electronics today

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BUYER'S GUIDE TO CONQUERING THE UNIVERSE:

VIDEO GAMES FROM BOTH SIDES OF THE SCREEN

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AUDIO.... COMPUTING.... MUSIC.... RADIO .... ROBOTICS

HOW IT WORKS — MAIN MEMORY

Once the data has been latched into the buffers it is transferred into the main memory by pressing the ENTER (E) key on the keypad. This provides the E and Ē signals (the latter being generated by IC5a). Several things now happen at once. IC2 is reset to '0' and the output of IC14 is set to the contents of the first buffer, IC6, which contains the light number. This forms the four least significant bits of the address for IC22, the memory IC. The seven most significant address bits are set by the scene address switches. The monostable IC1b provides a write pulse to the memory and the eight data bits from the buffer are transferred into IC22 via the tri-state bidirectional buffers IC23,24.

When the enter key is released, the tri-state buffers are set to output data from the memory to the data bus for the auto-fade units, and the memory is set to read. Nothing else is affected.

The multiplexing of the data to the individual auto-fade units during the 'replaying' of the scene information after programming is carried out by ICs 14–19. A standard clock oscillator formed by IC5b,c and their associated components has its output squared up by IC5d. The signal clocks a J-K flip-flop, IC20a, and the Q and Q̄ outputs of the flip-flop are NANDed with the signal to give alternate clock pulses at PC and DC, provided SW1 (the scene change switch) is switched to the clock. If SW1 is earthed then DC remains high. The signal PC clocks the counter IC14 and causes the lower four address lines (A0–A3) to ripple through a 16-byte block. These address lines are also decoded by IC19 (a 4-to-16 line decoder) to give a low voltage on the appropriate output. If SW1 is in the depressed position then the DC signal is clocking and the output of the NOR gate selected by IC19 will go high, ie one of the latch enables LE0–15 will go high. This causes the data on the data bus to be latched into the corresponding auto-fade unit.

Data is thus alternately fetched from the memory and sent to the appropriate fader unit as long as SW1 is not earthed. Therefore it is necessary to hold this switch depressed for at least 16 clock cycles to effect a transfer of all the data for one scene change.

The higher address lines for the memory, A4–10, are selected by two rotary switches, SW2 and SW3. One switch represents the units and the other the tens — the scene number may be set from 0 to 99. The number set is encoded to binary by the diode matrix and the appropriate bit pairs are summed by adders IC25,26.

The circuitry around Q2 is an auto battery back-up. When the console PSU is supplying power, Q2 is held on by R40,41,ZD1, and the chip select pin of the memory is held low, enabling the memory. When the console is switched off, Q2 turns off, the $\overline{CS}$ pin goes high and the memory goes to standby mode. B1 supplies the very small quiescent current required by the RAM (via D21), thus allowing the RAM to retain the data.

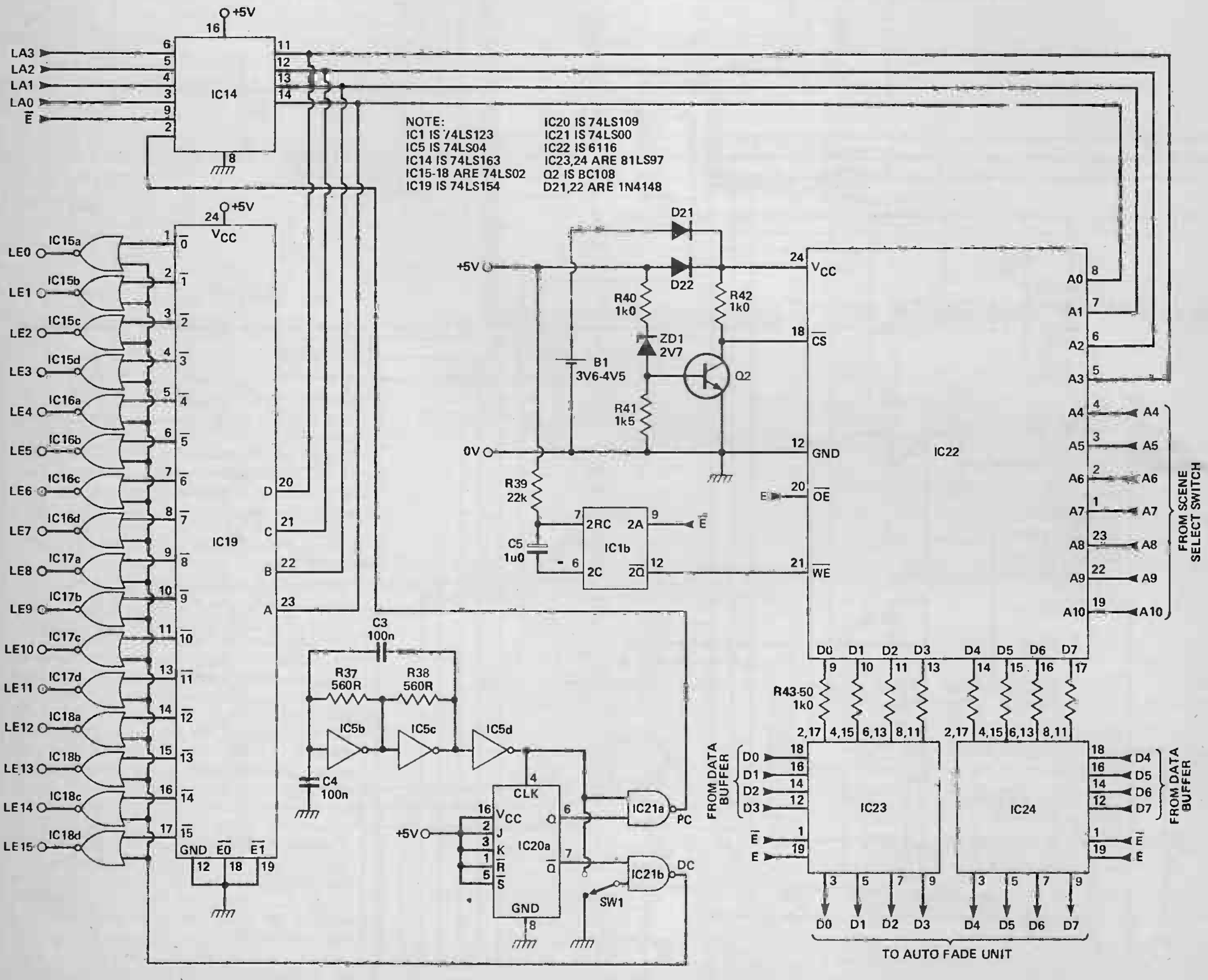


Fig. 4 Circuit diagram of the main memory section. This has an auto de-select and battery back-up system so that data is retained without mains power.

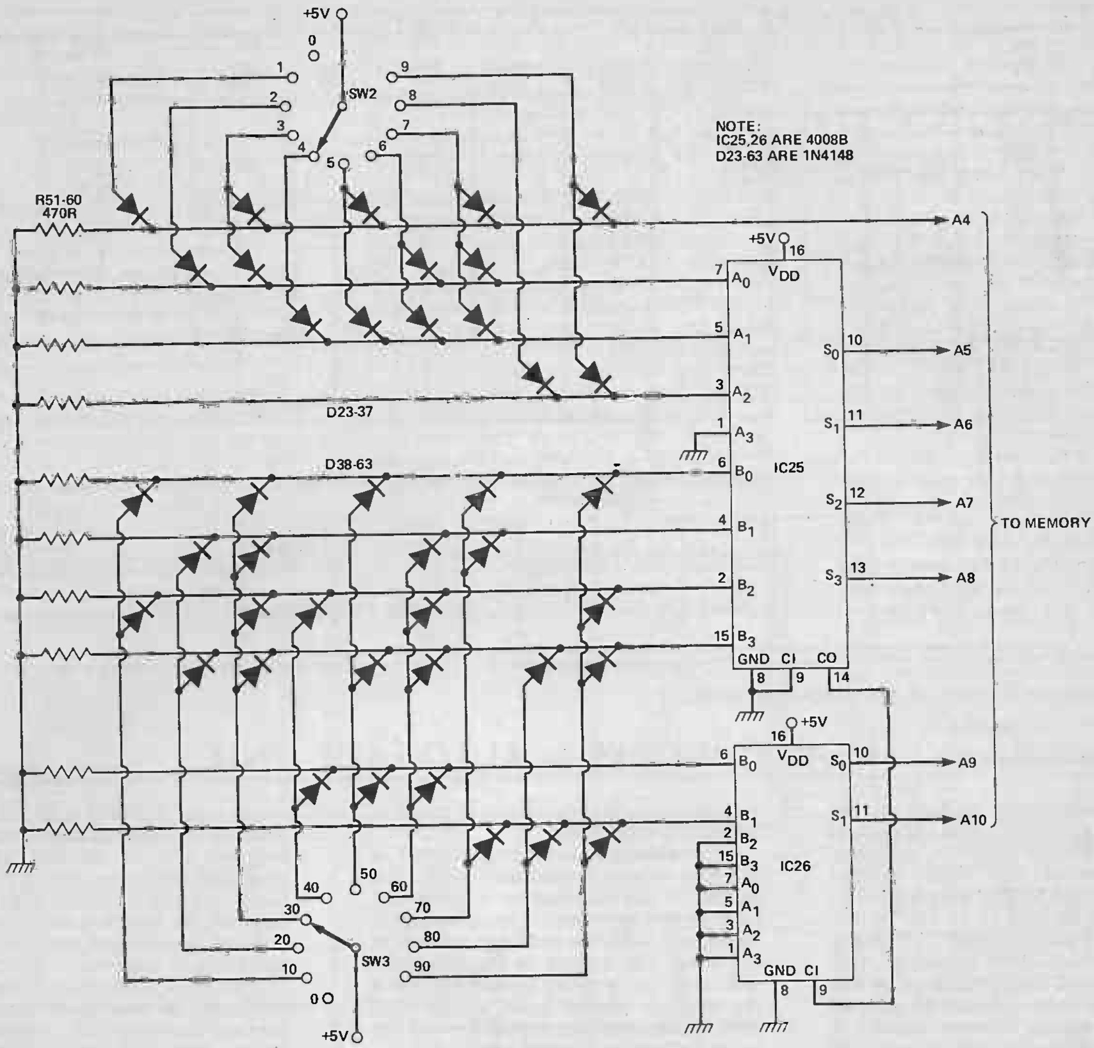


Fig. 5 Circuit diagram of the scene number selector.

be programmed from the auditorium with the stage in full view. The advantage of this arrangement is that setting-up can be done from any part of the theatre without having to lug round the main console and all its power cables, but the hand unit will require a sizeable length of multiway cable and with the prices these days we doubt whether anyone's budget will stretch that far.

The second unit contains the triac power circuits and can be permanently wall mounted with a suitable single-phase mains supply (up to 140 A may be drawn!). The pulses from the console are fed to opto-isolators in this unit and control the various lights.

The Keypad And Memory Buffer

This has eight numbered keys (0–7) plus a data entry key. A three-bit parallel code is produced along with a strobe signal. The data from the keyboard is held in a temporary buffer store whose contents are displayed on seven segment displays. The channel number to be programmed takes the first two keystrokes (any initial zeroes required must be entered) and requires four bits (00 to 17 octal). The next keystroke enters the light level (0 to 7) and the next two the fade rate (00 to 37 octal). The light number will be used as part of a memory address and the other eight bits are the data to be stored.

The Main Memory

When the enter key is pressed the data held in the buffer is placed in the main RAM and the buffer is reset. The eight data bits are stored in a memory location which depends on the light number and the scene number: the latter is set using a pair of rotary switches. The memory is structured in 16 byte blocks, each block representing one stage lighting change. The data for each light channel is stored in numerical order and is recalled in order before being latched into the autofade units. This transfer of data is activated by a single switch, which is held depressed for 16 cycles of the master clock.

The two 10-pole rotary switches which comprise the scene number switch are encoded to binary by diodes; the units and tens are then summed to give a seven-bit parallel address, the most significant bits of the address.

We've used a 6116 CMOS memory IC so that the lighting information may be retained even when the console is powered down. When this occurs the 6116 is forced into its quiescent mode and is supplied by its own private battery. The chip is automatically enabled as soon as the console is turned on again.

Auto-fade Circuits

Any number of auto-fade circuits up to a maximum of 16 may be connected to the memory module. The data for each channel for the current scene is held in an eight-bit latch/buffer. Three of the data bits are converted to a voltage

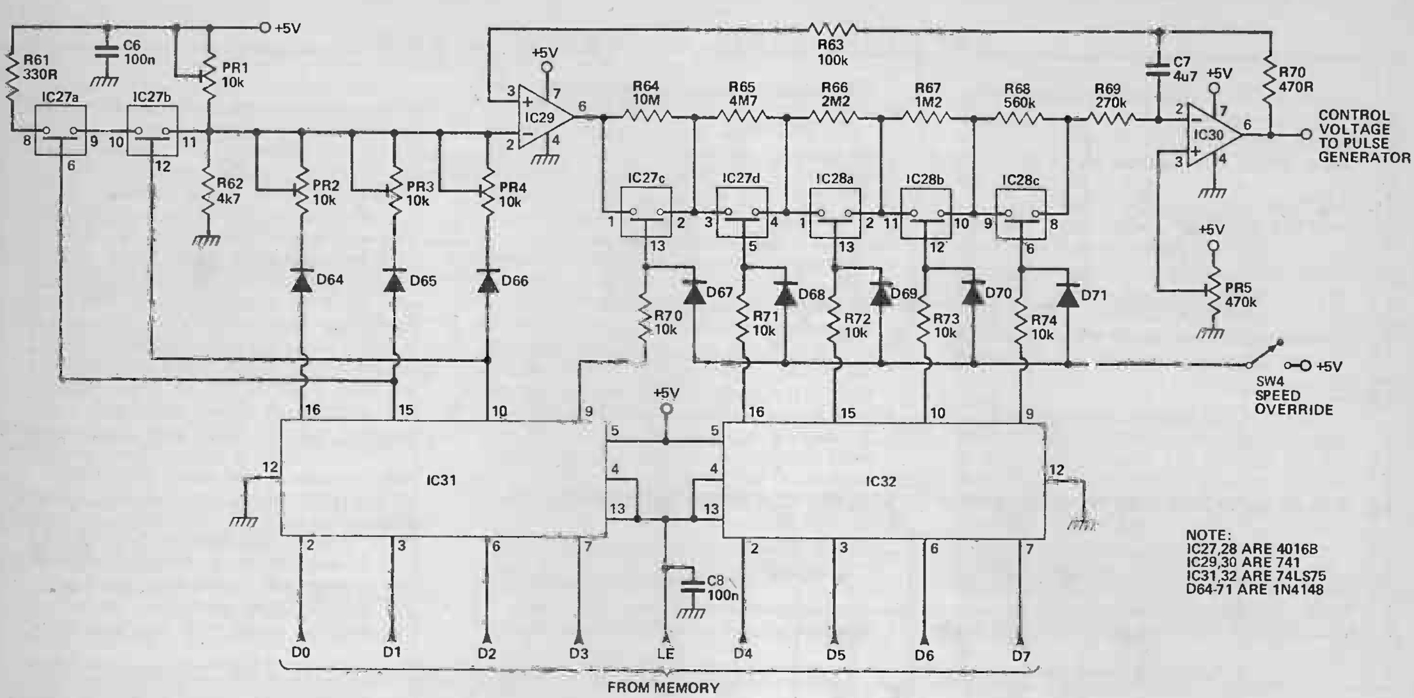


Fig. 6 Circuit diagram for one of the auto-fade units.

HOW IT WORKS — AUTO-FADE UNIT

The data buffer/latch in each of the possible 16 auto-fade units consists of two four-bit D-type bistables, and their contents control the light channel behaviour. Three of the bits from IC31 (those output on pins 16,15 and 10) are used as inputs to a digital-to-analogue converter, which gives a voltage level that controls the final brightness of the channel. With phase-switching control this voltage has to increase rapidly at low lighting levels, then more slowly and finally rapidly again. The currents from PR1-4 are fed into a low value resistor R62. To accomplish the high brightness boost, two analogue switches, IC27a,b, are used to deliver extra current into this part of the circuit when the data reads 110 or 111 (ie light levels 6 and 7). Table 1 summarises the conversion in order of increasing brightness.

The analogue voltage generated is fed to a voltage comparator, IC29. The output of this comparator is integrated by IC30 and the resulting ramp voltage is compared with the analogue voltage at the DAC. The output of the integrator will ramp up or down until it reaches a set multiple of the input voltage and then it will hunt imperceptibly until the input voltage is changed again.

Five more analogue switches (IC27c,d, IC28a,b,c) are used to control the ramp rate of the integrator depending on the data stored in the other five bits of the buffer/latch. The slowest rate is produced when all the resistors R64-69 are in series: this corresponds to a data input of 00000 octal. As the stored number increases in magnitude, various resistors will be shorted by the appropriate analogue switches and the ramp rate will increase, until for 11111 octal all the switches are closed, all the resistors are shorted and the maximum ramp rate is achieved.

PR5 gives a reference voltage for the integrator so that it will ramp up and down at the same rate. This voltage will be approximately 3V7 as the output from the voltage comparator will be either about 5 V or about 2V3.

If a high voltage is applied to the diodes D67-71, the data in the buffer will be overridden, all the analogue switches in the chain will close, and the ramp rate will increase to maximum.

which is integrated by a second circuit. The integrator ramps up or down until it reaches a level set by the input voltage, at a rate controlled by the other five bits stored in the buffer.

The actual work of regulating the power of the lights is done by the switching pulse generator: this works by sending mains-synchronised pulses to the triac power unit. The phase control is accomplished by a standard 'ramp and pedestal' UJT circuit. The ramp rate is set by the voltage from the auto-fade circuit and the sooner it reaches the pedestal trigger voltage the earlier in the mains half cycle the triac is triggered and the brighter the lamp will be.

Instead of using the auto-fade output voltage, the control for the pulse generator can come from a manually operated potentiometer, a blackout control or from an external sound-to-light or flasher circuit. Each pulse generator has its own pedestal zener diode to eliminate interaction between channels, and the pulse generators are connected to the power-controlling triacs by opto-isolators.

