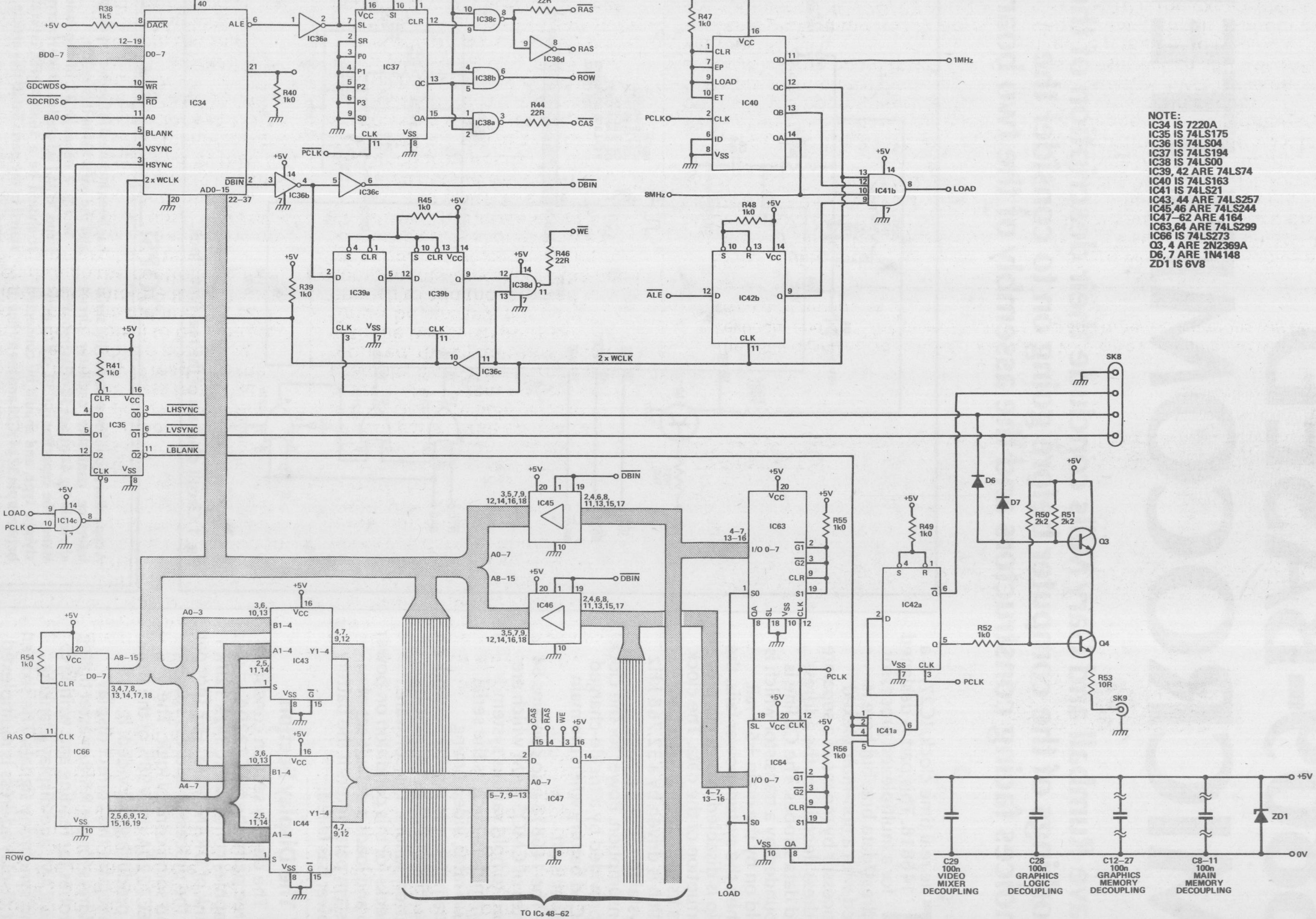


Fig. 2 circuit diagram of the graphics and RAMdisc section.

IC43 and IC44. IC66 latches the low order address lines so that they are stable during the later part of the memory cycle when the graphics controller is putting data onto the address/data bus.

The control strobes for the display DRAM are derived from the master timing signal ALE from the controller. This signal is clocked along a shift register by the pixel clock, to form a digital delay line. Various signals from the shift register are gated to provide the RAS and CAS strobes for the DRAM, and the row select signal for the multiplexer. The WE strobe for the DRAM is derived by delaying the DBIN signal from the graphics. The DBIN signal also gates read data from the DRAM to the controller data lines via tristate buffers IC45 and IC46. Note that the graphics controller data bus is sixteen bits wide.

The graphics controller draws by using a 'read-modify-write' cycle. First the draw address is output, then the data from that word of memory is read into the controller, modified according to the particular pixel to be plotted, and in the same memory cycle, written back into the RAM. Thus, even though the controller only draws one pixel at a time, it operates only on sixteen bit words. Every sixteen pixel times, data from the DRAMs is loaded into two shift registers IC63 and IC64. The load signal is produced by the counter IC40, which generates the graphics controller clock at 2MHz and an 8MHz clock used by the floppy disc controller.

The video data is clocked out at the pixel rate from the shift registers through a blanking gate IC41, and a latch which forces the blanking to a pixel boundary. The resulting video signal is then mixed with the horizontal and vertical syncs and converted to an impedance of 75 ohms by the video buffer. TTL level sync and video signals are also taken out for use with non-standard monitors. The graphics controller is only allowed to access the display memory during line and field blanking times, so there are no flashes on the screen during plotting.

System Choices

The basic kit supplied by Micro Concepts includes the main printed circuit board, the EPROM disc board, a programmed monitor EPROM (IC3), a diskette of system-related software and the necessary documentation. The remaining parts must be obtained from other sources by the constructor.

If cost is an important consideration, construction of certain parts of the system can be left for the time being and only the heart of the system assembled. For example, if serial interfacing is not required, the circuitry associated with the two serial ports can simply be omitted. It is easy enough to add the required components later should the need for a serial interface arise. The following notes should help you decide which components to include and which to omit.

Video output: the board will not function correctly if IC34 is not fitted, but the rest of the graphics circuitry is only required if a video monitor is to be used. If you plan to use the system with a terminal instead, ICs 35, 45, 46, 63, 64 and 47–62 can safely be omitted, along with SK8 and SK9 and the circuitry around Q3 and Q4. However, note that the RAMdisc facility will not function if the memory is not installed.

The 6809-based microcomputer fitted in a Vero case and equipped with a keyboard and 3.5" disc drive. Details of this and other case options will be given next month.

EPROM disc: if this facility is not needed, all of the components on the plug-in board can be omitted (ICs 29–33, RP3 and SK7) along with IC28 and SK6 on the main board.