Triac Control Circuit

As mentioned above, opto-isolators are used for safety (the prototype has suffered a few disasters which would have melted down the whole of the control unit if these hadn't been fitted). They also allow the control unit to be earthed while the triac trigger pulse is referenced to the neutral line.

The opto-isolator transistor drives a transistor switch and amplifier that pulses the gate of the triac negative via a resistor.

Power Supplies

These may seem to be a bit over-designed but this is necessary. The first of them supplies the +5 V for the main logic and memory boards and the autofaders: two independent 5 V rails are generated in order to prevent stray pulses on the auto-fade supply doing horrible things to the memory.

The second PSU provides the supply rail for the pulse generator circuits, together with a totally unsmoothed output of about 33-36 V which is fed to the zeners in each pulse generator to produce the pedestal voltage (which drops to 0 V twice each mains cycle). The input buffer amplifier transistor can suffer from thermal drift despite the resistor values around it being chosen to minimise the problem: this results in all the light levels increasing gradually after switch-on.

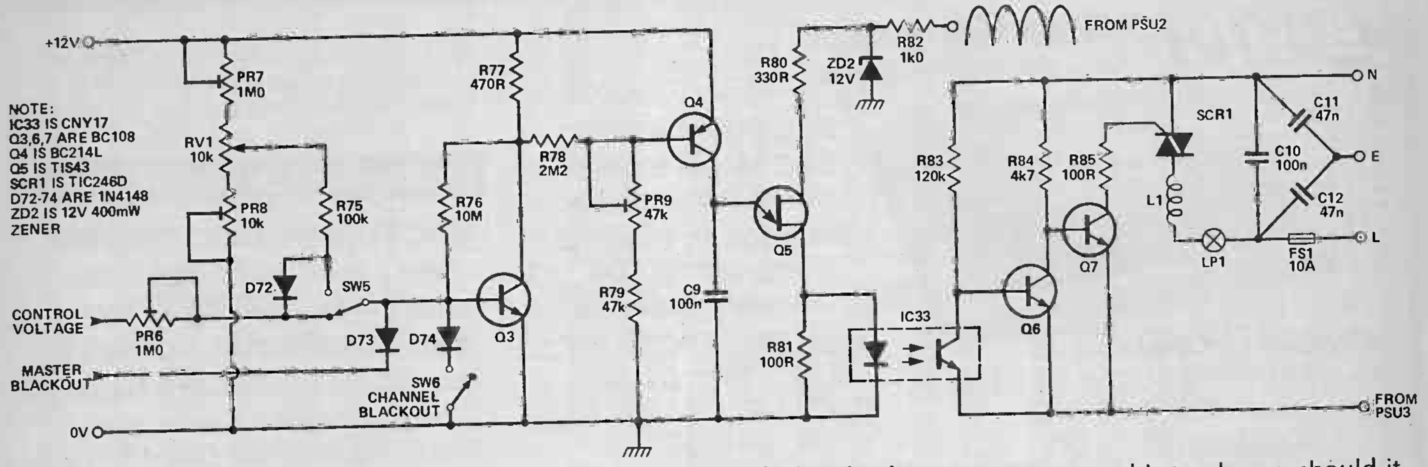


Fig. 7 Each auto-fade unit requires one of these pulse generator and triac circuits.

TABLE 1

LEVEL	CODE	CURRENT SOURCES	TYPICAL VOLTAGE
0	000	PR1	1V75
1	001	PR1,PR2	2V5
2	010	PR1,PR3	2V75
3	011	PR1,PR2,PR3	2V85
4	100	PR1,PR4	3 V
5	101	PR1,PR2,PR4	3V15
6	110	PR1,PR3,PR4,R61	4 V
7	111	PR1,PR2,PR3,PR4,R61	4V25

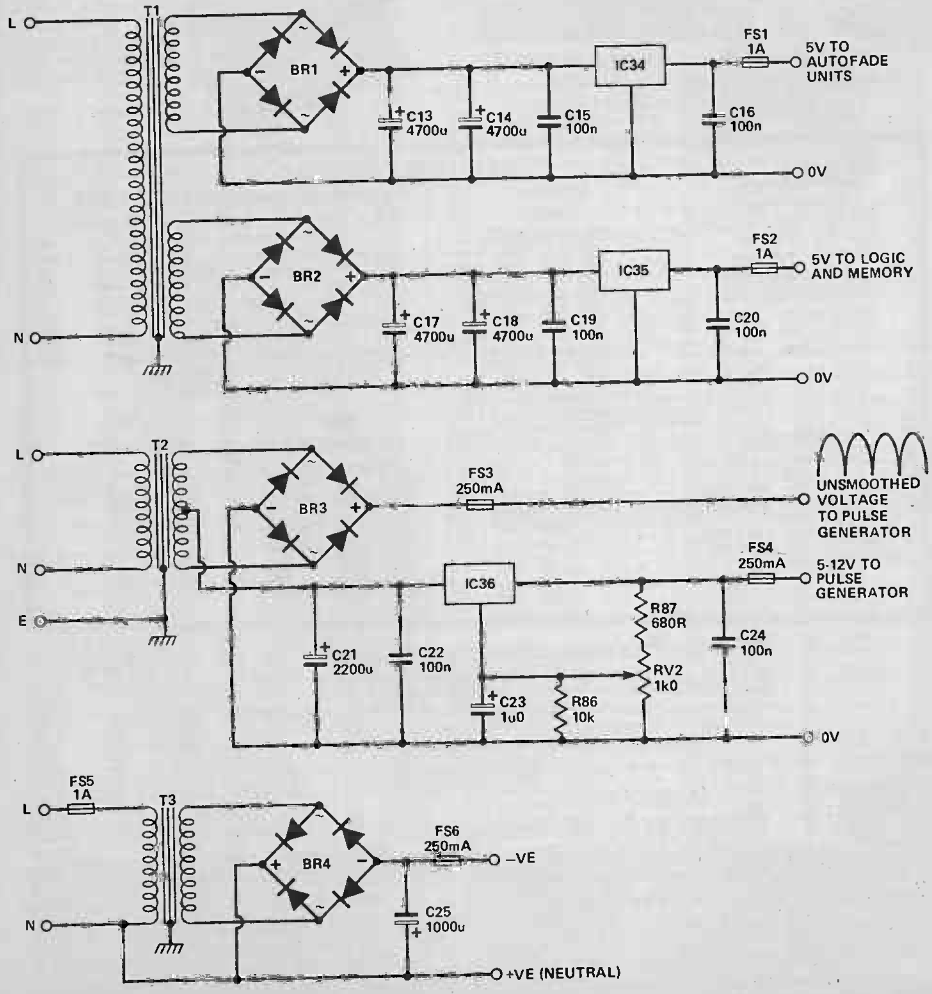


Fig. 9 Circuit diagram for the power supplies required by this project.

To correct this tendency, should it be present, the output voltage of the second PSU is made variable so that compensation may be made for any residual drift.

The third PSU is located in the triac power control unit and does not require regulation. It is capable of driving all the triac channels and has its positive rail connected to the neutral line as a reference for the triac gate.

Next month we give the constructional details of the Stage Light Dimmer.

HOW IT WORKS — PULSE GENERATOR

The input voltage to the pulse generator, either from the auto-fade unit or the manual control pot, is amplified and buffered by Q3. Q4 acts as a constant current source which charges up capacitor C9 at a rate that depends on the input voltage: PR9 and R79 set the minimum charge rate. The voltage on the emitter of the unijunction transistor Q5 will rise as C1 charges until it reaches the trigger voltage. The UJT then conducts, discharging C9 through R81 and the LED in IC33, the opto-isolator. This sends a trigger pulse to the triac. As C9 is discharged at the end of each half-cycle (when the b1/b2 voltage falls), this pulse is synchronised with the mains zero-crossing point. The delay is set by the rate at which C9 charges and hence the power level supplied to the lamp is varied.

The manual control RV1, working through D73, will override the auto-fade unit if the pot voltage is increased above the auto-fade voltage, allowing special effects. SW5 switches between auto and manual modes and SW6 can black out the channel by pulling the base of Q3 to earth. All the channels can be blacked out if the master blackout line is taken low.

When the opto-isolator is fired Q6 is switched off because its base is pulled negative. This allows Q7 to turn on, giving a negative voltage pulse via R85 to the triac gate which turns on the triac (if it isn't already on). The delta capacitor network C10-12 together with L1 help to minimise mains-borne interference caused by switching transients. A 10 A fuse affords some protection for the triac in the event of a fault occurring.

ETI

DESIGNING MICRO SYSTEMS PART 6

The previous article explained how the computer handles input and output of data but how many of us read and write in binary? This month Owen Bishop explains the operation of more user-friendly interfaces.

Quite a number of electronic circuits produce their output in analogue form, and it is beyond the ability of a computer to read such data unless it is first converted to digital form. Examples of devices with analogue outputs are electronic thermometers, pressure transducers, audio amplifiers (for speech recognition etc) and indeed any device which produces an output voltage varying over a predefined range. Even a simple carbon pot can be included in this list. The Games Controller of the Apple II, for example, uses a 150k potentiometer (there is also a push-button connected to a memory-mapped latch, but this is a digital input). The position, or setting, of the potentiometer is the analogue quantity to be measured. The computer has a quadruple timer IC and, when the Games Controller is plugged in to the computer board, the pot becomes part of the RC circuit of the timer. When the MPU is to read the setting of the Controller, it first triggers the timer (the trigger input is memory-mapped) then measures the length of pulse produced. It does this by reading the memory-mapped output over and over again, counting how many times it reads 'high' until it eventually reads a 'low'. The number of 'high' reads is approximately proportional to the angular setting of the control knob. The analogue-to-digital conversion is crude and far from linear, but certainly good enough for its intended application.

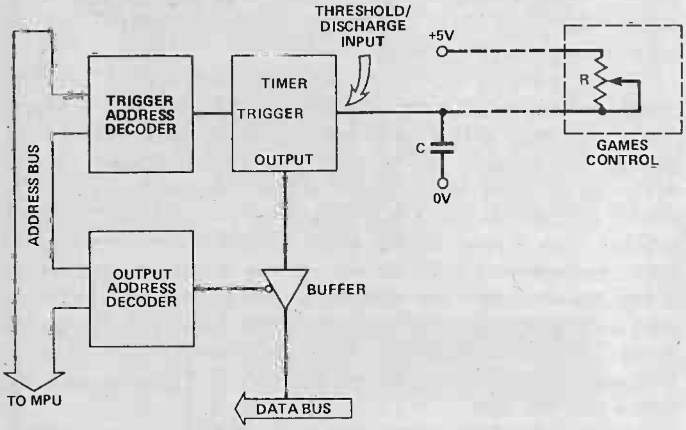


Fig. 1 Analogue-to-digital conversion for a games controller.

A-to-D Conversion . . .

Many computers have on-board A-to-D ICs such as the National Semiconductor ADC0801 (Fig. 2). This converts any input voltage in the range 0 V to 5 V to digital output in the range 0 to 255 (00 to FF in hex). The heart of the IC is a chain of resistors in series, with 5 V across the ends of the chain.

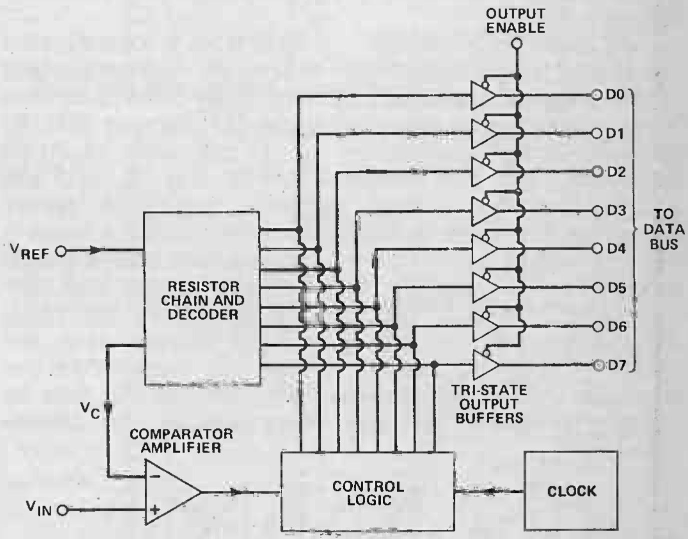


Fig. 2 Simplified block diagram of an A-to-D converter such as the ADC0801. V_{REF} is an on-chip or external reference voltage. V_C is the output voltage from the resistor chain, which is compared with V_{IN}, the analogue voltage which is to be converted.

Internal logic controls CMOS analogue switches which switch resistors into or out of the chain, so producing a voltage (V_c) which can range from 0 V to 5 V in 256 steps. At each stage a comparator matches the output of the chain against the analogue voltage (V_{IN}). The largest resistor is switched in and out first, to determine if the input is less than or greater than 2V5. Then the next largest resistor is switched in and out to narrow the possible range to within 1V25. At each stage the chain output and analogue input are matched more and more closely. After eight attempts the closest match will have been found. The logic signals which have produced the match are then used to set the eight output buffers to one of the 256 possible combinations which can be read as a byte (0 to 255) by the computer. This IC converts the voltage with true linearity, with an accuracy of half a step in 256 steps and takes only a few hundred microseconds to do so. If we want greater accuracy, there are similar A-to-D ICs with a 12-bit output. Note that it is the converter which does the work: the MPU only has to read the result. We do not need to write software to instruct the MPU to measure pulse lengths as with the Games Controller. This saves time and simplifies programming.

Most A-to-D ICs have ways of altering the span of the input range, so that voltages from, say, 0 V to 2 V produce the full-scale output range, 0 to 255. In addition you can

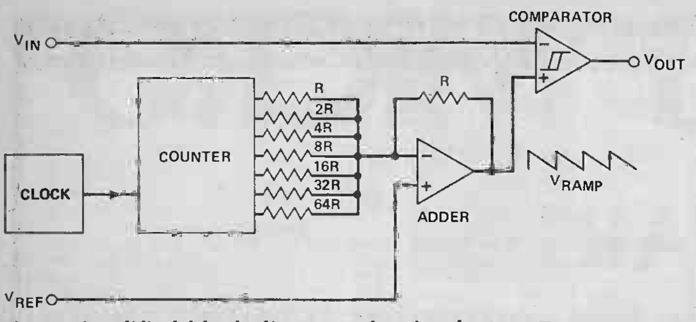


Fig. 3 Simplified block diagram of a simple A-to-D converter, the 507C. V_{REF} is an on-chip or external reference voltage. V_{IN} is the analogue voltage to the converted; V_{OUT} is the square wave output.

adjust the offset so that, for example, you obtain a reading of 0 when the input is 10 V and reading of 255 when the output is 12 V.

As might be expected, a A-to-D IC is a sophisticated circuit and is correspondingly expensive. If an application requires several analogue inputs and high conversion time is not of paramount importance, the inexpensive 507C IC provides linear conversion in 1 mS with seven-bit resolution. This has a resistor ladder (Fig. 3), and the counter supplies current to each resistor in binary sequence. The op-amp adds the currents and the result is that the output ramps down a voltage from 0.75 x supply voltage to 0.25 x supply. If the enable input is high, the comparator gives a high output whenever the ramp voltage exceeds the analogue input voltage: thus the length of time the output is low is a measure of the analogue voltage (Fig. 4). The MPU can find this time by using a program like that described for the Games Controller.

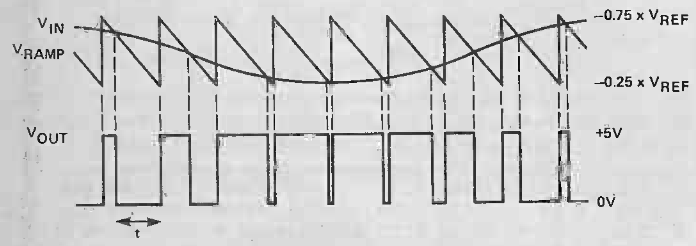


Fig. 4 The input and output voltages of the 507C A-to-D converter. The computer measures t, which is proportional to V_{IN}.

. . . And The Converse Conversion

If a peripheral needs an analogue signal to control it (eg controlling the speed of a motor), we need circuits which can convert the digital output of the computer into its analogue equivalent.

The ZN425 D-to-A converter makes use of an R-2R ladder (Fig. 5). The switches are under the logical control of the eight-bit input. As the count increases, the output voltage increases in proportion (see panel). To drive a low impedance device the output must be buffered by an operational amplifier.

This IC may also be used for A-to-D conversion, using its binary counter. The counter is clocked by an external pulse generator, and as it counts the pulses, switches controlling the R-2R ladder are closed and opened in a binary sequence. The output is a staircase ramp of 256 steps. An external amplifier compares the output from the ladder with the analogue voltage which is to be converted. When the ramp output equals the analogue voltage, the output from the amplifier inhibits the clock. At this point the logic output which controls the switches can be read as an eight-bit equivalent of the analogue input.

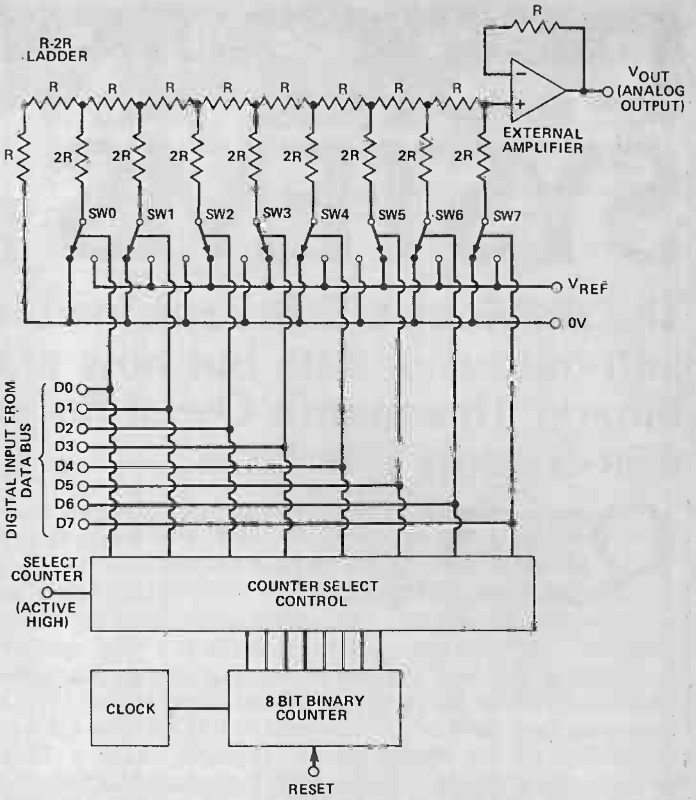


Fig. 5 Block diagram of the ZN425E D-to-A converter. V_{REF} is an on-chip or external reference voltage. The amplifier is not on the chip but is an external op-amp (eg 741).