Floppy disc: ICs 24–26, RP2, R27–30 and SK5 can be omitted if this facility is not required. Note that only the monitor mode is accessible if the board is run without discs.

Serial ports: if the RS232 ports are not needed, ICs 20, 22 and 23 can be omitted along with SK3 and SK4 and the circuitry around XTAL2. This is the only section of the board which uses the plus and minus 12V supplies so, unless these rails are required for a disc drive or other peripheral unit, dispensing with the serial ports will reduce the power supply requirements to a single +5V rail.

A number of other components can be omitted in certain circumstances. SW2 is the on-board reset switch and will only be needed if the board is to be used free-standing (that is, without a case). SK10 is the expansion bus socket and need only be fitted if the expansion bus is to be used. Some or all of the decoupling

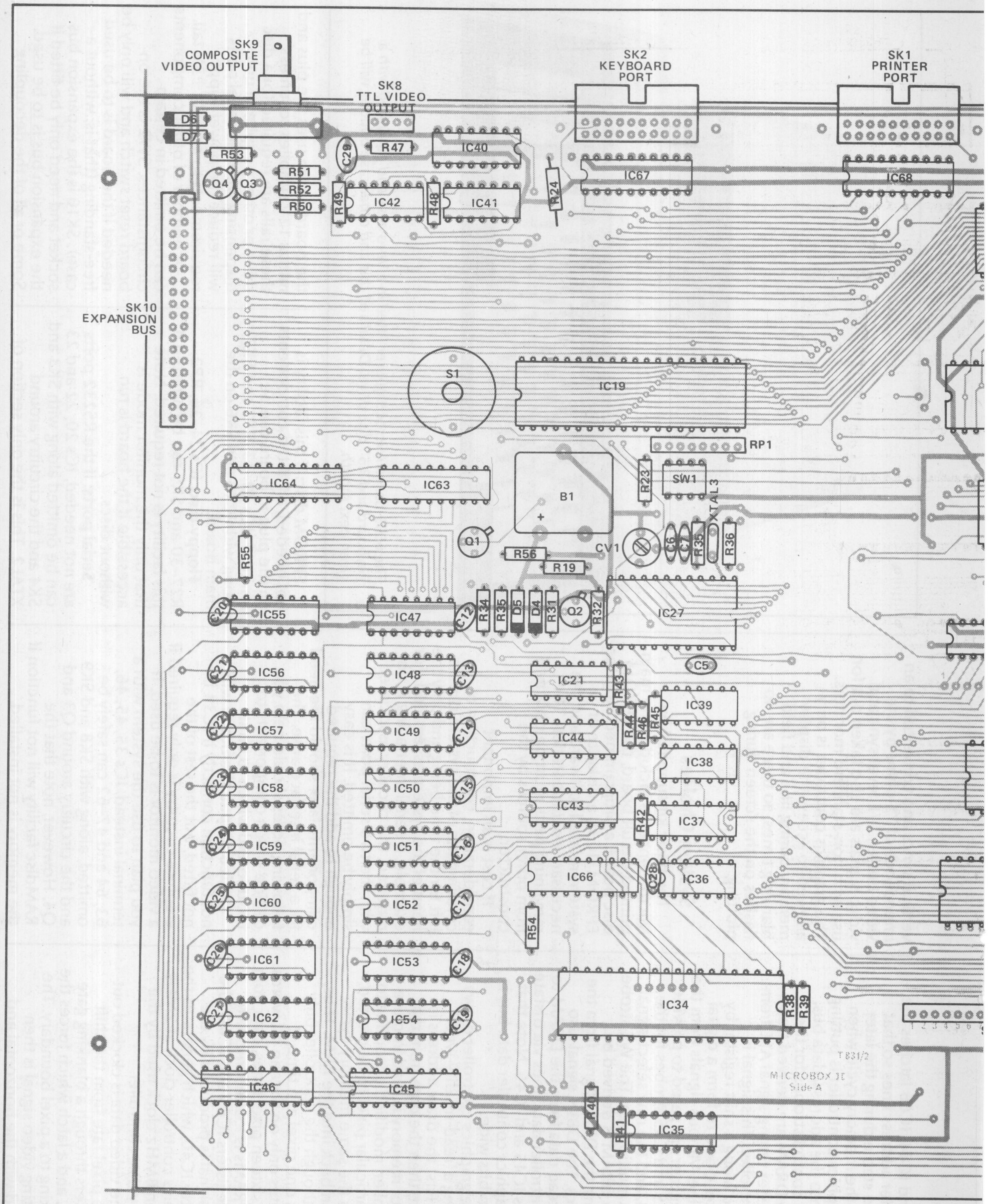
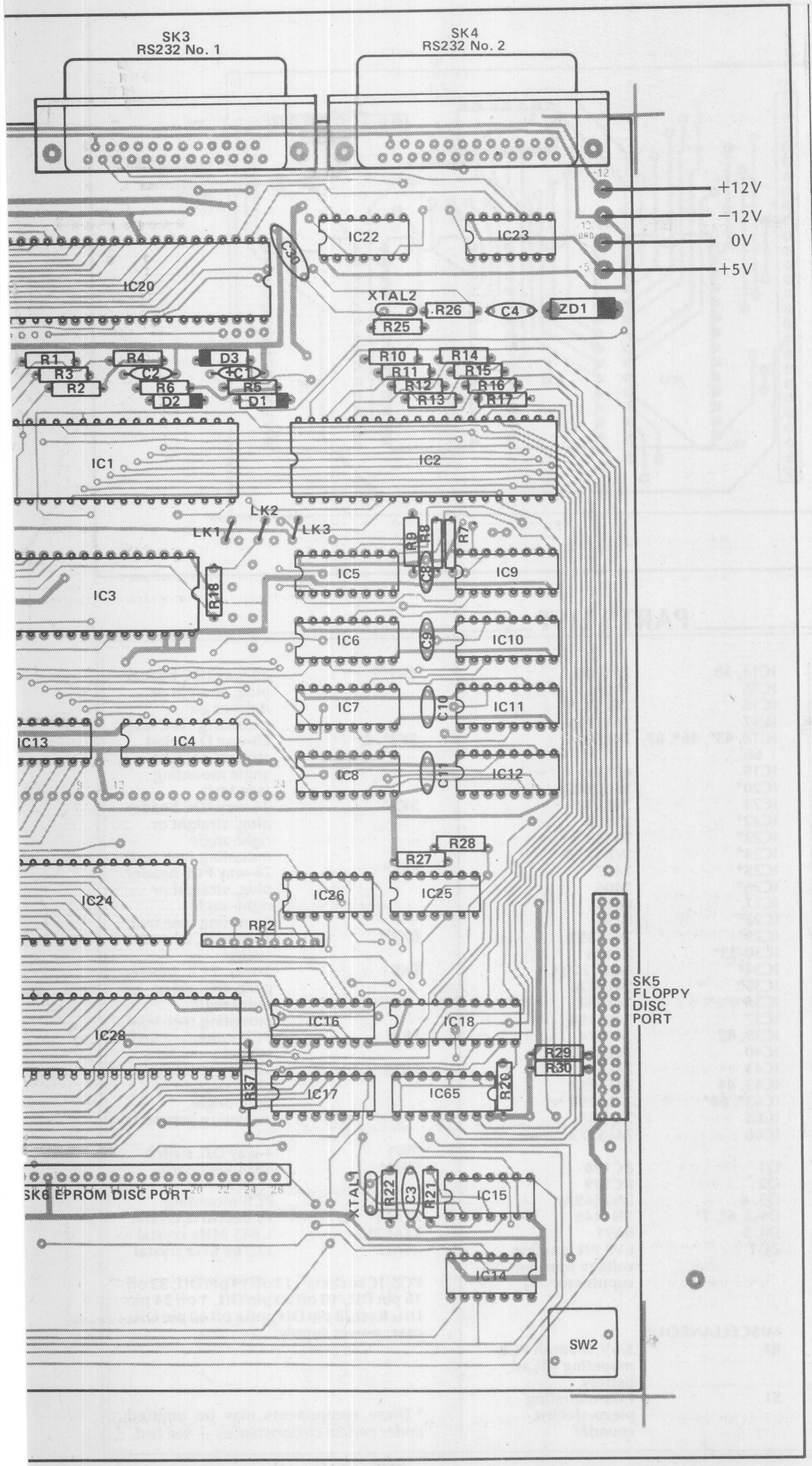