Screens And Printers

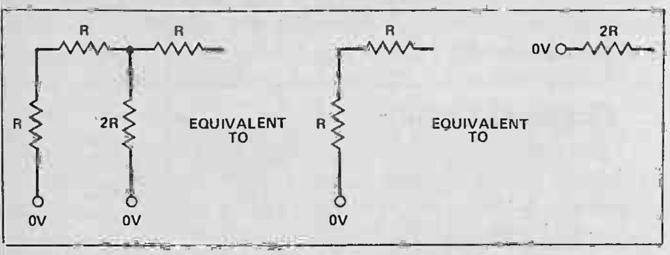
The way most owners receive information from their micros is through the screen. This may be a domestic TV set or a monitor unit specially designed for the purpose. Those whose main interest lies in arcade games, adventures, and the like usually need no more than the screen, but anyone with an interest in programming soon finds that the screen alone is not enough. There is the tedium of copying long listings of favourite programs from the screen, and the frustration of being able to see only a few lines of program at any one time. Sooner or later, the serious programmer adds a printer to the system. This month we shall deal with both these ways of receiving information from the micro.

The fact that the technology of high-speed (for the time) printing was already available in the form of teletype machines, lead to the early mainframe computers having a printer but usually no screen. We are reminded of this early use of teletypes by some of the curious control codes which abound in the ASCII character set (see last month's article). The screen of the early mainframe computers, if any, was often a CRT in which the X and Y deflection plates were under the direct control of the computer. It was a kind of high-grade oscilloscope, with the computer using the electron beam to 'draw' an image on the screen. This was suitable for displaying charts and graphs, but not much use for text.

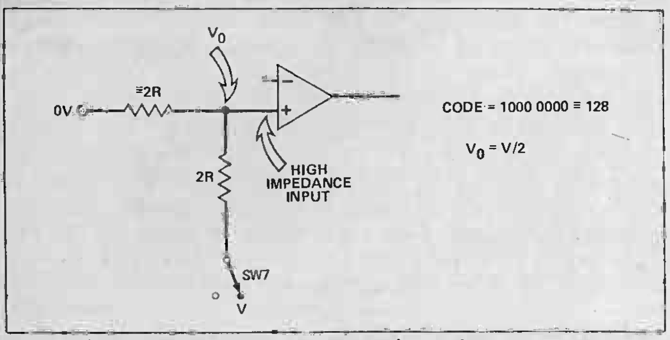
With a modern computer, the electron beam scans a rectangular area on the end of the CRT, in the same way as a TV set. The field (or **raster**) consists of a large number of horizontal lines (the number varies according to the system) placed close together (Fig. 6). Each line is scanned in turn, from the top to the bottom of the screen. Most TV systems have an interlaced raster in which the beam first scans alternate lines down the screen and then returns to scan the ones between the first set. As the beam scans, its intensity (and hence the brightness of the glow produced

HOW THE R-2R LADDER WORKS

Assume all switches are set to 0 V. The three left-hand resistors are equal to 2R and 2R in parallel, and so can be replaced by a single R resistor. Thus the four resistors shown are equivalent to 2R switched to 0 V. We can carry this reasoning all along the ladder, until we reach a switch that is not set to 0 V.



If all except SW7 are set to 0 V, and SW7 is set to V (the reference voltage), we can consider all resistors to the left as equivalent to a single 2R resistor, switched to 0 V. We have a potential-divider, and $V_o = V/2$. This corresponds to the expected output, since $128/256 = 1/2$.



If all except SW6 are set to 0 V and SW6 is set to V, we can consider all resistors to the left to be replaced by a single 2R resistor, switched to 0 V.

$$I_o = V/3R; \quad I_1 = (V - V_1)/2R; \quad I_2 = V_1/2R$$

By Kirchoff's Law (sum of currents entering a point must equal sum of currents leaving a point):

$$I_o = I_1 - I_2, \text{ so}$$

$$V_1/3R = (V - V_1)/2R - V_1/2R, \text{ giving}$$

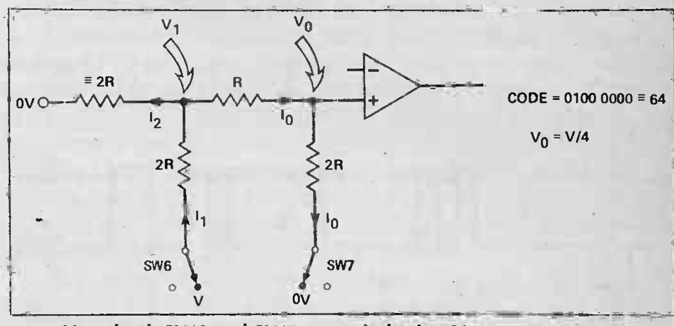
$$2V_1 = 3V - 3V_1 - 3V_1$$

$$V_1 = 3V/8$$

Now we can calculate V_o:

$$V_o = 2V_1/3 = V/4$$

This corresponds to what is expected since $64/256 = 1/4$.



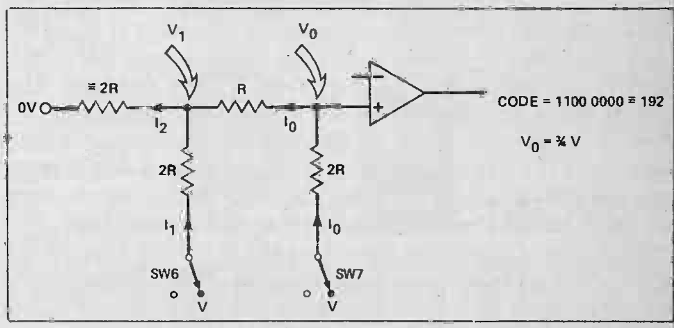
Here both SW6 and SW7 are switched to V.

$$I_o = (V - V_1)/3R \text{ but } I_1 \text{ and } I_2 \text{ are as above.}$$

$$I_2 = I_o + I_1, \text{ so}$$

$$V_1/2R = (V - V_1)/2R + (V - V_1)/3R,$$

which simplifies to $V_1 = 5V/8$.
Now $V_o = V_1 + (V - V_1)/3 = 5V/8 + V/8 = 3V/4$.
This is what we expect, since $192/256 = 3/4$.



This kind of reasoning can be repeated all along the chain, getting more and more complicated, but with the same kind of result. If all the switches are set to V, the maximum V_o is obtained, ie 255/256V.

on the screen) is modulated. If the beam is strongly modulated, so that it produces either bright light or none, we can use it to produce a textual display of good contrast. Fig. 7 shows how a line of text can be built up from dots of light in seven successive scans. These are followed by a number of lines in which the beam is blanked (off) to provide spacing between rows of text. This process is repeated all the way down the screen.

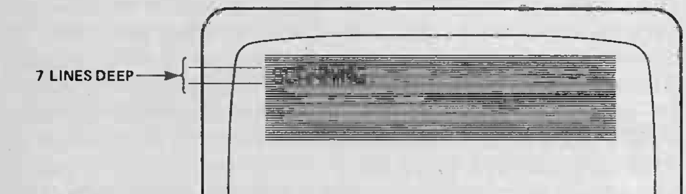


Fig. 6 How text is displayed on a TV screen.

As Fig. 7 shows, it is possible to build up well-defined alphabetic characters from a 7×5 matrix of dots. Numeric characters, punctuation marks and various other symbols can also built up in this way. We will now look in more detail at what the computer has to do in order to produce such a display. Visual displays are a field in which microcomputer designers have felt themselves free to use their inventiveness. Consequently, there are almost as many ways of producing the display as there are makes of microcomputer. Our discussion will therefore deal only with the main principles which are common to most micros.

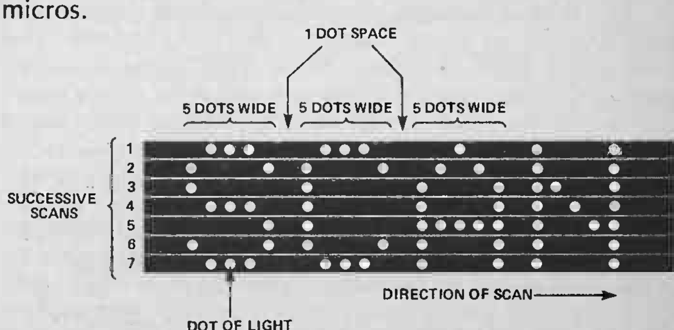


Fig. 7 Enlarged view of the first few letters shown in Fig. 6.

The Writing's On The Screen . . .

Figure 8 shows the signal which is fed to the grid of the CRT to modulate the beam to produce scan 5 of Fig. 7. The length of a single dot-producing pulse is of the order of 15 uS. This waveform is produced by a circuit like that shown as a block diagram in Fig. 9. Most micros have what is termed a **memory-mapped display**. A certain block of memory addresses is set aside for holding the text. Normally it requires one byte of data for each character. For example, if the screen has 16 lines, with 64 characters per line, the memory area must consist of 1024 bytes, or 1 kilobyte. Whenever text is to be displayed, the CPU stores the ASCII codes corresponding to each character in the appropriate memory cell.

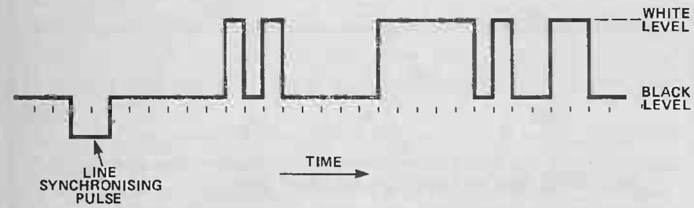


Fig. 8 The signal required to produce the fifth scan of Fig. 7.

The **video RAM**, as this section of memory is usually called, is read in sequence by the video circuitry. Although video RAM can be addressed by the MPU like any other part of RAM, in some micros it has its own control signals and its own data bus to connect it with the video circuit. For most of the time it operates independently of the microprocessor. The ASCII code for each character in turn is transferred to the data latch. It is held there while the next code is being fetched. The output from the latch goes to a **character generator** IC. This is a special kind of ROM (see Designing Micro Systems, ETI October 1982) which converts an ASCII code into the corresponding pattern of dots. It has inputs from the latch to tell it which character is to be generated, and from the synchronising circuit to tell it which one of the seven lines of dots is to be generated. It has five outputs that indicate which dots are to be displayed as white and which will be black.

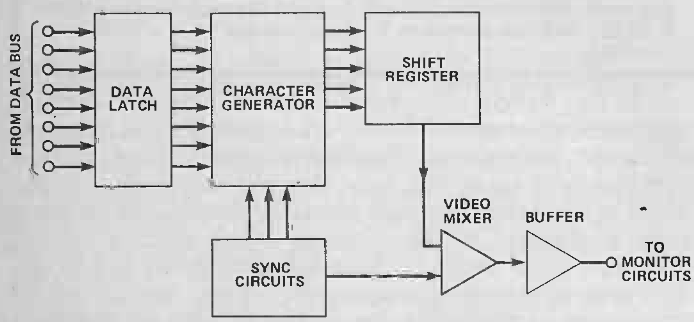


Fig. 9 Block diagram of the circuit for displaying text.

The output from the character generator is converted from parallel to serial form by the shift register. This produces a train of pulses, some high, some low, like those shown in Fig. 8. These are fed to a video mixer circuit where line synchronising pulses and frame synchronising pulses are added. The combined video signal is then passed through a buffer circuit to the monitor.

Such a signal is not suitable for sending to a domestic TV set. The TV is expecting a UHF carrier signal from an aerial, modulated by the video signal. So, if a TV is being used, the signal from the video mixer must first go to a modulator. This produces a UHF carrier signal (usually on Channel 36) with the video signal imposed on to it. When the TV receives this signal it demodulates it, recovering the original video signal that it then uses to produce the display. The additional processes of modulation and demodulation inevitably lead to distortion; consequently, the resolution obtainable on a TV is inferior to that obtained on a proper monitor screen. A TV is acceptable when there are 40 or fewer characters per line, but when there are 60 characters or more the use of a monitor is much to be preferred.

Graphics Galore

The variety in methods of producing textual displays is exceeded by the variety of techniques used for producing graphics. A few micros (eg ZX81 and PET) use the character generator to produce geometrical shapes and other designs and symbols. These can be combined on the screen to produce designs of almost infinite complexity. This technique exploits one of the useful features of character generators: they can be programmed to produce any or all of the possible patterns on a 5×7 (or larger) matrix. For example, we can have them programmed for different styles of letter or for special letters for different languages. There 2^{35} permutations of dots, far more than can be accommodated within a single IC, so the snag of this method is that the user is limited to the range of symbols selected by the manufacturer. If you are writing programs for playing Bridge or Blackjack, the hearts and clubs symbols will be useful but, if your interests lie in cash account programs, they are a waste of space on the chip.

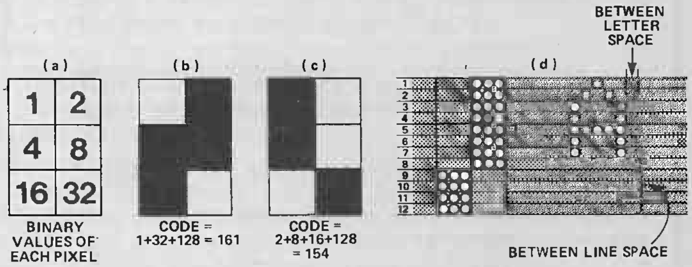


Fig. 10 Graphics blocks, as used in the TRS-80 Model I. (a) Each pixel has the binary value shown. (b) and (c) The sum of values of 'on' blocks plus 128 gives the code. (d) How a block is displayed by scanning (letter A for comparison of sizes). The blocks are displayed on a 6 × 12 matrix, leaving no space between adjacent blocks.

Many computers use graphics blocks (Fig. 10) as a means of constructing displays. A block may consist of six sub-blocks (or **pixels**, which is the name used for picture elements). Designing displays by this method involves interpreting your picture six blocks at a time and programming the computer with the corresponding code. The codes are stored in video RAM, as with text. Separate circuits are used in place of the character generator to convert the code to the corresponding set of video signals and feed them to the shift register. If the designs required are regular (such as decorative borders), programming is simple but it becomes very time-consuming if you want to draw complicated pictures.

A third approach to graphics is to deal with each pixel separately, and allocate one bit in video RAM to each pixel. If the value of the bit is '0', the corresponding pixel is 'off' (black screen). If it is '1', the pixel is 'on' (white screen). A medium-resolution graphics display, for example MODE 5 on the BBC Microcomputer, has 256 lines, each with 160 pixels. This gives a total of 40960 pixels. Allotting one bit per pixel, the video RAM must provide 5 kilobytes. If the display is to be in colour, an additional 5K bytes are required to indicate colour information for four colours, or an additional 15K for 16 colours. With the high-resolution display on the BBC Microcomputer (MODE 0) there are 640 pixels per line, requiring 20K, but allowing for only two colours. It can be seen that high resolution graphics, and particularly high-resolution *colour* graphics, require a very extensive video RAM. The cost of RAM has fallen in recent years, making it feasible to provide micros with good high-resolution colour graphics at relatively low cost. But, unless special 'paging' address circuitry is introduced, a micro with a 16-bit address bus is limited to 64K of memory, into which ROM, program RAM and the video RAM must be fitted. Consequently, an increase in the size of the video RAM means a decrease in the address space left for program RAM. If video RAM is physically a section of RAM itself, instead of being a separate entity as in some micros (see above), this section of RAM can be used for video when a program is to have plenty of graphics in colour, but can be turned over to program or data storage when graphics are not required. This is the system generally adopted in micros with high resolution graphics.

A Colourful PAL

In the PAL system of colour television, used in most European countries, colour transformation is transmitted by modulating the luminance (brightness signal) with a very high frequency chrominance (colour) signal. The way in which the chrominance signal is derived and subsequently decoded in the TV set is too complex to go into here. The final result is that three separate signals are derived to control the red, green and blue guns of the colour tube.

The output from a computer to an RGB colour monitor consists of four signals, on separate lines. The 'sync' signal provides the pulses needed for synchronising scanning with the reading of video RAM. The other three signals (R, G and B) control the three electron guns of the colour tube. Whenever there is a pulse on R, a red dot is produced on the screen. Whenever there is a pulse on G, we obtain a green dot. In either case only one kind of phosphor (red or green) is made to glow. If there are pulses on R and G at the same time, both electron guns are activated. A red dot and a green dot are produced in the same region of the screen. From the normal viewing distance it appears that there is a yellow dot on the screen. All colours are produced by mixing red, green and blue in various combinations and proportions.

The availability of separate signals for the red, green and blue guns means that excellent colour rendering with full saturation may be readily obtained on an RBG monitor. For those who wish to use a domestic colour TV, micros with colour graphics usually have a TV output. In the video mixer circuit the RGB signals are combined with the luminance signal before modulation and the composite signal is sent to the TV set. As with monochrome TVs, losses of signal quality occurring during demodulation and decoding mean that resolution and colour rendering is not as good as with a monitor.

High resolution colour graphics can give an intricate picture but, with so many pixels to be individually dealt with, one might think that programming would be too laborious for the average user. In fact, high resolution graphics may be easier to handle than the graphics blocks or generated characters described earlier. Since there is only one shape (a dot) instead of dozens or hundreds, we avoid the need to specify which shape is to be displayed. Since each pixel can be specified solely by its X and Y coordinates of the screen, the basis of pixel graphics is mathematical and it lends itself readily to mathematical treatment. It is easy to write routines for drawing lines, circles, or triangles, and for filling in areas with solid colour. The high-level language may include commands such as DRAW, PLOT, and CIRCLE, which perform these functions automatically, leaving the user to supply only the parameters. Graphs, bar charts, clock faces and all kinds of designs which are composed of reasonably simple geometrical shapes can be programmed in a few lines.