Fig. 3 Component overlay for the main printed circuit board. The board is double-sided but for reasons of clarity the top foil only is shown here.



capacitors around the graphics memory and logic (Cs 12–29) can be left off if this circuitry is to be omitted and of course, IC sockets will not be required for ICs which are not to be fitted.

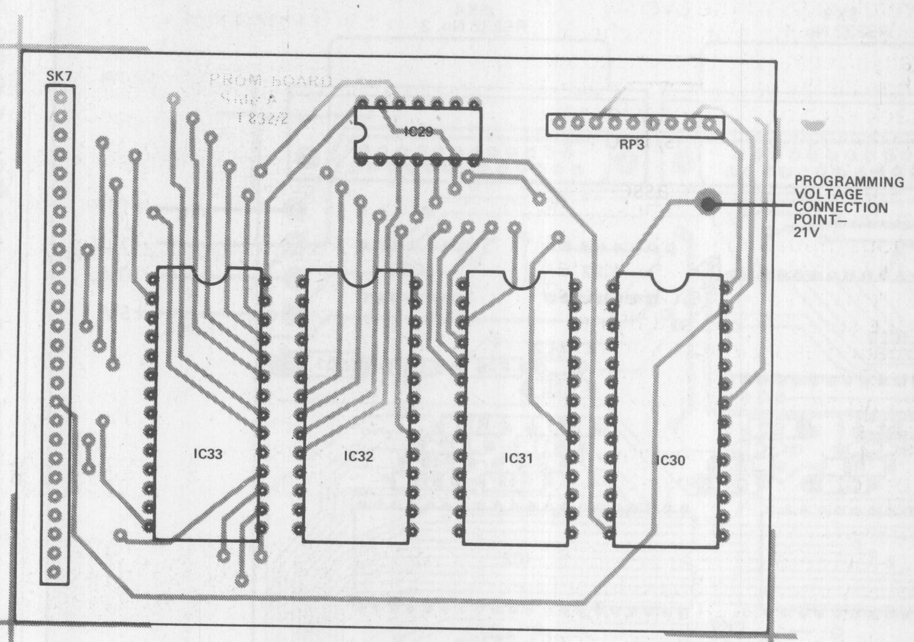
One more thing has to be decided before construction can begin, and that is whether to use straight or right-angled plugs and sockets for the various connections to the board. This will largely depend on the choice of case. Whatever size of case is used, it will probably be most convenient to use right-angle connectors at the rear of the board and poke them directly through holes in the back of the case. It may also be possible to use right-angle connectors for the floppy disc port and expansion bus socket and bring these out directly to the sides of the case. The EPROM disc socket, however, is not adjacent to the edge of the board, and it may be easier to use a straight connector here and punch a slot in the top of the case to provide access. Those who really want to keep costs to a minimum may decide to use the board without a case, thus removing all constraints on the angling of the connectors. One of the prototypes has been working perfectly in this way for some time now, fixed vertically to a wall above the workbench.

Construction

The boards supplied by Micro Concepts are electronically tested for shorted and broken tracks before despatch. However, given the complexity of the board, it is a good idea to examine it carefully against a strong light before starting since any errors which have slipped through will be much more difficult to identify once all the components are in place. It is also a good idea to check that the larger components fit comfortably into their holes. If necessary, the holes can be enlarged slightly with a drill, but bear in mind that this will remove the through-hole plating and make a note to solder carefully on both sides of the board at such points.

Begin by installing the IC sockets. Although most of the ICs have to be inserted with pin 1 towards the left-hand side of the board (the side on which the video outputs and the battery are located), a number of them face in

Fig. 4 Component overlay for the plug-in EPROM disc board. This board is also double-sided and again, only the upper foil is shown.



PARTS LIST

RESISTORS

R1-5	10k
R6	100k
R7-17, 43, 44, 46	22R
R18	68R
R19, 20, 23, 24, 26*, 31, 39-42, 45, 47-49, 52*, 54-56	1k0
R21, 22, 27-30*	330R
R25*, 32	1M0
R33	1k2
R34	2k0
R35	5M6
R36	150k
R37	3k9
R38	1k5
R50*, 51*	2k2
R53*	10R
RP1	10k x 7SIL resistor pack
RP2*	1k0 x 7 SIL resistor pack
RP3*	10k x 8 SIL resistor pack

CAPACITORS

C1	47u 6V tantalum
C2	100n 63V polyester
C3	10n polystyrene
C4*	56p polystyrene
C5	5n0 polystyrene
C6, 7, 30*	27p polystyrene
C8-29*	100n ceramic
CV1	2-22p trimmer

SEMICONDUCTORS

IC1	68B09E
IC2	6883
IC3	2764 (monitor EPROM)
IC4	74LS465
IC5-12, 47-62*	4164
IC13	74LS245
IC14, 38	74LS00
IC15	7404
IC16	74LS139
IC17	74LS138
IC18, 45*, 46*, 67, 68	74LS244
IC19	68B21
IC20*	WD2123
IC21	74LS02
IC22*	75188
IC23*	75189
IC24*	WD1770
IC25*	7407
IC26*	7406
IC27	6818
IC28*	8255
IC29*	74LS393
IC30-33*	27128
IC34*	NEC7220A
IC35*	74LS175
IC36	74LS04
IC37	74LS194
IC39, 42	74LS74
IC40	74LS163
IC41	74LS21
IC43, 44	74LS257
IC63*, 64*	72LS299
IC65	74LS85
IC66	74LS273
Q1	BC108
Q2	BC109
Q3, 4	2N2369A
D1-3, 6*, 7*	1N4148
D4, 5	0A91
ZD1	6V8 PN junction voltage transient suppressor

MISCELLANEOUS

B1	3.6V 100mAh PCB-mounting NiCad battery
S1	PCB-mounting piezo-electric sounder
SK1, 2	20-way IDC header plug, straight or right-angle mounting (see text)
SK3*, 4*	25-way D socket, straight or right-angle mounting (see text)
SK5*	36-way IDC header plug, straight or right-angle mounting (see text)
SK6*	26-way PCB header plug, straight or right-angle mounting (see text)
SK7*	26-way PCB header socket
SK8*	4-way PCB header plug, straight or right-angle mounting (see text)
SK9*	PCB-mounting BNC socket
SK10*	40-way IDC header plug, straight or right-angle mounting (see text)
SW1	4-way DIL switch
SW2*	SPST keyboard switch, PCB-mounting
XTAL1	16.000MHz crystal
XTAL2*	1.843 MHz crystal
XTAL3	32.768 kHz crystal

PCB; IC sockets*: 13 off 14 pin DIL, 32 off 16 pin DIL, 10 off 20 pin DIL, 1 off 24 pin DIL, 6 off 28 pin DIL and 6 off 40 pin DIL; case; power supply.

* These components may be omitted under certain circumstances — see text.

the opposite direction. Check carefully against the overlay diagram as you work and check again afterwards just to make sure. When all the sockets are in place, check each one carefully for solder splashes between pins, bad joints and so on.

Continue with the assembly by installing the three wire links, the various input and output sockets, the switches, the piezo-sounder, the resistors and the capacitors. Make sure that you install the tantalum capacitor, C1, and the three resistor packs the right way around. Solder the diodes and transistors into place, again taking care that they are the right way around, but do not insert the ICs or the Nicad battery. Finally, install the three crystals.

Now comes the tedious bit! Visually check the board for solder bridges and missed joints, then check again that every component is in the right place and that the critical components are all the correct way around. Using a multimeter, carefully check the following buses for continuity and for short circuits between adjacent lines:

the address lines between the CPU (IC1), the SAM (IC2) and the EPROM (IC3);

the data lines between the CPU (IC1), the EPROM (IC3) and the buffers (IC4 and IC13);

the data lines between the buffers (IC13) and the various peripheral device controllers (ICs 19, 20, 24, 27 and 34);

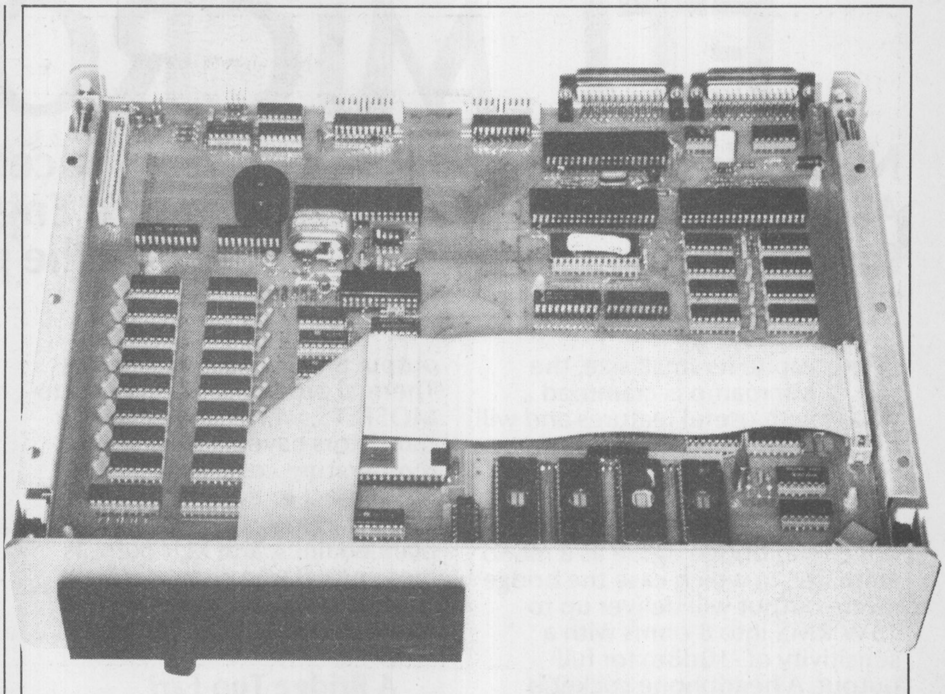
the address and data lines between the controllers and their associated circuitry (eg., between IC19 and the buffers IC67 and IC68);

the main (64K) RAM address lines;

the graphics (128K) RAM address lines.

Connect up a supply of +5V to the board and check that the IC sockets all have +5V and 0V appearing on the correct pins. Repeat the procedure with the +12V and –12V rails. If all is well, insert the ICs into their sockets, taking great care that each IC is in the correct socket and the right way around.

Construction of the plug-in EPROM disc board should present no problems at all, but again, it is a good idea to check the bare PCB before starting and the usual care should be taken with the orientation of the resistor pack and the ICs. One refinement worth considering here is the use of a ZIF (zero insertion force) socket in the IC30 position. This is the position in which EPROMs can be programmed, and the additional cost of a ZIF socket may well be justified if you plan to make extensive use of this facility.



Another view of the cased board. Note that the EPROM disc board shown here (lower centre-right) is a prototype.

BUYLINES

Almost all of the integrated circuits are available from Technomatic, but there are a number of exceptions. The WD2123 and WD1770 (IC20 and IC24) are available from Pronto Electronics Systems Ltd, 466–478 Cranbrook Road, Gants Hill, Ilford, Essex IG2 6LE, tel 01–554 6222. Pronto currently offer the two chips together at a discount (the WD2123 is very expensive) and you should contact them for details. Note that there are two versions of the disc controller, the WD1770 which supports stepping rates from 6 to 30ms and the WD1772 which supports stepping rates from 2 to 6ms. Both versions will work on this board. Pronto can also supply the 68B09E (IC1) and the 68B21 (IC19).

The NEC7220a graphics controller chip is available from Semi Components Ltd, Vine House, 104 Ashley Road, Walton-on-Thames, Surrey KT12 1HP, tel 0932–241866. There are two versions of this chip, the 7220 and the 7220A. Only the 7220A will work in this design. The MC6883 SAM chip (IC2) can be obtained from Jermyn Distribution Ltd, Vestry Estate, Sevenoaks, Kent, tel 0732-450144. Note that this device is also known as the 74LS783. The transient suppressor ZD1 is an RS part, stock number 283–255. RS Components will only supply to trade and professional customers but Crewe-Allan & Company of 51 Scrutton Street, London EC2 or Trilogic Ltd of 29 Holm Lane, Bradford, will obtain parts from them on payment of a small handling charge.