Getting Into Print

Controlling a printer is very different from controlling a monitor or TV. When controlling a monitor, the computer is responsible for all the timing and signal generation. The monitor merely transfers this signal to the screen as a raster of lines, varying in brightness along their length. Once the data has been transmitted, there are no further problems for the computer, for the monitor is able to work fast. The signals it receives are almost immediately translated into a pattern on the screen.

A printer takes a much larger share of the work on itself. The computer simply tells the printer which letter is to be printed next. Then the printer works out how and where to print the letter, or when to feed the paper on to print the next line. It can even organise itself to save time by printing alternate lines from right to left! In order to do this the printer needs an elaborate logic circuit. This may often include a microprocessor specially devoted to managing its activities. If the printer is of the dot-matrix type, it also needs a character generator to tell it which combinations of printing needles to fire at the ribbon (Fig. 11).

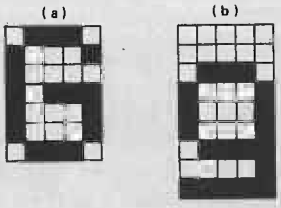


Fig. 11 Dot-matrix printers use a matrix of printing needles. If a needle is fired it hits the ribbon and makes a dot on the paper. In (a) a capital G is produced on a 5 x 7 matrix. In (b) a lower-case g is produced with a tail beneath it using a 5 x 9 matrix. In general, printers with few rows are not able to offer descenders like this.

The main disadvantage of a printer compared with a screen is that it deals with data much more slowly. There is a physical limit on how rapidly we can accelerate and then decelerate the appreciable mass of the print head (be it a matrix of needles or a daisywheel) and the rollers or sprockets which feed the paper to it. By contrast, the beam

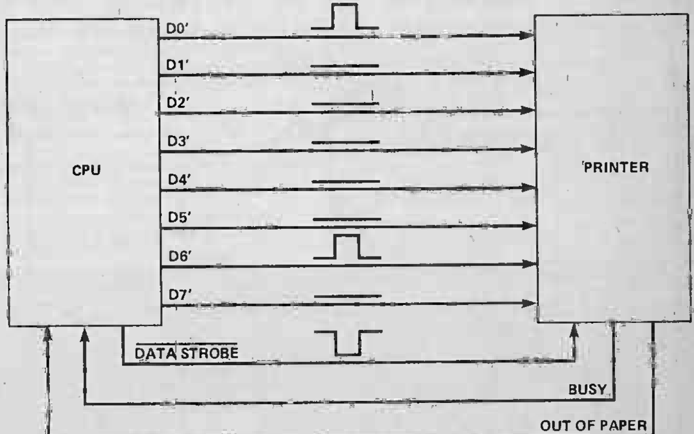


Fig. 12 Parallel data transfer between computer and printer.

of electrons in a CRT is virtually massless and can be directed and modulated almost instantly.

There are two main ways in which a computer and printer may be connected. The parallel transfer of data is illustrated in Fig. 12. An example of this system is the Centronics interface, originally devised by manufacturers of Centronics printers but now adopted by many other manufacturers. The first point to note is that there is two-way communication, in contrast with the one-way communication between computer and monitor. This is a consequence of the relatively slow speed of a printer. A computer can instruct a printer far faster than the printer can print. Rather than have the computer waste its valuable time waiting for the printer to operate letter by letter, we let the computer send a long string of commands to the printer in rapid succession. Since there are eight data lines, the computer can send a byte at a time. This is normally the ASCII code for the letter required. The printer can also interpret ASCII control characters for operations such as line feed (LF) and carriage return (CR). Whenever the computer is outputting data it makes the $\overline{\text{DATA STROBE}}$ line low. this has the same function as the $\overline{\text{WR}}$ control line used internally, and is derived almost directly from it. Similarly, the data lines are separated from the data bus of the computer only by latches, which hold the data long enough for the printer to be able to receive it. In some micros a general-purpose I/O device is used for this purpose (see Designing Micro Systems, ETI December 1982).

The I/O device or the buffers leading to the printer data lines need only one decoding circuit to enable them. Thus a printer needs to have only one address in RAM allocated to it. In comparison with the video screen, the printer makes minimal demands!

Printer Buffer

When data is received by the printer it is stored in a small RAM, called the **holder buffer**. This holds the codes for about 80 characters (maybe more), which is enough to print one line of text. It stores codes as they come in, then reads out codes previously stored and prints the characters they represent. When the computer sends a long string of codes the buffer is likely to become full. Also the printer has occasionally to stop printing to move on the paper to the next line. Again, codes will accumulate in the buffer. At this stage the printer puts a signal on the BUSY line. The effect of this is to interrupt the computer and make it stop sending any more data. When the printer has printed all that it has stored and its buffer is empty, the BUSY signal is taken off the line and the computer is free to send the next batch of data. On some interfaces there is also an acknowledge line ($\overline{\text{ACK}}$), a handshaking line by which the printer informs the computer that it has done whatever it was told to do and is awaiting fresh instructions. There may be an OUT OF PAPER line for signalling this fact to the computer. The level on this line is usually controlled by a micro-switch connected to a lever which is in contact with the paper. An OUT OF PAPER signal causes the computer to send no more data until the normal level is restored.

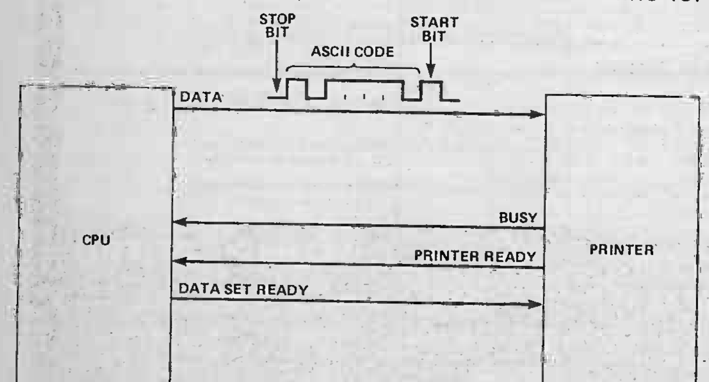


Fig. 13 Serial transfer of data between computer and printer.

Are You Being Serialed?

The alternative way of sending data to a printer is to transmit a series of pulses along a single line. This has obvious advantages in that only a single data line is required instead of eight. The most frequently used system of serial data transfer is known as the RS232C standard. The standard specifies voltage levels and rates of data transfer and the system to be used for coding the data. The standard also covers the types of connector to be used so that any pair of devices employing RS232C may be coupled together and expected to communicate reliably.

In Fig. 12 the pulses drawn above the parallel data lines indicate that the computer is sending 0100 0001 (or 65 decimal, the ASCII code for 'A'). In Fig. 13 the same ASCII code is being sent serially along one data line. Sending eight bits one after another is obviously slower than sending them in parallel, a byte at a time, as in Fig. 12, but since printers are relatively slow this is not a great disadvantage.

There are various ICs available for converting parallel data to serial data. A simple parallel-in-serial-out (PISO) shift register such as the 74LS166 will do the job, but ICs specially designed for computers do it better. A universal asynchronous receiver transmitter (UART) is an example of such an IC. This provides two-way communication, being able to receive parallel data from the CPU and transmit it as serial data, and to receive serial data from a peripheral and pass it to the CPU as parallel data. The latter function is not required for use with a printer, but would be used, for example, when two computers are required to communicate with each other. Not only does the UART convert from parallel to serial (or the other way about) but it takes the parallel data, makes it into a train of eight pulses, and adds a 'start' pulse and a 'stop' pulse to the beginning and end of the train.

Correcting The Errors

Since it requires only one data line, serial data transmission is suited for long distance. Parallel data transmission is rarely used under such circumstances. The longer the line, the greater the chance of stray electromagnetic interference finding its way on to the line and into the data receiving circuit. This is why the train of pulses often includes an extra pulse known as the **parity bit**. The idea of this is to allow the receiving device to check that no spurious pulse has been added as a result of interference during transmission. The parity bit is calculated by the UART before the data is transmitted, and is added to the end of the train of data pulses, then followed by the stop bit or bits. The value to be given to the parity bit is found by counting how many 1s are present in the data. If the number is even, the parity bit is made 1, so the total number of 1s becomes odd. If the number of 1s in the data is already odd, the parity bit is made 0, so retaining the odd number of 1s. At the receiving end the UART simply has to count the number of 1s in the train. If it is odd, all is well and it then sends on the train (minus the parity bit) to be decoded. If the number of 1s is even, a transmission error has occurred and the device or its operator can be alerted. This system is not absolutely error-proof for two errors could occur which would be self-cancelling. However, if the average rate of error is, say 1 in 100,000 bits on any occasion, the chance of two errors occurring on that occasion is 1 in

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FEATURES

PROJECTS

INFORMATION

10,000,000,000 bits, which can be fairly safely disregarded.

The system described above is known as **odd parity**. It is also possible to work with **even parity**, in which the parity bit makes up the 1s to an even number. Most UARTs can be programmed to deal with either type of parity.

It's Your Timing That's Crucial

Figure 10 shows the train of pulses required to transmit the ASCII code for 'A serially. It includes an even parity bit. The voltage level specified for signalling 0 is +3 V or more, while the level for 1 is any voltage lower than −3 V. The interval between successive *groups* of pulses can be as long as necessary. The receiver waits until a start bit arrives and then decodes the nine or so bits which follow. There is no interval between successive pulses. The sequence of five 0s, for example, is received as one long high pulse. It follows that the transmitter and receiver must both have a method of timing the duration of pulses. Both circuits have oscillators or clocks built in to them to fix the rate at which they work. When two devices are coupled both clocks must operate at the same frequency. To assist standardisation, a number of frequencies have been selected for use with RS232C interfaces.

The rate of transmission of data is expressed in **baud**. This unit, named after a French engineer, J. M. E. Baudot, is equal to the number of bits transmitted per second. Standard rates are 110, 150, 300, 600, 1200, 2400, 4800, 9600 and 19200 baud, though the higher ones are not included in the RS232C standard. To simplify circuit design there are baud rate generator ICs. These are driven by a high frequency crystal oscillator circuit; the high

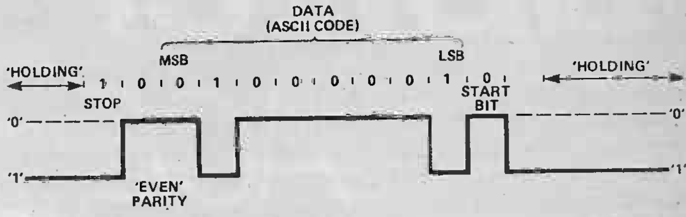


Fig. 14 The waveform of a serial signal (see text). There may be one or two 'stop' bits. The holding period between successive signals may be any length, which is why the system is called asynchronous.

frequency is divided by internal counter circuits to produce a range of output frequencies at standard baud rates. A UART may be connected to one or other of these outputs, depending on which baud rate is to be used. An interface usually has the facility for switching the UART to any one of the generator outputs, so that the rates on transmitter and receiver may be matched.

Since this is an asynchronous system, matching of timing does not have to be of high precision. Timing at the receiver begins when a start bit is received. The clock at the receiver has to remain in phase with the transmitting clock only for the duration of 10 to 11 pulses. The receiving clock probably runs slightly slower or faster than the transmitting clock, but this does not matter. It can get only a fraction of a pulse out of phase in such a short time, and this is not enough to cause errors in decoding. When the *next* train of pulses arrives, timing begins all over again from the arrival of the start pulse. Any discrepancies of timing which might have accumulated between trains are eliminated. **ETI**

CORTEX PART 3

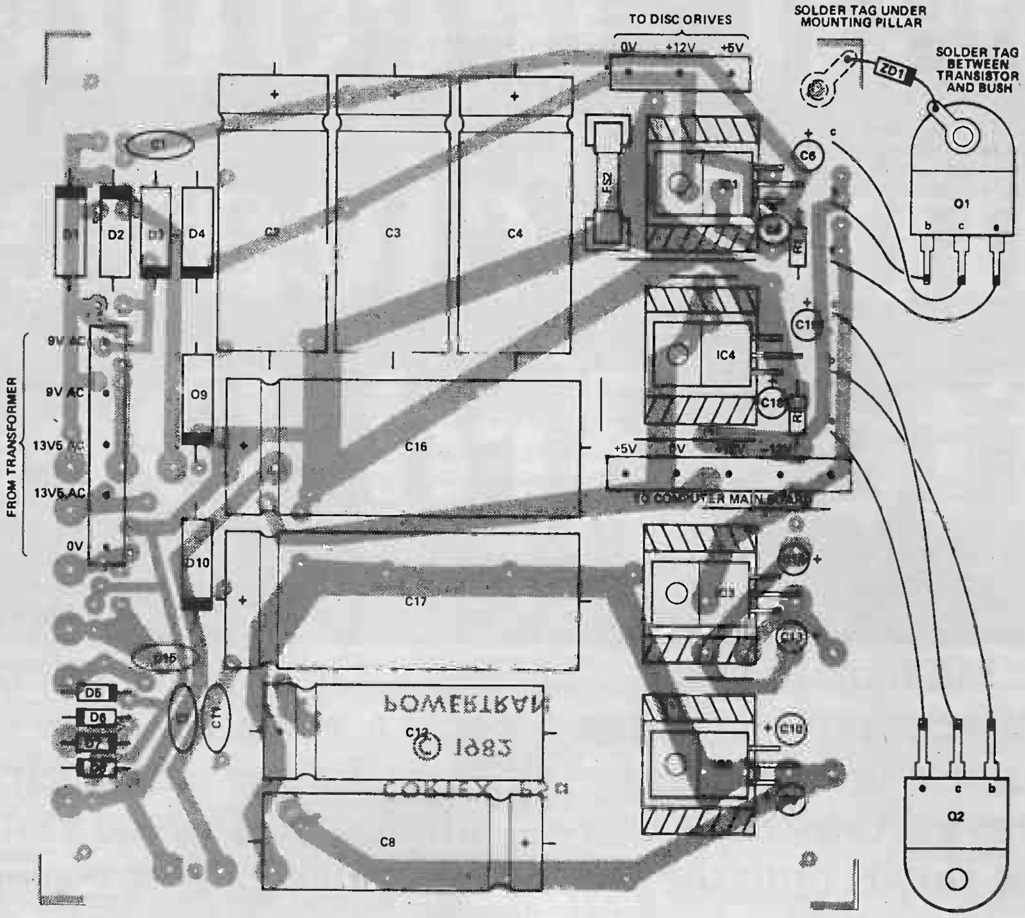


Fig. 1 Component overlay for the power supply.

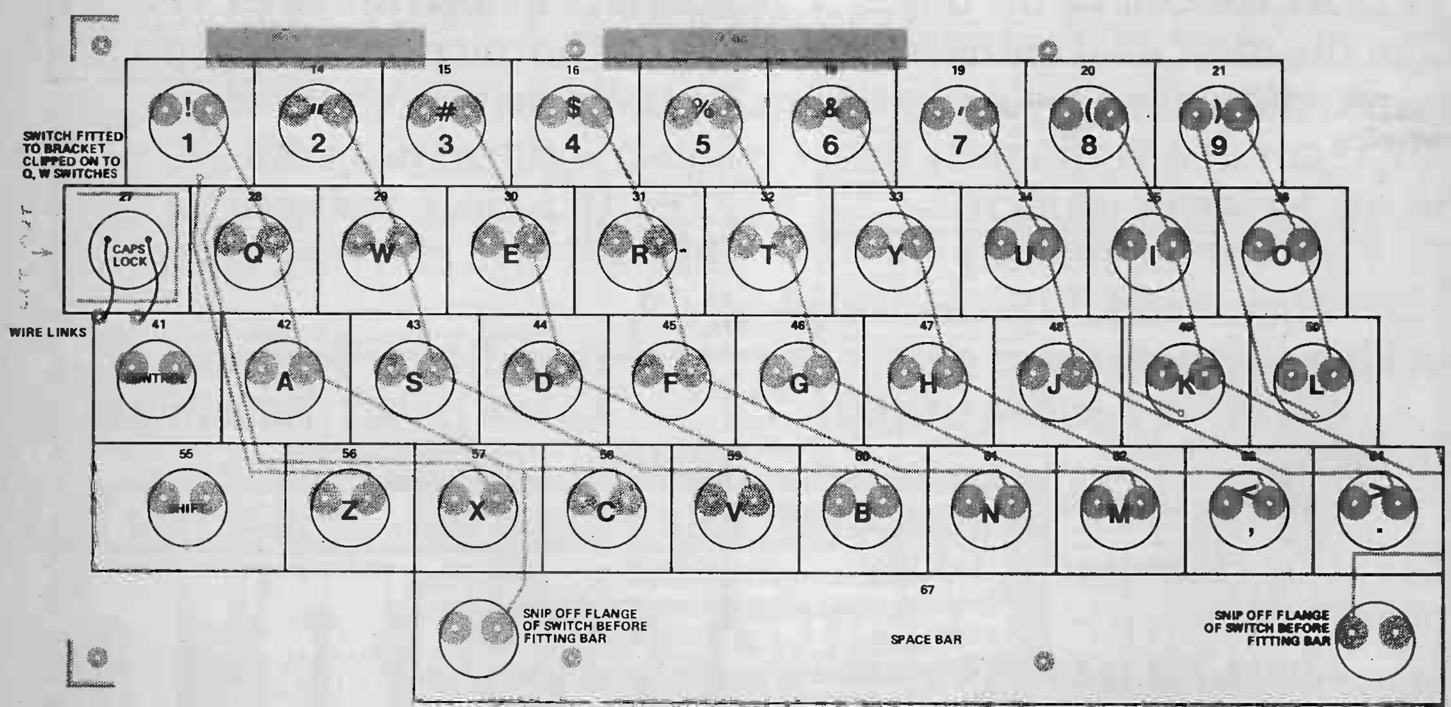


Fig. 2 The keyboard overlay, in two halves so it doesn't get stapled into illegibility.

PARTS LIST

POWER SUPPLY

Resistors (all ¼W, 5%)

R1,2	10R

Capacitors

C1,7,11,15	100n polyester
C2-4	4700u 16 V axial electrolytic
C5,6,9,10, 13,14,18,19	1u0 35 V tantalum
C8,12	2200u 25 V axial electrolytic
C16,17	4700u 25 V axial electrolytic

Semiconductors

IC1	7805
IC2,4	7812
IC3	7912
Q1,2	TIP2955
D1-4,9,10	1N5402
D5-8	1N4002
ZD1	BCW70 5V6

Miscellaneous

PCB (see Buylines); one off three way connector; two off five way connectors; transformer (13.5-0-13.5 V at 3 A, 9 V at 4 A; fuseholder clips; four off TV5 heatsinks.

KEYBOARD

Resistors (all ¼W, 5%)

R1,2,6,8	4k7
R3	18k
R4	12k
R5	680k
R7	100k

Capacitors

C1,2,5	220n 35 V tantalum
C3,4	4u7 16 V tantalum
C6	4n7 ceramic
C7	33p ceramic

Semiconductors

IC1	74LS123
IC2	74LS08
IC3	74LS157
IC4	2376
Q1	BC182L

Miscellaneous

PCB (see Buylines); 67 off momentary push-to-make switches; one off latching push-to-make switch; set of 67 double shot moulded key tops; IC sockets; switch mounting bracket; mounting pillars etc.

The CAPS LOCK switch is physically different from the rest and is wired in with wire links. Press this switch into its bracket together with the Q and W switches before fitting to the board. It is most important that the switches fit squarely on the board. The best way to be sure of this is to solder only one pin of each switch and then holding the board, press in turn each of the switches while reheating the soldered joint. If any are misaligned this will correctly position them. The key tops can now be pressed on and the remaining pins soldered.

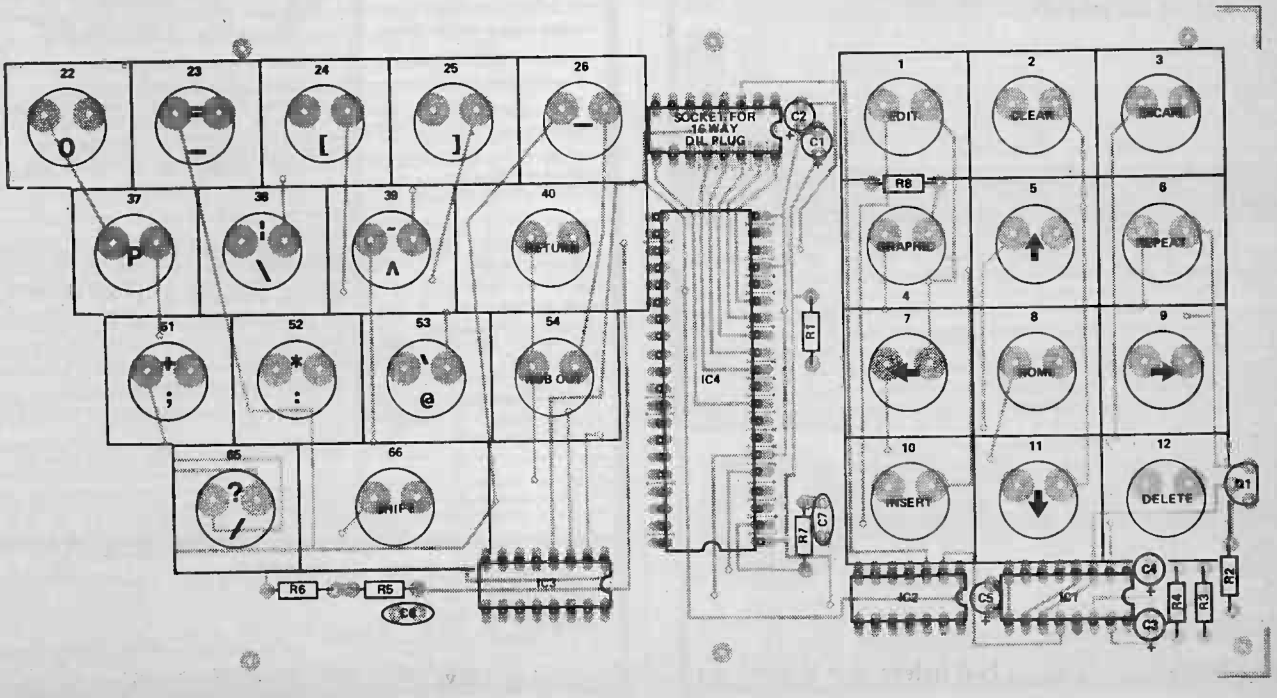
The power supply is on a single-sided PCB with six wire links and it is best to fit these before any components. Connections to and from this board are made via connectors and to ensure that their pins are soldered in squarely, fit the sockets on to them during soldering. The power supply is all on the back panel and the power transistors use this as a heatsink, being fitted to it with mica insulating washers.

As well as holding the input and output sockets, the rear panel has provision for a cooling fan and one should be fitted when disc drives are used.

The disc drives pass through the front panel and are screwed onto a mounting plate. Plates on the sides of the drives press against the panel, thereby making a rigid sub-assembly which fits into the cover of the computer. The standard kit has a panel with no cut-outs for disc drives and a new panel is provided with the drives when purchased.

There are two positions in which the main board can be fitted. The board has provision for a Eurocard connector for expansion purposes and there is a cut-out in the side of the computer through which the connector passes; for external expansion the board fits at the far right hand side. However, if the add-on units are to be fitted internally then the position to the left is used.

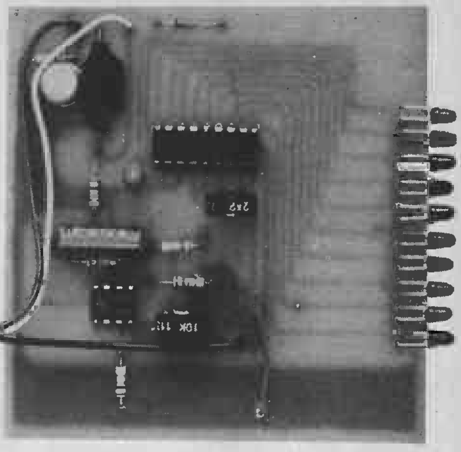
BUYLINES



ETI

FUEL GAUGE

Moving coil meters? How passé. If Ford is prepared to spend millions of pounds on computer-aided design and robot assembly, the least you can do is fit your car with an electronic fuel gauge. Design by A. M. Smithers.



The standard petrol gauge, as fitted to most cars, is of a primitive 'hot-wire' design, the gauge responding to the heating effect of the current through it, which in turn varies with the resistance of the fuel gauge sender unit located in the fuel tank. The chief disadvantage of such a gauge is the inaccuracy of reading. Running out of petrol is advantageous only in certain circumstances and even then it would be nice to know exactly when it was going to occur!

A far more elegant, and indeed, much prettier solution would be a bargraph type display which could be accurately calibrated. With the help of the LM3914 bargraph display driver this can easily be effected. The standard sender unit in the tank is retained, but the petrol gauge is disconnected at the instrument panel and the sender unit is, instead, connected to the input. R2 provides the current source for the sender unit previously obtained from the gauge itself. Please note that considerable adjustment is provided on the circuit resulting in the value of R2 and, indeed, the resistance of the sender unit being not at all critical.

The voltage developed across the sender unit of the car in which the prototype was fitted varied from around 10 V when empty to around 2 V when full. A 741 operational amplifier is used to invert this signal by comparing it with a 5 V reference provided by R4 and R5. The output of the op-amp varies from about 0V5 when the tank is empty to about 8 V when it is full. This output is now of the correct sense to be fed to a standard LM3914 expanded scale voltmeter. The potential divider formed by R7 and PR1 provides a full scale adjustment which may be calibrated against a brimming full petrol tank. Similarly PR2 provides a zero adjustment for calibration against an empty tank.

Construction

The circuit is relatively simple and may be constructed on Veroboard or the PCB design as illustrated. IC sockets are recommended, particularly to novice constructors, as LM3914s do not come cheap and removing an 18-pin IC is no easy task in any case. The LEDs may be soldered directly to the board as shown or may be mounted remotely, for instance on the car dashboard with flying lead connections to the PCB. If mounting the LEDs on the board specified, please note that 0.125" LEDs must be used as 0.2" types will not fit!

R2, the 100R 2 W resistor is not of a critical value and to save costs, on the prototype this component was made up of 4×470R ½W resistors in parallel. Any similar combination resulting in a power handling of 1W5 or more may be used.

Provision is made on the PCB for converting the circuit to dot-mode display. Although this modification would not be advantageous for a fuel gauge, the project can of course be used for

HOW IT WORKS

A current source for the fuel gauge sender unit is provided by R2. A voltage proportional to the resistance of the sender is therefore developed between the input and ground. In a typical vehicle this voltage will vary from 2 V when full to around 9 V when empty. This variable input is inverted around a reference voltage derived from R4 and R5 by a unity gain inverter consisting of IC1, R3 and R6. C1 is deliberately larger than is normal for frequency compensation to slow down the response of the circuit, thus providing a far more static display, free from annoying flicker. A variable potential divider formed by R7 and PR1 sets the FSD of the LM3914 bargraph display driver.

PR2 serves two purposes: the *setting* of this pot adjusts the zero level of the voltmeter, while the *value* sets the LED current. A value of 2k2 was chosen to given an LED current of around 7 mA according to the formula:

$$I_{LED} = \frac{1.2\ (10 + R)}{R}$$

where R is the value of PR2 in kilohms. A current of 6 mA per LED with all LEDS illuminated corresponds to a maximum dissipation in IC2 of around 600 mW which is inside the rated maximum of 660 mW.

The components ZD1, R1 and Q1 form a simple stabilised power supply of around 10 V. This value allows for a weak battery while still maintaining accuracy.

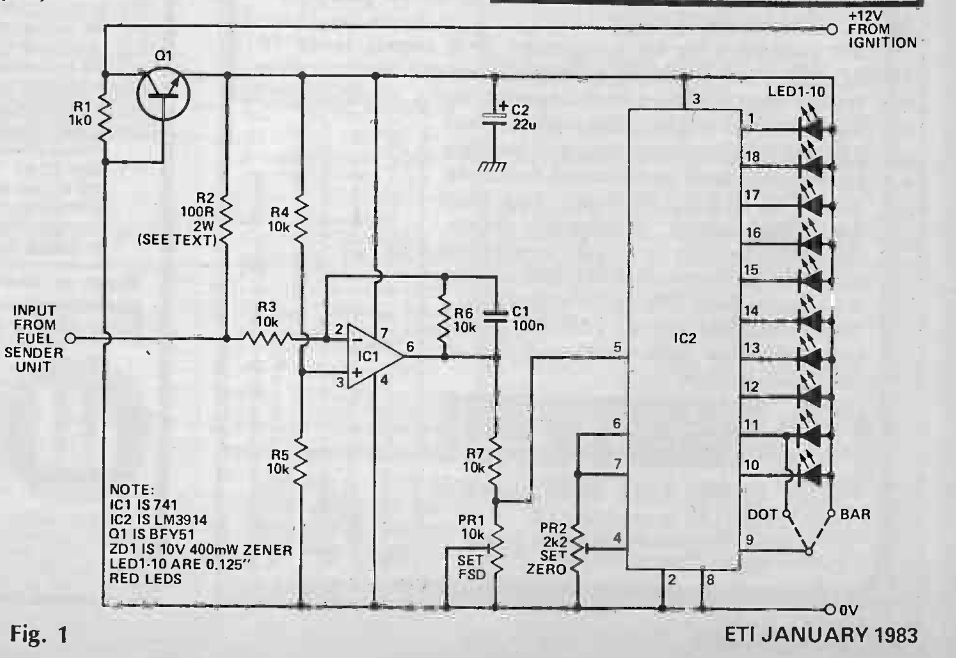


Fig. 1

any purpose requiring a monitor with a response that is inversely proportional to a linear input.

Testing And Calibration

After assembly of all components, connect the unit to a 12 V supply and short the input terminal temporarily to 0 V. It should be now possible by adjustment of PR1 to obtain a full 10 LED display with adjustment to at least half FSD. With the input shorted to +10 V PR2 should adjust for no LEDs illuminated, again with considerable adjustment both ways. If the unit fails to function check for solder shorts, misfitted components, broken PCB tracks and faulty components — in that order.

To calibrate the unit it is obviously necessary to have access to the car with fuel tank full and empty; we recommend that the following procedure is adopted. Run the car until the tank is nearing empty. Drain the tank into a suitable container by disconnecting the fuel line at the pump and refill the tank with about 2–3 pints of fuel to allow a certain safety margin even when the gauge registers empty. Connect the unit temporarily to the car and after allowing the tank contents to settle, accurately measure the voltage at the input and record this value. Replace the tank contents, drive to a garage and fill the tank completely with fuel. Again accurately measure the voltage at the input.

Remove the unit to the test bench, apply power and connect a low value potentiometer between the input and ground. Now using the recorded values, the unit may be calibrated on the bench by applying the correct voltages by adjustment of the potentiometer. This method of calibration is necessary because the two adjustments are highly interactive and calibration would otherwise entail filling and draining the fuel tank several times, which would be time-consuming and possibly expensive. When calibration is complete, seal the presets with wax or nail varnish and finally install the unit in the car. Take care not to allow the track around the edge of the PCB touch the chassis when mounting the unit — this is the +10 V rail and blown fuses will result.

The display brightness is set by the *value* of PR2. This value is chosen to give a current of about 6 mA per LED which corresponds to a dissipation of around 600 mW in the LM3914 when all LEDs are illuminated. As the maximum allowable dissipation of the device is 660 mW, on no account should the value of PR2 be reduced.

A design point is that the display is of 10 LEDs and most modern cars have tank capacities of around 10 gallons. Thus an approximate direct readout of 'gallons remaining' is obtained and a fair estimation of fuel consumption may be made.

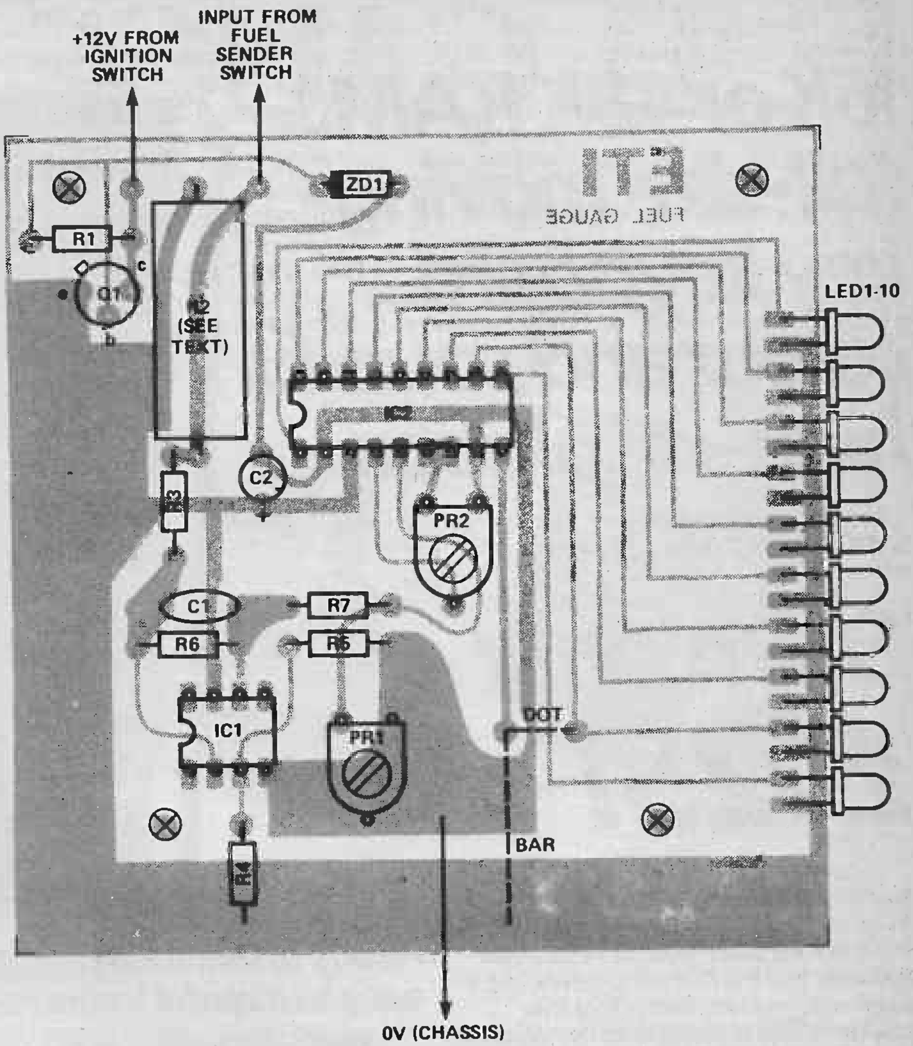
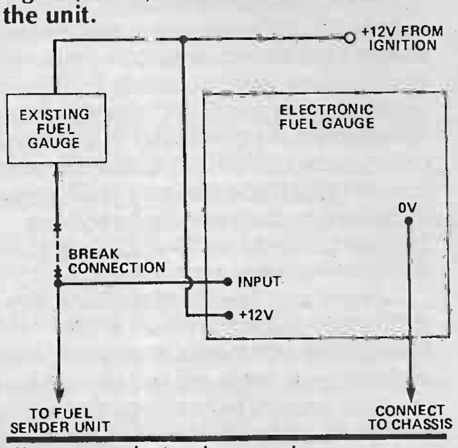


Fig. 2 (Above) Component overlay. This is slightly altered from the prototype shown.

Fig. 3 (Below) Connection details for the unit.



PARTS LIST

Resistors (all ¼W, 5% except where stated)	
R1	1k0
R2	100R 2 W (see text)
R3–7	10k
Potentiometers	
PR1	10k miniature horizontal preset
PR2	2k2 miniature horizontal preset
Capacitors	
C1	100n polyester or polycarbonate
C2	22u 16 V tantalum
Semiconductors	
IC1	741
IC2	LM3914
Q1	BFY51 or similar
ZD1	10 V 400 mW zener
LED1–10	0.125" red LEDs
Miscellaneous	
PCB (see Buylines); hardware for mounting	

BUYLINES

No problems with any of the components here; everything should be sold by everybody, and most of it could be found in your junk box. The PCB can be obtained using the PCB Service order form on page 91.