The resistors and capacitors are all widely available from our advertisers and the usual mail order suppliers. Eight-resistor SIL packs are easy to obtain but seven-resistor ones are not. You can either obtain them from RS via one of the suppliers mentioned above or use eight-resistor packs and cut off one pin. The 2-22p trimmer is also an RS part but similar devices from other suppliers should prove suitable provided their pin-out matches the holes in the board. The same applies to the 3.6V NiCad battery. The basic kit, which includes the PCBs and IC3, is sold by Micro Concepts, 2 St Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel 0242 – 510525. The PCBs will not be available from our PCB Service.

● Next month's article will cover the choice of case, power supply, keyboard and monitor for use with the board and the testing and setting up of the system.

ETI

6809-BASED MICROCOMPUTER

Gary Mills discusses the choice of I/O devices and case to complete the system before going on to describe the testing and initial power-up procedures.

With assembly of the boards complete, the next step is to select and interface the appropriate input/output devices, attach a power supply, and install the complete system in a case or cases. Diagnostic test routines can then be run using the ROM monitor program.

The board can be used either with a separate keyboard and video monitor or with a serial terminal which includes both keyboard and VDU. Unless you already have such a terminal, you will probably wish to use separate devices. There is a wide range of suitable equipment to choose from.

The video monitor chosen may have either a composite video or a TTL interface. Using the composite video interface, any monitor that sinks 1 volt into 75 ohms will do. Since this is an almost universal standard, most composite video monitors can be used. Because the video resolution of the board is very high, the higher the resolution of the monitor, the better your display will look. 20MHz or over is a good figure to go for. Also, the picture will improve significantly if the video phosphor is a long persistence type, for example P39 or amber. Monitors that satisfy the requirements above include the Phillips Computer Monitor 80, No. BM7502/05 G (green) or A (amber), and the Kaga/Taxan KX1201, KX1202, and KX1203.

Pin No.	Signal
1.	Gnd
2.	TTLVID
3.	HSYNC
4.	VSYNC

Table 1 Pin connections on the TTL-Video output socket, SK8. Pin 1 is the pin nearest the composite video output socket, SK9.

Pin No.	Signal
1.	Gnd
2.	XMIT
3.	RCVE
4.	RTS
5.	CTS
7.	Gnd
11.	+5v
25.	-12v

Table 2 Pin connections on the RS232 serial ports, SK3 and SK4.

Pin No.	Inner row	Outer row
1, 2	D0	+5v
3, 4	D1	Gnd
5, 6	D2	Gnd
7, 8	D3	Gnd
9, 10	D4	Gnd
11, 12	D5	Gnd
13, 14	D6	Gnd
15, 16	nc	Gnd
17, 18	STROBE	Gnd
19, 20	RST	-12v

Table 3 Pin connections on the parallel keyboard port, SK2.

TTL video monitors can also be interfaced to the board. One of the commonest types is the IBM compatible monitor. There is a slight problem here in that the signals required (HSYNC, VSYNC and TTLVIDEO) are active high while the signals coming from the board are active low. To get around this problem, inverting buffers can be connected to the TTL video output lines. This is not available as a modification from Micro Concepts, but those who require it should not have too much difficulty sorting it out for themselves.

Keyboards

As with monitors, the 6809 board can be interfaced to a wide range of keyboards, including both parallel and TTL-serial types.

The WD2123 chip was expressly chosen because it can support serial TTL keyboards, and for greatest flexibility the RS-232 drivers were also provided. To interface a serial TTL device such as a keyboard, it is necessary to circumvent the drivers. Remove the 75189 receiver chip and replace it with a header, jumpered so that each input line connects directly to an output. When the port is required as an RS232 interface, swop back to the driver. Two serial TTL keyboards which would be suitable are the IBM Work-Alike from Diamond H Controls, Vulcan Road North, Norwich NR6 6AH, tel 0603-45291, and the GAT-0414

Pin No.	Signal
1	PA4
2	PA3
3	PA5
4	PA2
5	PA6
6	PA1
7	PA7
8	PA0
9	Gnd
10	PC7
11	PC6
12	PC5
13	PC4
14	PC0
15	+5v
16	PC1
17	PB7
18	PC2
19	PB6
20	PC3
21	PB5
22	PB0
23	PB4
24	PB1
25	PB3
26	PB2

Table 4 Pin connections on the EPROM disc board connector, SK6.

from Verospeed. Any serial keyboard used should be set to 9600 baud, eight data bits and no parity on start-up.

The second keyboard option is the parallel interface. Quite a few low cost parallel interface keybards can be found, but caution must be exercised. Make sure that the keyboard is ASCII encoded, and that it has a full set of upper and lower case letters, numbers and punctuation marks. The keyboard must provide a negative going strobe of at least one millisecond width to the board with each character.

If you are going to use a serial terminal instead of a separate keyboard and monitor, it should be set to 9600 baud, 8 data bits and no parity. The board requires RTS/CTS handshaking. If this is not available from the terminal, link the two pins together.

Power Supplies

The next piece of equipment is the power supply. There are two important considerations here, the dimensions of the power supply which must be determined in relation to the cabinet you are going to use, and the output current and number of voltage rails required. This in turn depends on whether you will also be powering your drive(s) with the same supply, whether you use the serial driver chips, and what the power requirements of your keyboard are.

The general requirements for the power supply are +5 volts at 2.5 amps, +12 volts at 2 amps, and -12 volts at 0.1 amps. This assumes that you will be powering two drives, and that you have a separate keyboard drawing a small amount of power. One supply which is suitable is the Model PRD 303 from Power Rail Electronics Ltd, tel 0582-600277. This unit is recommended for use with the Vero Total Access case used on the prototype because it fits easily within the limit the cabinet places on height.

The Case

This board does not necessarily require a case. Indeed, as we mentioned in the last issue, a prototype can be found mounted to the wall of the designer's workroom. However, a case does protect things, and it can also help to collect and organize the cables, power supply and drives.

The case pictured is from Vero and is a Total Access case type 212-8154H. To use it you will also need a chassis plate type 212-27826K. Use of this case requires that you mount the disk controller cable socket and the buss extension socket vertically. The power supply should be the one mentioned above, or should conform to the dimensions of the case. There is sufficient room available inside it to mount one 5 ¼ or two 3 ½ inch drives.

Further, a slot must be cut in the front of the cabinet to allow the EPROM disk to be installed. A connector cannot be taken out to the front of the case because the extension of the EPROM connector would create too hgh an impedance. Micro Concepts will substitute a reduced size EPROM board, in the kit if you specifically ask for it. This will fit fully within the cabinet but must be soldered on to the main board rather than socketed. In practice this only means you will have to replace EPROMs rather than replace the whole EPROM board.