ETI

BUYER'S GUIDE TO

CONQUERING THE UNIVERSE

Only a few shopping days to Christmas, and we're full of goodwill to all men and xenophobia towards aliens. Peter Green has been killing as many as possible (aliens, that is), and this is how he got on.

No doubt you all think it's a pretty cushy job, playing video games day after day and getting paid for it too. That's because you're not sitting here trying to type this article with the twin ailments of Intellivision Thumb and Atari Cramp. The former is caused by excessive pressure on the direction disc through sheer panic when you're trapped by a falling boulder in Astrosmash. The second is the result of trying to keep a firm grip on the joystick while throwing the USS Enterprise all over the known universe.

Which brings me to my first complaint. Oh great video game companies, when are you going to produce a decent hand controller? The offerings of the two giants leave a lot to be desired. The Atari controller needs a lot of force on the joystick if you're to be certain you've closed the switches, and as a result the left hand which is gripping the controller base starts to go numb quite quickly: especially when you have to tighten your hold because you're starting to sweat and lose your grip. On the Intellivision the flat direction disc is, I think, a lot easier to use (although there are many in the office who'd dispute that), but I still find that in the excitement of a game I'm pressing too hard, which quickly makes the end of the thumb sore. I suppose the real answer is to cultivate a calm attitude during play, but this is almost impossible (maybe we should produce a book on Zen and the Art of Videogames!).

By far the worst problem with the Intellivision is the fire buttons on the sides of the Controller. These need a ridiculous amount of pressure to push them in, which isn't so bad when they have to be momentarily pressed; but in one game which required continuous pressure for rapid firing, I ended up dead because my hand simply couldn't grip the controller any longer. So loosen your springs, gentlemen!

The next problem was actually getting hold of anything to review! At this time of year it seems everyone has the same idea, and time after time I was told by the PR companies that they had nothing for me because everything was out on loan and none of the journalists would return it. This explains the lack of reviews for the Atari VCS in particular, and as for the Philips G7000 — I never managed to lay my hands on one.

Maybe I should propose a new video game in which a screenful of journalists acquire video games and when they've had them for a certain length of time you can blast them with a 30 kW X-ray laser . . .

Eventually I managed to get a reasonable selection together, though, and play-testing began. It became apparent that there are three broad categories of game: ones where you have to kill an infinite series of strange things and get the highest number of points, those where you have to kill a finite number of strange things in the fastest possible time, and those that simulate some real human activity. The success or failure of any of these types depends mostly on how well the designer has struck the balance between challenge and skill level. If a game is so easy you can master it after playing it once, it's a bad game; so, too, is one that kills you off within 30 seconds no matter how much you practise. The ideal game is fairly easy at the lower levels but increases in difficulty at just the right pace to keep step with your increasing familiarity with it. It should be possible to play it again and again and always find that extra challenge that brings you back for more: unfortunately few games can achieve this.

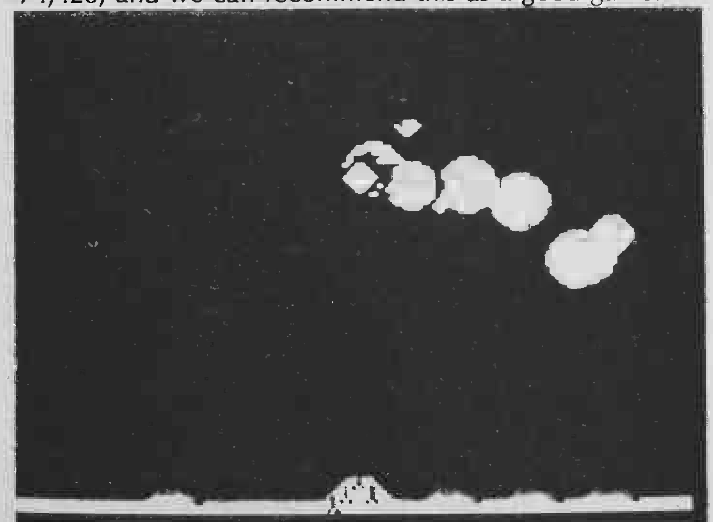
One of the best guides to the success of the game, I found, was the number of people that started looking over my shoulder while I was playing, and how many of them fought to take my place when I went to the loo! There are a lot of dedicated gamers in our office and the highest scores that we give are not necessarily mine (in fact they're rarely mine!).

Star Raiders (Atari 400)

This is one of the best Star Trek simulations you can buy. The TV shows the view through the viewscreen of the Enterprise, with stars drifting past very realistically, and an array of readouts at the bottom giving co-ordinates, energy left, number of kills and so on. The joystick is used to steer the ship and aim and fire the photon torpedoes, while the keyboard gives functions such as forward and aft view, shields on/off, long range scan, galactic chart, attack computer on and hyperspace controls. Basically the idea is to protect your starbases by locating your enemy (and there's a lot of them) on the galactic chart, travelling to their location by hyperspace (a spectacular effect as you storm through the starfield) and kill all the aliens you find there. Simple, huh? Until you discover that the controls work as they would in real life so that when the joystick is pushed forward the ship's bow drops and the view through the screen rolls up. Ditto left and right movements. This topsy-turvy system takes a bit of getting used to, and the only course is to stick at it until your brain finally clicks. Once you get the knack of steering you still have to cope with the fact that your photon torpedoes move with true perspective and dwindle in size, so aiming is an acquired art too. Mastering all this is quite satisfying, but once you've beaten the basic game and try to move up you find that the difficulty leaps enormously: your shields are no longer impervious, you quickly take a lot of damage and die fairly rapidly. This assumes you actually found any aliens in the first place, because on the higher levels you have to steer through hyperspace and this is damned difficult. No-one in the office has beaten this game on anything other than novice level, and our highest rating so far is Lieutenant Class 4.

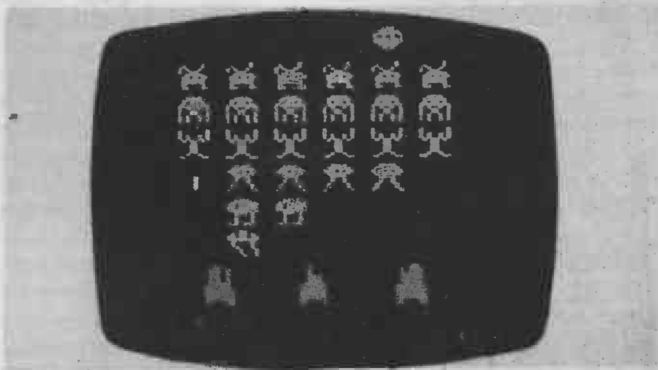
Missile Command (Atari 400)

Another cracker for the 400, this is the one where a central missile base is trying to defend the cities on either side by shooting down the aircraft, satellites and nuclear warheads which are doing their best to decimate the landscape. The catch is that you have to position your target cursor just the right distance in front of the enemy because they only detonate if they fly into the explosion of your missile and it takes a finite time for your missile to reach its target. And don't miss — most of the warheads are Multiple Independent Re-entry Vehicles, so if you don't knock them out fast you suddenly find they split into half-a-dozen or so. Bonus points are awarded each time you clear the screen for cities saved and missiles not used, and the amount you score increases as the game progresses, but after a certain point the nasty smart bombs appear. These don't fly blindly into your fireballs, but will always dodge them if possible. This means you either have to lay a pattern of charges around them, or get good enough to hit them spot on. Tricky. Our maximum is 74,420, and we can recommend this as a good game.



Space Invaders (Various)

Here I have to admit that I've never been able to understand the runaway success of this game — it bores me rigid. Anyway, what can I say? Everyone's seen this and knows that there's a screenful of aliens who fly in gradually descending rows while you try to stop them doing same by shooting upwards with your laser. Whoopee. Since I can't get up the enthusiasm to practise this one my score is derisory, but my brother-in-law's sister is so good she can get the score on a VCS up to all nines and then clock it round to zeroes. It's safe to say that if you can manage that you're not doing too badly.



Defender (BBC Model B)

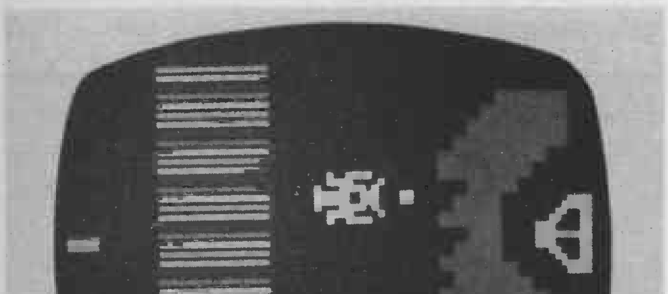
Possibly the best simulation of an arcade game on a micro that we've seen yet. Full colour, excellent high-resolution graphics, all the sound effects you could ask for and a fast, challenging game. Acornsoft have definitely come up with the goods on this one. The game follows the standard Defender format: your spaceship is flying over the surface of a planet populated by little men who are prone to being kidnapped by alien landers. Your task is to prevent this antisocial behaviour by lasering the alien ships before, during but not after — because if they complete their task by reaching the top of the screen, they turn into very fast mutants which plough straight into you. Extra points are awarded if you can rescue a human in mid-air, and even more if you land him safely. Once you've cleared the first wave things turn progressively nastier, with bombers, pods, swarmers and other whatsits all after your blood. This is when you really need your smart bombs, which instantly detonate everything on screen: very useful in a tight corner. There are seven control keys for various functions so just getting yourself co-ordinated takes a while, but it's worth persevering. I started out by getting maximum scores of 450 (by ramming three landers!) but after a couple of hours I was soon getting respectable totals. Current office maximum resides with a colleague on Personal Computing Today, who racked up 54,350.

The Empire Strikes Back (Atari VCS)

This is one of the new releases for Christmas from Parker and quite good it is too. The game recreates the battle from the film of the same name, in which Luke Skywalker and his pals take on the Imperial Walkers in their snowspeeders on the ice planet Hoth. You are the pilot of a snowspeeder trying to prevent a line of walkers from reaching the right-hand side of your TV. The action actually takes place over an area eight screens wide, and a small radar view at the bottom of the screen tells you exactly where you are in the larger scheme of things. Walkers are tough critters — you have to hit them 48 times in the body to destroy them, whereas they can take you out with five shots or fewer. This would make the game almost impossible but for two things. The first is that for every two minutes you can keep the snowspeeder alive, you get 20 seconds of the Force being with you, which makes you invincible; as soon as this happens you can just sit there blasting away and ignoring enemy missiles. The second thing is the occasional appearance of very small 'bomb hatches' on the body of the walker; if you can get a laser bolt into one it destroys the walker immediately. The bad news is that if you play the harder games, these bomb hatches will often launch homing smart bombs which chase you for a considerable time (of course there's bonus points in it if you can shoot them down). There's an infinite sequence of walkers, and they get faster and more accurate as time goes on, so this game ends when your last snowspeeder has been destroyed, the object being to score as highly as possible. On game 13, the hardest (smart bombs and solid walkers that destroy you if you fly into them), the current maximum is 5,562.

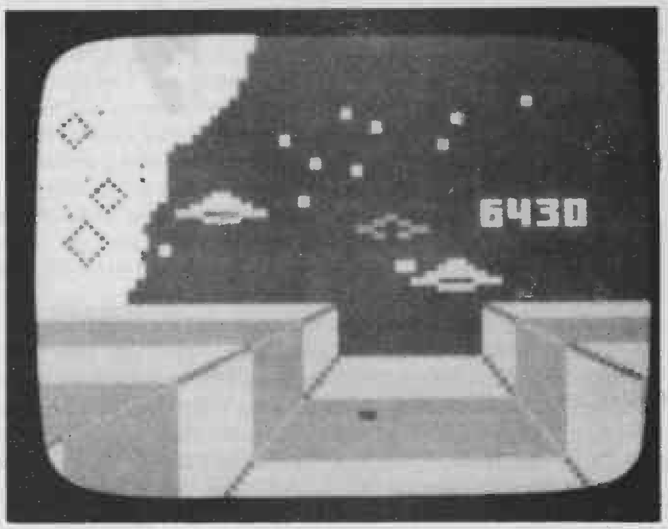
Yar's Revenge (Atari VCS)

Now most of the time you can play a video game and when someone asks what you're doing, you can give a coherent answer. But when you reply that you're a Yar who's trying to kill the deadly Qotile with your Zorlon cannon, you tend to get forehead-tapping and pitying looks. Well, ignore the infantile plot and concentrate on the game: which isn't one of the most gripping we've played. You're a sort of intelligent space-going housefly (stop laughing at the back there) and your enemy, the Qotile, is hiding behind a shield. Your job is to break through the shield, either by shooting out cells from a distance or getting in close and eating them. Eating a cell or touching the Qotile loads your Zorlon cannon, which is the only thing which will destroy the Qotile (tough things, Qotiles). Shoot through the gap in the shield and pow! Exit one Qotile and enter another. To give some added spice the Qotile periodically turns into a spinner and fires itself across the TV at you. Possibly a good game for the kids but it won't keep you engrossed for long. Our maximum score on the normal game with maximum difficult setting was 116,923. If you're interested, Yar's Revenge is the second game from the right on the top row at the end of Atari's TV ad.



Starstrike (Intellivision)

Now you've all seen this one — it's in the Mattel TV adverts. It doesn't take too much intelligence to figure out that this is meant to be as close to the Death Star canyon sequence from Star Wars as Mattel can get without breaching the copyright laws. Your ship is flying above a trench (actually your ship stays stationery and the trench rotates beneath you). You can manoeuvre about but you have to be careful not to hit any part of the enemy space station or the game's over. You can judge your position and height by the shadow under your caraft. The score starts at 8000: it decreases steadily as time goes on and increases every time you shoot down the enemy ships which fly down the trench at you. The object of the game is to successfully bomb the five red targets that appear over the horizon and pass beneath your ship (if you haven't got out of position by chasing aliens). Get killed or fail to hit all five targets before your score reaches zero and it's bye-bye Earth — the red thingies take off and decimate the ol' home planet. The idea isn't bad, but the balance of the game could do with a bit of work: it's too easy to beat on the lowest level and too fast to beat at the higher ones. Our maximum — 6462 on level 1. There's a good video game lurking in the Death Star sequence, but this isn't it.



Astrosmash (Intellivision)

Superficially this seems almost identical to Space Invaders, and yet I found it a lot more to my liking. You have a laser base at the bottom of the screen which you can move right and left, and which fires upwards at all sorts of space debris which is dropping out of the skies towards you. Every time you hit an object, it explodes (and if you're lucky it detonates another piece which was flying too close): every time an object hits the ground, you lose points. Now and again large or small white 'spinners' start falling — you must hit these or you lose a base when they land. As your score goes up you can score points faster, but the action speeds up and you then get guided missiles which home in on your laser and attack UFOs which fly across the screen lobbing huge bombs at you. The main trick with this game is to get a good rapid-firing technique established, but as pointed out earlier, the stiffness of the

Mattel push-buttons gets you cramped very quickly. At least Mattel have had the decency to provide a pause facility on this game, so you can loosen up your fingers before carrying on. As is usual in games of this type, the various scoring levels are indicated by the background changing colour and some of them make the targets a bit harder to see; I'm not sure if this is deliberate obstruction or not! Not a bad game at all, and worth trying to beat our maximum of 23,190.

Skiing (Intellivision)

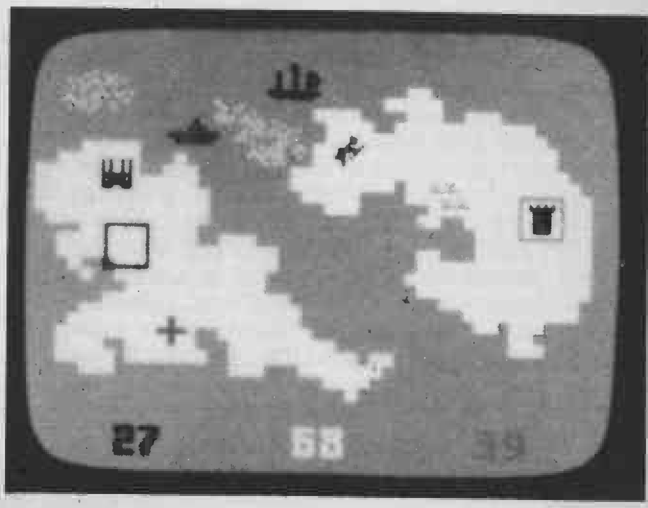
Not a bad little simulation, this, though if I were programming it I think I'd alter the rates of acceleration and deceleration which seemed a bit exaggerated to me. There's a choice of two courses, downhill or slalom, 15 degrees of mountain slope, and up to six different skiers so you can make it a team event with your friends. The difference between the two courses is that the downhill course is designed for speed, with a fair distance between gates (and mounds of snow to jump over), while the slalom requires some precision skiing with tight turns (which were a bit beyond my abilities!). The game is improved immensely by the excellent detail of the skiers (Mattel have always been best at this aspect of graphics) and by the sound effects, which include realistic thumps as you collide with the trees and a cheering crowd as you pass the finish line. Unfortunately I didn't seem to be able to complete the course in less than a minute (best time was 64.6 seconds, making me a hot-dogger), but I'll keep trying. Now where's that wax . . .?

SNAFU (Intellivision)

Peculiar name for a game (especially if you know what it stands for — and we can't print it here), but quite good fun to play. There are four snakes on the screen, two controlled by the computer and two which can be steered using the hand controllers. There are various types of game based on two basic ideas: trap games and bite games. In the former the trail grows continuously so that a complex maze develops on the screen, and the object is to force your opponents to trap themselves and crash into a wall. The other type involves snakes of a finite length, the trick being to run your head over your opponent's tail and gradually eat him away. Some permutations allow the possibility of diagonal movement, some have obstacles which must be avoided. Once the number of snakes on the screen has been reduced to two, the computer takes it upon itself to play one of two rather catchy little tunes, just to make things a bit more entertaining. There's no score of ours to beat, since all the games involve you against an opponent. A good game when you're fed up with killing aliens.

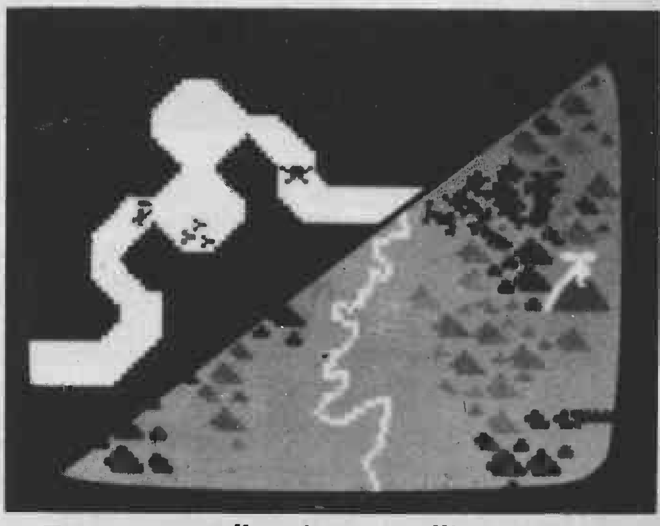
Utopia (Intellivision)

Now here's an unusual one: this is a sort of graphics-based version of Kingdoms, where you rule an island community and score points by maximising the well-being of your people. Tyrants need not apply. You can play against an opponent, who takes the other island, or simply try to beat your previous best score. As head of the Treasury you can decide whether to buy fishing boats or PT vessels, crops, houses, schools, factories, forts, or hospitals: you decide whether to co-operate with your neighbour or wage war on him. Natural hazards include storms and hurricanes: unnatural hazards include pirate ships who sink your fishing vessels. The game consists of a number of rounds from 30 seconds to 2 minutes, after which you are told how many points you scored, how much your population has increased (or decreased), and the amount of gold in the treasury. I liked it.



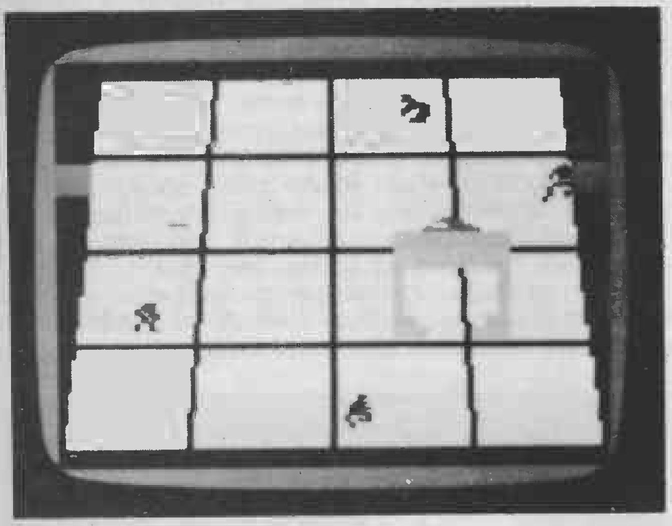
Dungeons And Dragons (Intellivision)

This is great! I've always been a fantasy lover and this is a really different type of computer game. Set off across the mountainous terrain towards Cloud Mountain, with the ominous snoring of the fearsome Winged Dragons in the background as they wait for their next meal — you. Plan your route carefully, as some mountains are impassable while the rest have caves containing arrows, tools, and fierce monsters to guard them. The caves and tunnels only light up as you pass along them so you have to become adept at tracking your prey. Some monsters leave visual clues to their presence (though what I thought were dragon droppings turned out to be something else) and some can be heard as you approach. It's up to you to learn the various signs and strengths of the foe, because the manual won't help you: in fact it was a long time before I realised what made the spiders dangerous. If you can keep at least one of your three men alive to the end, you get to find the two halves of the Crown of Kings, although when you do the finale is something of an anticlimax. There are four skill levels, sightseer, weekend adventurer, seasoned adventurer and hero, and I finally managed to reach hero, despite the incredible speed of the baddies and the paucity of arrows on this level. Who is this Conan chap anyway? One of Mattel's better games.



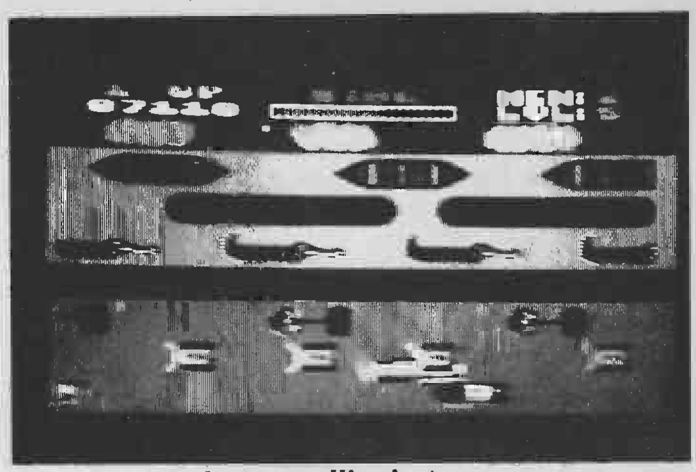
Tron — Deadly Discs (Intellivision)

Mattel have managed to tie up the licence for the home video game market from Disney (there are also Tron arcade games on the way), and this first cartridge is based on the Frisbee fights from the film (see the review on page 16). You take the part of Tron, facing three opponents on the Game Grid in a duel using identity discs. You can move about, throw your disc in any of eight directions (judging the lead on your moving target if you don't want to miss), or block your opponents' disc when they aim at you. The bad guys enter the arena through doors which you can jam open — get two opposite each other and you can teleport through from side to side, giving strategical superiority as well as allowing you to recover one hit (three hits and you're dead). Should you clear the screen, however, one of Sark's Recognizers appears to repair the jammed doors. Knock out its robot eye, a devilishly tricky manoeuvre, and you get 10 times warrior value bonus points. Watch out after 10,000 points, though: your scoring rate has increased considerably but your opponents are faster and more accurate at aiming. Sometimes you'll get dark blue Leaders, who can carry homing discs or discs that count as two blows; the purple Bulldog warriors are slower but need two hits to kill them. After you reach a million points (and by now I've played enough to believe it's possible), the computer switches tactics and sends on orange guards with paralyzer sticks, which need four blows to kill them and can end the game simply by touching you. My new ambition is to get up to this stage of play: I've already racked up 242,500, and a curse on the homing disc that got me just short of reaching the quarter million! The only way to score highly, by the way, is to learn to use the hand controller by feel alone. If you keep looking down to see which button to push, you aren't going to last very long. This gets my vote as favourite game of the article.



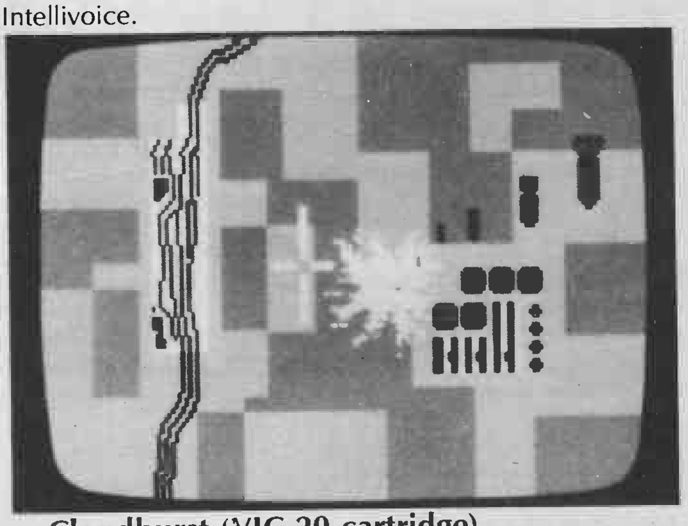
Preppie (Atari 400)

And this gets my vote as the best-written piece of 'non-alien' games software yet published. The game is based on the arcade game of Frogger, and the playing area is a golf course. Preppie is the American for caddie, and the poor soul has to retrieve a series of lost golf balls in a fixed time limit. The problem is that he has to traverse a fairway being criss-crossed with lawnmowers, golf carts, and on the harder levels, bulldozers (don't ask me what they're doing on a golf course), then leap from log to log, barge and alligator to cross a river. All the time you're playing, the computer is seranading you with a selection of catchy tunes in three-part harmony, and the graphics are quite superb. We particularly liked the bit where the caddie gets flattened out after hitting a lawnmower — sadists that we are. There are 10 difficulty levels, and no-one here has yet succeeded in surviving level 6 (it's the killer frog on the towpath that causes the problems). Our high score is 14,730. Very highly recommended, despite its rather frightening price tag of £23 (this is a tape, not a cartridge).



B-17 Bomber (Intellivoice)

The first of the games for the Intellivision that requires the use of the add-on Intellivoice module. You are flying a bombing mission over Europe during the Second World War, and throughout the flight you're getting a series of comments and warnings in a (pretty appalling!) Texan drawl. "Bandits at six o'clock", it announces, and you switch to the view from that gunnery position to shoot down der Luftwaffe. Sometimes this doesn't work, because there's a line of bullet holes across the canopy and your gunner is dead! Once you've reached your target, you can sight through the bomb doors and release your thousand-pounders ("Bawmbs awaay . . .") and hopefuly hit something ("That was awn tarrgit . . ."). The cockpit displays leave a lot to be desired, considering the sort of quality you *can* get out of an Intellivision: just a green horizon wobbling about as you try to dodge the flak. Not a bad game, but I think I'd want to see some better software than this before I went out and bought an Intellivoice.



Cloudburst (VIC 20 cartridge)

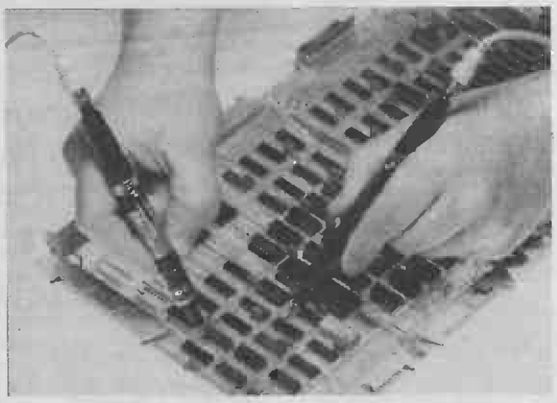
We've included this one for people who aren't very good at Space Invaders etc. Basically it's just sheer carnage, with enemy practically throwing themselves onto your laser bolts. At some unspecified future time, the Earth's atmosphere has become so polluted that mutant creatures have spawned in the acid clouds and are dropping down amidst acid rain to ravage the planet. Your laser gun can fire up, or to the left and right to slaughter any creatures making their way across the surface after landing. The screen colours are restful tints of pink, red and blue, to counterpoint the machine-gun speed of your laser fire and the ferocity with which the mutants hurl themselves at you. In between games the VIC plays you a snatch of rather incongruous 12-bar boogie. The easiest

DIGEST

New Logic Probes and Pulsers

Two new products are now available from the OK Machine & Tool (UK) Ltd. The PRB-1 Digital Logic Probe detects pulses as short as 10 nS, has a frequency response of better than 50 MHz and an automatic pulse stretching to 50 nS but is competitively priced at £33.24. It is compatible with RTL, DTL, HTL, TTL, MOS, CMOS and microprocessor logic families and also features 120 k impedance, power lead reversal protection and over-voltage protection to 200V (+V–V). Supply voltage range is 4–15V but a PA-1 adaptor can be supplied for use with voltages from 15–25V.

The PLS-1 for £43.13 is a pocket-sized, multi-mode, high-current pulse generator that will superimpose a dynamic pulse train (20pps) or a single pulse on-to the circuit node under test, without having to unsolder pins or cut printed circuit traces, even when these nodes are being clamped by digital outputs. It can source or sink sufficient current to force saturated output transistors in digital circuits into the opposite logic state. OK Machine & Tool (UK) Ltd, Dutton Lane, Eastleigh, Hants SO5 4AA. Tel: 0703 610944.



High-Rise RAM

High speed erasing, writing, modifying and reading of non-volatile data is made possible for software engineers by the MEMIC model T by Camel Products. Two kilobytes of fast access, low power static CMOS RAM is built into a 'Tower block' unit needing no more real estate than the 24 pin IC socket it plugs into. Even when plugged into a ROM socket, the flylead provided allows write operations. Hi-K Lo-K or 2K operation is switch selectable. A power down switch permits months of non-volatility off NiCd batteries. At £29.95 (incl.) the ready to use unit comes with clear and easy user notes. Cambridge Microelectronics Ltd, 1 Milton Road, Cambridge CB4 1UY. Tel: 0223 314814.

Inside-Out TV

Philips' new CTX small-screen colour TV, the 14" CT2006, turns on itself to show what makes this advanced receiver tick: a single board with a third less parts than previous sets.

The VDU Approaching Platform 6. . . .

Jasmin Electronics have won important contracts to supply British Rail (London Midlands Region) with their new Information Display System, which utilises a new Character Generator to give the unique choice of presenting the same information in up to seven different formats on television screens — but only having to generate it once.

St. Pancras Station (London) and Preston Station are the first to order this new model which will become operational in the new year. Similar systems are in use for many applications in the UK and overseas, particularly at airports. More stations are expected to adopt this information system as a key part of London Midland Regions' improvements in passenger information facilities.

The versatility of the design means that the same basic system can be very easily adapted to differing requirements of other stations while still gaining the benefits of standardisation. For each station, an important feature is the capacity to modify or extend the system without major re-design. Jasmin Electronics Limited, St. Matthews Way, Leicester LE1 2AA. Tel: (0533) 58128.

3½ Digit Panel Meter

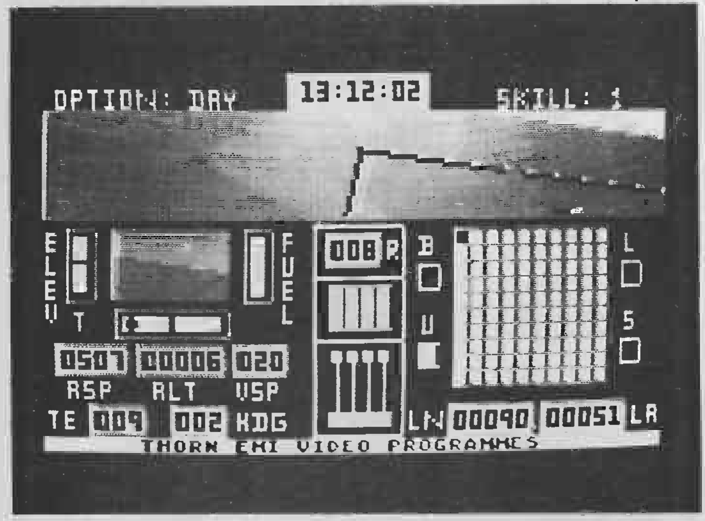
A new 3½ digit DPM recently announced by Lascar Electronics can be operated by 5 V DC, 110–120 V AC or 220–240 V AC. The meter fits into a standard DIN cut-out and will replace many existing types, but offers improved performance with very low cost. Standard features include 0.43" (11mm) high efficiency LED's, Auto-zero, Auto-polarity, bandgap reference, polarised filter and programmable decimal points. The meter is capable of single ended, ratiometric or differential measurements. Although offered in a standard FSD of 200 mV, the meter can be easily programmed by the user to read many other engineering units, such as current, resistance, temperature, etc. Lascar Electronics Limited, Oakland House, Reeves Way, South Woodham Ferrers, Chelmsford, Essex CM3 5XQ. Tel: Chelmsford (0245) 329797.

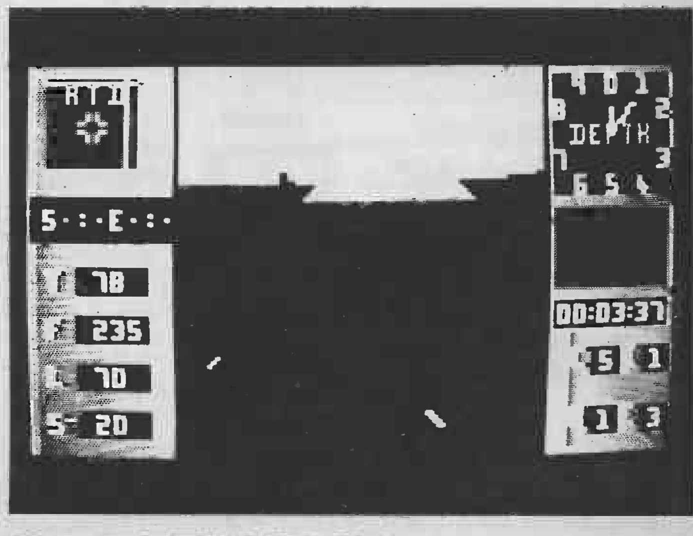
level is damn fast, and anyone who claims he can survive longer than 10 seconds on level 9 is a liar.

Jumbo Pilot/Sub Commander (Atari 400)

Here are two especially for those of you with very poor reflexes. You require the reaction time of a corpse to play these because they are 'real-time simulations' ie pretty slow. In Jumbo you have to take off, fly across country and land. It takes 11 minutes or so just to taxi into position and lift off, and you can then spend anything up to two hours watching the dials in the cockpit do very little, until you attempt to land and plough into the tarmac. Then all you can do is start again. Frustrating, huh? The least the author could have done was to include an option to practise landing without going through the rest of the game. Our highest score is zero, since no-one's been able to land yet; but one of us did manage to do a barrel roll successfully!

Sub Commander is a simulation of World War Two submarine combat against shipping convoys in the Mediterranean. You have all mod cons like sonar, periscope, hydrophones and torpedoes, plus a satellite reconnaissance of the Med (in WW II? Oh well . . .). You stalk the ships, aim through the periscope and hopefully torpedo them before they blow you out of the water with depth charges. Rather more action in this game, but still a bit slower than my tastes run to. Highest score so far is 10,420.





ETI

ZX ANALOGUE-TO-DIGITAL CONVERTER

Expand the consciousness of your computer and let it sample the delights of the real world with this low-cost ADC. Design by Rory Holmes.