The board should be mounted to the chassis plate with four standoffs. The fit is a bit snug, so make sure you mark the holes correctly before you drill.

The Total Access case is the only one we have tried using, but there is no shortage of other case designs for those who don't mind experimenting a little with mounting and connector positioning. Vero sell several larger sizes of Total Access case which would allow more flexibility in the choice of power supply, number and type of disc drives and in the use of the EPROM disc board. There are also a large number of other cases on the market which would no doubt be suitable. For those who want a really professional look, a number of manufacturers offer suites of matching cases to house processor, monitor, keyboard, disc drives and peripherals in several combinations of stacking and distributed units. One such packaging system from Vero was described briefly in a short item in last month's News Digest, and West Hyde Developments and OK Industries are among the other manufacturers who produce this type of case.

Power-Up And Testing

Assuming that you have purchased your hardware, assembled the board, tested for continuity, inserted the ICs, and connected the peripherals, the next steps are as follows.

First set the switches on SW1 to match the peripherals you have connected. The appropriate settings are shown in Table 5. Now connect power to the board. If all

Hardware	Switch Settings			
	1	2	3	4
Parallel keyboard and video monitor	off	off	off	off
Serial keyboard on Port 1 and video monitor	on	off	off	off
Serial Terminal on 1	on	on	off	off

Table 5 SW1 switch settings to select peripherals.

Pin No.	Inner row	Outer row
1, 2	Gnd	nc
3, 4	Gnd	nc
5, 6	Gnd	nc
7, 8	Gnd	Index
9, 10	Gnd	Select 0
11, 12	Gnd	Select 1
13, 14	Gnd	nc
15, 16	Gnd	Motor on
17, 18	Gnd	Direction
19, 20	Gnd	Step
21, 22	Gnd	Write data
23, 24	Gnd	Write gate
25, 26	Gnd	Track 0
27, 28	Gnd	Write prot
29, 30	Gnd	Read data
31, 32	Gnd	nc
33, 34	Gnd	nc

Table 6 Pin connections on the floppy disc port, SK5.

is well a header and a prompt will appear. The prompt should look like this

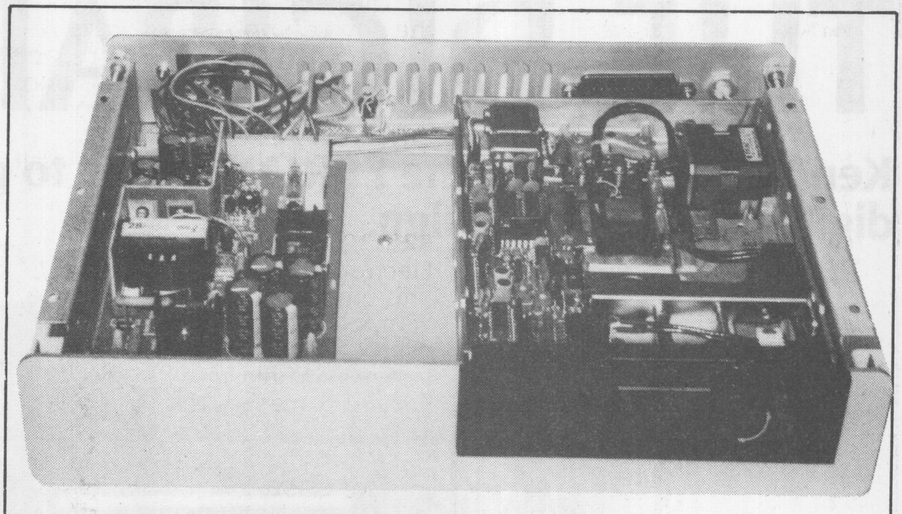
=>

Try typing a few characters. If they appear correctly on the screen, use the TM (test memory) command to test memory from 0000 to DE00. While the test is proceeding, tap the board gently. This will show up any bad solder joints.

Now switch off, disconnect all connections to the board and fit the NiCad battery. Be extremely careful not to short circuit it, as it can break open and foam over, damaging the board and making a mess. Momentarily short pin 22 of the clock chip to ground. This will cause it to load the default values into its RAM on power up.

Memory	
AD=	ASCII dump of memory
HD=	Hex dump of memory
ME=	memory examine
PM=	Poke memory with value
FM=	Fill memory with value
SM=	shift a block of memory
FI=	find ASCII string in memory
TM=	test memory
DR=	display registers
CD=	calculate displacement
Input/Output	
SI=	Set keyboard input port
SO=	set output port
SB=	set baud rate
LK=	load ASCII text from keyboard
Real Time Clock	
DC=	display contents of RTC memory
MC=	modify contents of RTC memory
Disc	
DF=	format disk
TS=	test stepping
TD=	test drive
RS=	read sector
WS=	write sector
Running Programs	
JU=	jump to program
CP=	continue program after software interrupt
RP=	run program
Flex	
BF=	boot Flex from disk
BO=	boot Flex from wherever it was last booted
JT=	jump to Flex warm start

Table 7 A list of monitor commands, arranged according to the area they serve.



An internal view of the computer showing the power supply and disc drive installed below the chassis.

Reconnect the board. If you have drives, now is the time to hook them up. They should be set for head load with motor on and the drive selected.

A further suite of routines in the monitor which can be used for testing the disk drives is listed in Table 7.

If you have got this far and have Flex, you are ready to boot it. If you don't have Flex, you can still use some of the powerful monitor commands. A list of commands is given in Table 7, each with a short description.

If there are problems with the board here are some things you might check:

are the configuration switches set correctly?

are your serial devices connected correctly?

are any of the chips getting overly hot?

do any of the address or data lines look shorted?

is the 16MHz clock being generated?

are E and Q getting to the processor?

are the DRAMS getting the correct signals?

is the MONO9 EPROM getting the correct signals?

are there any spurious interrupts?

is there a video signal?

Pin No	Inner row	Outer row
1, 2	D6	Gnd
3, 4	D7	Gnd
5, 6	D4	Gnd
7, 8	D5	Gnd
9, 10	D2	Gnd
11, 12	D3	Gnd
13, 14	D0	Gnd
15, 16	D1	Gnd
17, 18	$\overline{BUSY}$	Gnd
19, 20	$\overline{STROBE}$	Gnd

Table 8 Pin connections on the printer port, SK1.

Pin No	Inner row	Outer row
1, 2	+5v	+5v
3, 4	Gnd	Gnd
5, 6	$\overline{BA0}$	IC19 pin 6
7, 8	$\overline{BRTS}$	BA1
9, 10	BD1	BD0
11, 12	BD3	BD2
13, 14	BD5	BD4
15, 16	BD7	BD6
17, 18	BA2	BR/W
19, 20	BA4	BA3
21, 22	16MHz	BE
23, 24	WDS	Q
25, 26	$\overline{RTC}$	$\overline{LPEN}$
27, 28	$\overline{I/02}$	$\overline{RDS}$
29, 30	$\overline{I/01}$	$\overline{I/OBUFF}$
31, 32	$\overline{NMI}$	$\overline{RST}$
33, 34	$\overline{FIRQ}$	$\overline{IRQ}$
35, 36	$\overline{TTLVID}$	VSYNC
37, 38	Gnd	Gnd
39, 40	-12v	+12v

Table 9 Pin connections on the expansion bus socket, SK10.

● Next month's concluding article will discuss applications and the use of the machine and will include a list of some of the Flex software available. A basic kit for this project is available from Micro Concepts, 2 St. Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel 0242-510525. **ETI**

6809-BASED MICROCOMPUTER

Gary Mills concludes this series of articles with a discussion of the two main chips used and the software available to run on the machine.

Although the visual star of the show is the NEC7220A graphics controller, the 6809 is itself a very noteworthy chip. It was designed as a sophisticated answer to the 8080 and 8085 Intel chips, and incorporates a vastly improved set of addressing modes.

One of the most important features of the chip is the capacity to use program counter realtive addressing. This allows the programmer to generate Position Independent Code (PIC). PIC can be loaded and run anywhere in the available address space, and is easily ROMable. Both of these features are used to great advantage by operating systems which run on the 6809.

In terms of sheer speed the 6809 compares favourably with the Z80. A straight clock speed comparison is misleading because the Z80 takes an average of four clock cycles to perform instructions while the 6809 takes one. From benchmarks published in the 68XX Micro Journal, a two megahertz 6809 performs at almost exactly the same level as a 6 megahertz Z80. The 6809 in this design switches between 1 and 2 megahertz under software control.

The NEC7220A

The NEC7220A is a state-of-the-art graphics chip. While not a games chip, it has immense power for CAD applications and driving high resolution displays. It is currently used in the Epson QX10 and new QX16, and in the NEC personal computer series.

A full description of its capabilities would require several complete articles, but a brief list may help to convey the general idea:-

line and arc drawing
area fill
zoom and pan
up to four independently scrollable areas
software definable character set
resolution of 768h by 576v (in this computer)

It does all of this at the incredible drawing rate of 80 nanoseconds per pixel. To understand how fast this is, look at the four figures over the page. They can be drawn and erased on the screen in succession in under 7 seconds.

The publications listed below may be of interest to those who wish to explore in more detail the facilities offered by this chip.

uPD7220/GDC, uPD77220-1/ uPD7220-2 Graphics Display Controller
This is a fundamental document describing the chip's capacities and instruction set. However, it is terse and sparse on examples. It is published by NEC and can usually be requested when you purchase the chip, or ordered directly from them.

Product Description Graphics Display Controller uPD7220
Another NEC publication but better furnished with examples of the chip in use. It is available free-of-charge.

Application Note APN — 02 uPD 7220 Graphics Display Controller
Again from NEC, this document contains techniques and hints for programming the chip. It is available free-of-charge.

"Super Graphics Hardware from NEC"
An article by Steve Levin in BYTE magazine, April 1983. It gives a clear and concise summary of the chip's capabilities. A good introduction.

Monitor Routines Supporting Graphics

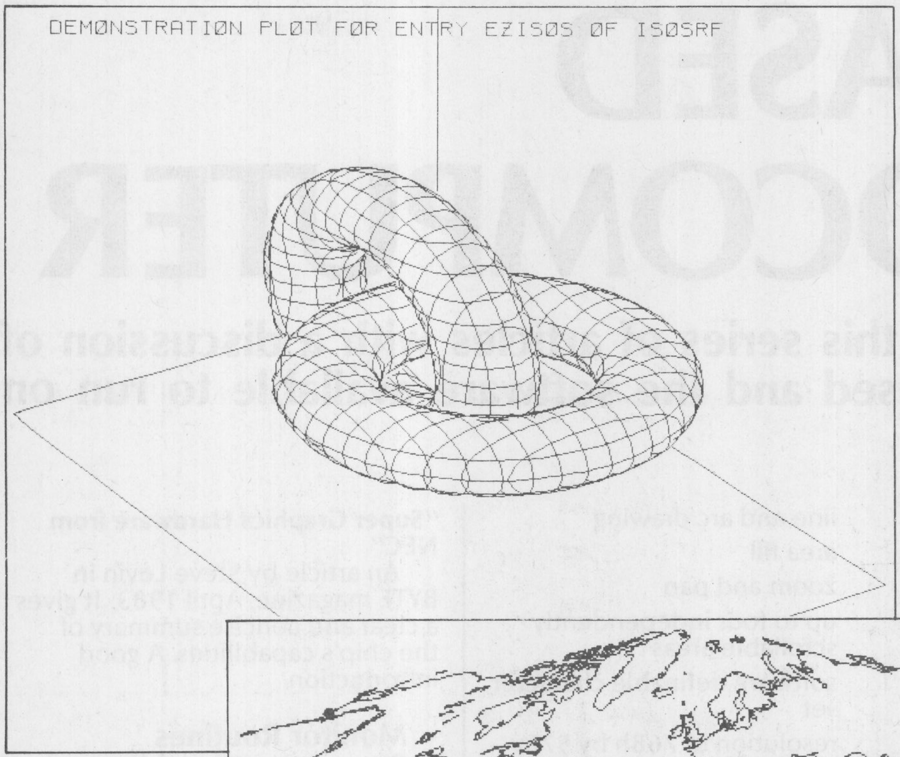
While contemplating the list of literature above, it may help to know that a great deal of work has been done for you. The kit for the project as supplied by Micro Concepts has a full set of assembly level graphics routines delivered in its firmware. They include:

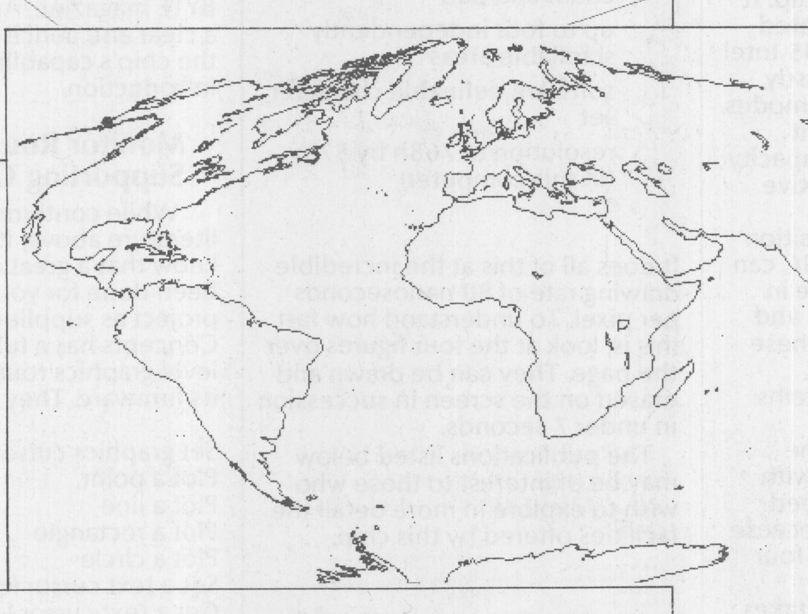
Set graphics cursor position
Plot a point
Plot a line
Plot a rectangle
Plot a circle
Set a text cursor location
Get a text cursor location
Put a character on the screen
Get or set a zoom factor
Set an area fill pattern
Fill an area

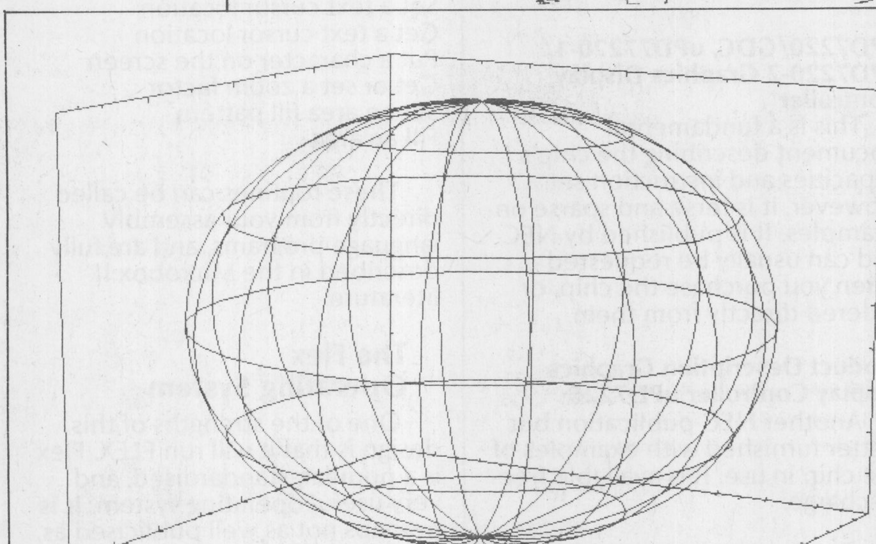
These routines can be called directly from your assembly language programs, and are fully described in the Microbox II literature.

The Flex Operating System

One of the strengths of this design is that it will run FLEX. Flex is a popular, standardised, and very useful operating system. It is perhaps not as well publicised as, for example CP/M because it has had different, less conspicuous areas of application rather than being used as a background for word processors and spreadsheets.







FLEX *can* run wordprocessors and spreadsheets (very good ones, too), but is primarily known as an engineer's operating system. It is consistently found on software development machines. Because of this there is a welter of languages, compilers, interpreters, assemblers and cross assemblers that run on FLEX, and because this machine can look like a standard FLEX machine to them, they all run on it.

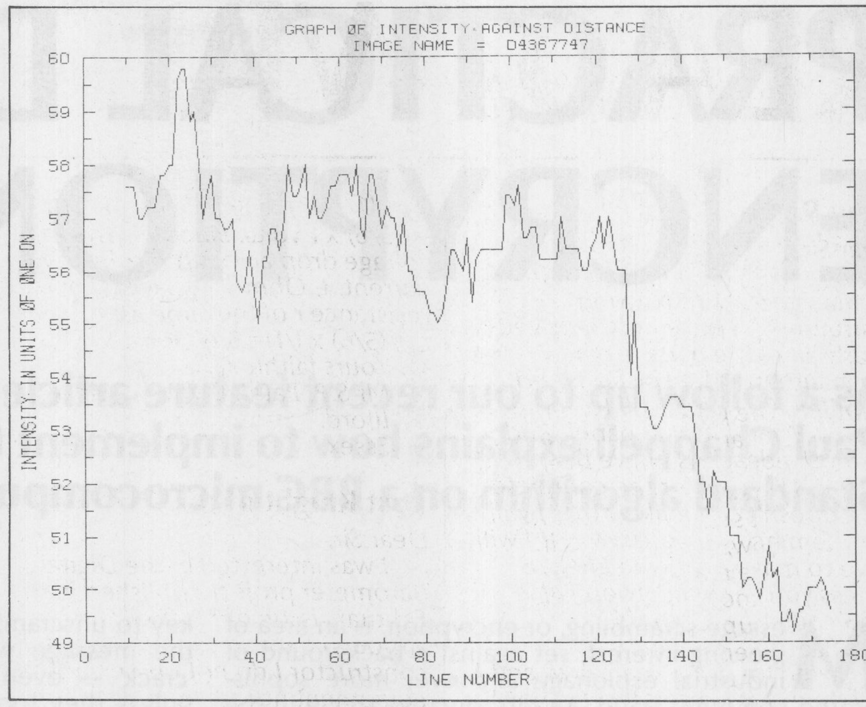
The list of languages and applications that Micro Concepts sells is representative. The high-level languages include BASIC, both interpreted and compiled, COBOL, C, Small-C, PL9, Pascal, a Pascal cross-compiler for the 68000, Forth and BCPL. Assembly language packages include cross-assemblers for just about every commercially available chip, relocating assemblers, debuggers, simulators and translators. Applications include word processors, mail merge packages, database managers, and spreadsheets.

Not only does FLEX support disk, EPROM disk and EPROM programmer in this design, but a graphics macro library compatible with FLEX's native macro-assembler is provided with the kit. Further, two of the FLEX compilers, PL9 and Small-C, have graphics libraries expressly written for this machine. Already there is a character set editor, graphics screen dump, save, and restore routines, several games and an interactive graphics package for The four figures with this article were dumped to printer using the routines above.

Another aspect of a machine or system's useability is the number of people using it, and their availability. For FLEX there are several sources of information and news. One is the "68XX Micro Journal", an American publication that can be purchased in London at Stirling Microsystems on Baker Street or subscribed to directly. There are also various Dragon and Tandy Colour Computer organs.

6809 User's Group

The 68 Micro Group is a very active user's group which includes a large number of user's who have already built this kit. They hold meetings every four weeks in London, and maintain a disk library of around 30 volumes for FLEX and the 6809. You can have access to this library as a member either at their meetings or through the mail. At the moment they have 3 full disks devoted especially to this machine including the character set editor, screen save and dump routines, and the PL9 graphics interface mentioned above. You can contact the membership secretary about joining. Jim Turner, 63 Millais Road, London E11, tel 01-558 3681.



A basic kit for this design (the Microbox II) is available from Micro Concepts, 2 St. Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel, 0242-510525.

ETI