How about a fast, eight-channel, eight-bit analogue-to-digital converter, all in one small box that plugs neatly onto the back of your Sinclair computer and costs about £15? A rhetorical question, really, because that's what we're presenting in this article. The applications for this project are numerous since A-to-D converters allow your computer access to the 'real world': and the real world, as the data acquisition experts call it, is anything which varies smoothly and continuously, such as temperature, sound level, voltage, position, speed and so on. Eight channels of analogue input data, each with a resolution of one part in 256, will open up a whole new field of applications for your computer and programs. For example, some of the things you might consider include real-time graphs for multi-variable displays, eight-channel spectrum analysers (or even Spectrum analysers!), VU meters for recording work, process control programs, central heating control, potentiometer-type joystick inputs (up to four sets of two axes), weather station computers, waveform analysis by computer, aircraft simulations and so on. You might even be able to make good Uncle Clive's boast that the ZX81 could control a power station!

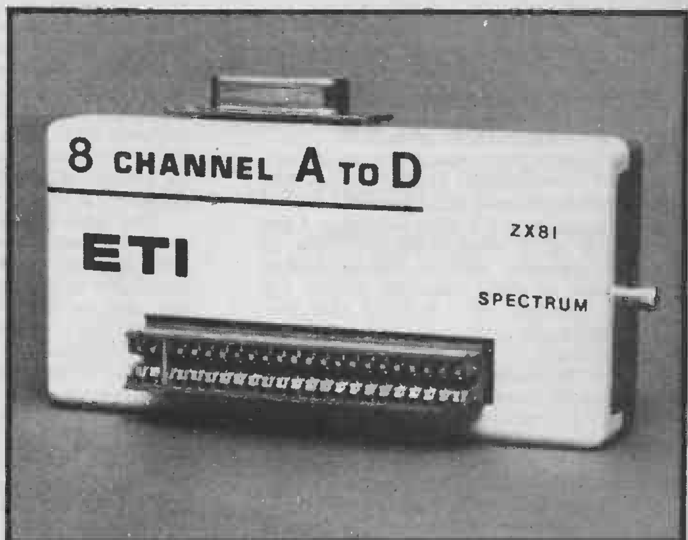
The ADC IC

Our analogue-to-digital converter is based around the new 7581 IC, a complete data acquisition system on a chip with some very handy features. The best of these features concerns the way in which data is made available to the host computer: by using a 'dual port RAM' and internal scanning logic the conversion process is made completely transparent to the user. Basically this means that the microprocessor need do nothing: the latest analogue data is always available and may be read from a small memory-mapped region of the computer's address space (eight consecutive bytes).

The chip will convert each channel in 50 microseconds and performs a complete conversion update of all eight channels in 400 microseconds. The analogue input voltage range is 0-10 V and these limits will correspond to 00 and FF Hex respectively.

The unit plugs into your computer via a double-sided edge connector, and, if you want, you can include a switch to enable the unit to switch between the ZX81 and the Spectrum port configurations. The eight analogue inputs enter the unit via a 15-way 'D' type connector. The system derives its low-current 5 V supply directly from the expansion bus, so it will start functioning as soon as the computer is switched on,

The ADC plugs on like a commercial unit.



Here you see the protruding edge socket.

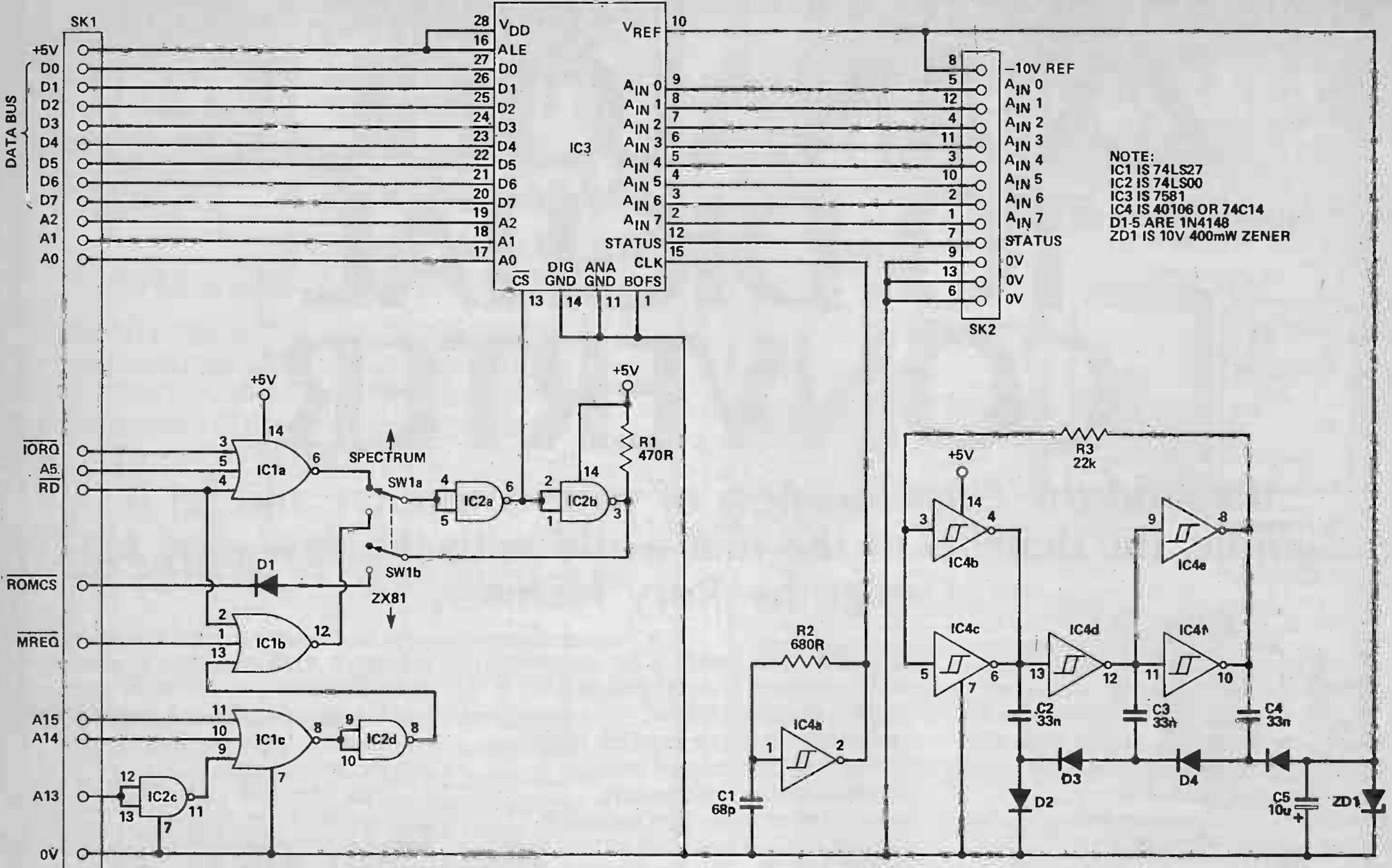


Fig. 1 Circuit diagram.

HOW IT WORKS

Figure 1 shows the complete circuit of the eight-channel analogue-to-digital converter. There are four separate parts to this circuit: the main converter device IC3, the master clock oscillator (a single CMOS gate), a negative voltage reference generator, and the address decoder. The 7581(IC3) is a complete eight-bit, eight-channel data acquisition system, designed for direct interface to microprocessor buses. The 7581 accepts eight analogue inputs and sequentially converts each input into an eight-bit binary word using the successive approximation technique. Results from the conversions are stored in an internal eight-bit eight-word 'dual port RAM'. The dual port RAM allows a microprocessor to access the analogue data independently of the internal updates; all the data acquisition is therefore transparent to the programmer. The analogue data appears to be permanently available in eight successive 'read only' RAM locations — you cannot write to these addresses.

The converter requires a master clock for its scanning logic and this is provided in our circuit by IC4a, a Schmitt inverter gate wired as a 1.6 MHz oscillator. Conversion of a single channel takes 80 clock periods, with a complete scan through all eight channels taking 640 clock periods. At 1.6 MHz this corresponds to 50 uS and 400 uS respectively.

The converter is wired in our circuit for simple unipolar conversion using a —10 V reference supply. In this case the eight-bit word covers an analogue range of 0-10 V as illustrated in the transfer characteristic diagram of Fig. 2. The actual analogue input circuitry is shown in Fig. 4. An R-2R resistor ladder forms a multiplying DAC to perform the A-to-D conversion. Each input, including the reference input, has an impedance of about 20k. A status output is also available which allows an external device to identify which channel is being updated at a given moment: it provides a signal, synchronised to the master clock, which follows the scanning logic and pulses low for channel 0. The status signals as related to the master clock are shown in Fig. 5.

The reference voltage generator that provides —10 V for IC3 is based on the voltage multiplier principle and allows a single 5 V supply to power the entire unit. The voltage tripler is constructed using CMOS Schmitt trigger inverters, and a capacitor-diode multiplier chain formed by C2-4 and D2-5. The inverters are connected as a self-oscillating ring running at several kilohertz to provide the AC square wave to the voltage multiplier. The tripler should give 15 V at the negative side of the smoothing capacitor C5 but due to diode and impedance losses this is reduced to about 12 V. The zener diode ZD1 is then used to clamp this voltage to the 10 V reference level.

The address decoding is performed using the same system we designed for the Message Panel Interface (why re-invent the wheel?). IC1 and IC2 perform the address decoding and the slide switch SW1 selects either memory-mapped decoding for the ZX81, via IC1b, or I/O-mapped decoding for the ZX Spectrum via IC1a. When the decoder is switched for the Spectrum the states of the bus lines $\overline{IORQ}$ (I/O request), A5 (address bit 5), and $\overline{RD}$ (the read signal) are continuously monitored for logic lows. If they all go low together, then the Spectrum is performing an IN addr, X command, and the output of NOR gate IC1a will go high. This output is inverted by IC2a, which in turn takes the chip select pin of the converter (pin 13) to logic low. As the chip select goes low the data from IC3's internal memory (addressed by the three lower address bits A0, A1 and A2) is made available to the data bus for the read operation. Thus any of the eight-bit data words may be read at any time.

The rest of the gates in the decoder section are effectively ignored, and as far as the Spectrum is concerned the A13, A14 and A15 inputs are connected to the wrong bus pins anyway.

When plugged into a ZX81, however, with the selector switch in its other position, these other gates become usefully active. With IC2c wired as an inverter, address bits A14 and A15 must be high and A13 low in order to take the output of IC1c to logic high: this means the second 8K address block is being selected. The output of IC1c is inverted by IC2d and fed to one input of IC1b, a NOR gate. The other two inputs of this gate monitor logic low states on the $\overline{MREQ}$ (memory request) and $\overline{RD}$ bus lines.

Thus the output of IC1b will only go high when the ZX81 is performing a memory read operation at a location between 8192 and 16383. The output of IC1b is fed to the chip select pin of IC3 via the selecter switch and inverter as before. IC2b inverts and buffers the enable signal to drive the $\overline{ROMCS}$ line (linked via SW1b): consequently this line will go high through diode D1 whenever the interface is addressed and switch off the 8K ROM in the ZX81.

The 15 mA or so supply current for the TTL and CMOS is taken directly from the 5 V supply rail on the ZX bus.

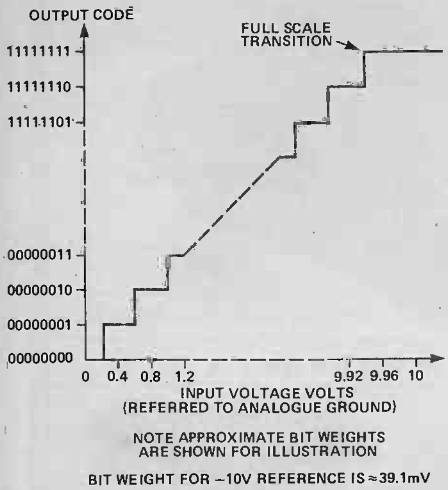


Fig. 2 Transfer characteristic diagram.

updating the analogue data at the chosen memory locations ready for PEEKing or machine code access.

There's no reason why this device couldn't be used with any other computer. All you have to do is find a handy unused hole in your system's address space and design suitable circuitry to decode the chosen range of addresses. This circuitry will replace the section of our circuit involving IC1 and 2.

Construction

The entire eight channel converter is built into a plastic Verocase to form a very neat and solid unit which plugs directly into the Sinclair expansion connector, either on the ZX81 or the Spectrum. A standard 15-way 'D' type socket allows access to the eight analogue inputs and a few other internal connections. This is a right-angled PCB-mounting type which is soldered directly to the track side of the PCB to reduce interwiring. Since the wire-wrap edge connector socket is also soldered to the PCB, the only part external to the PCB is the selector switch, which is optional. If you anticipate using only one computer then wire links can be used to replace the switch contacts at the appropriate overlay points.

The PCB should be assembled first, following the overlay diagram of Fig. 6. Don't forget the six wire links and take care over the orientation of all the diodes and ICs. The 23-way edge connector must be mounted the right way round and with the polarizing key at position three. The edge socket must have long wire-wrapping pins so that when mounted it will protrude through the front of the box as illustrated by our prototype (see the photograph). The socket is mounted from the component side, and the pins should protrude about 2 mm through the track side for subsequent mounting of an optional edge connector plug (to allow other ZX add-ons to be plugged in). Ensure that the socket is square and parallel to the PCB before soldering the pins. A 43-way edge connector could also be used, provided it is sawn off at either end to leave the polarizing key at position three.

The 'D' type socket should be left until last, when its right-angled pins can be inserted from the track side of the board and pushed home as far as possible. The soldering of this component is difficult but not

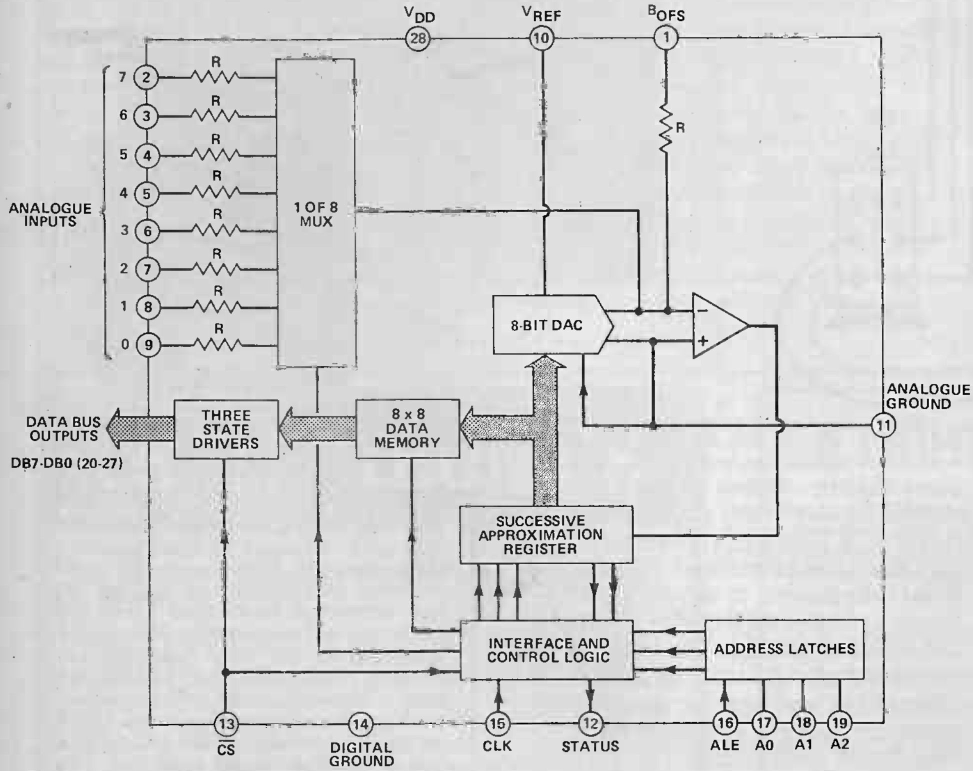


Fig. 3 Internal block diagram of the 7581.

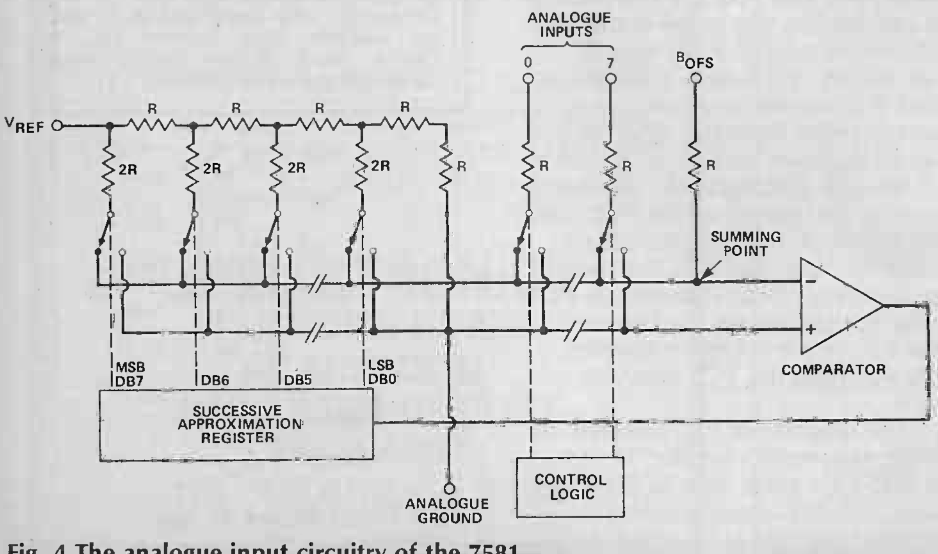


Fig. 4 The analogue input circuitry of the 7581.

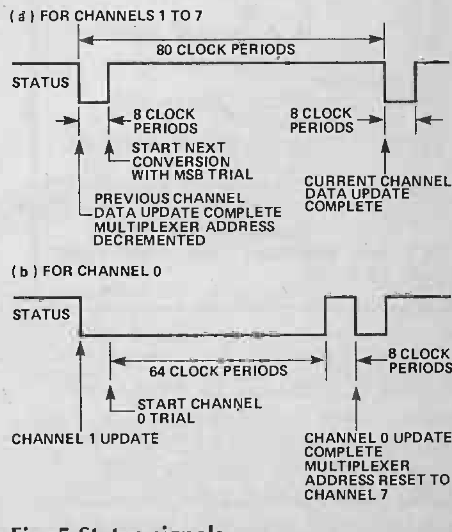


Fig. 5 Status signals.

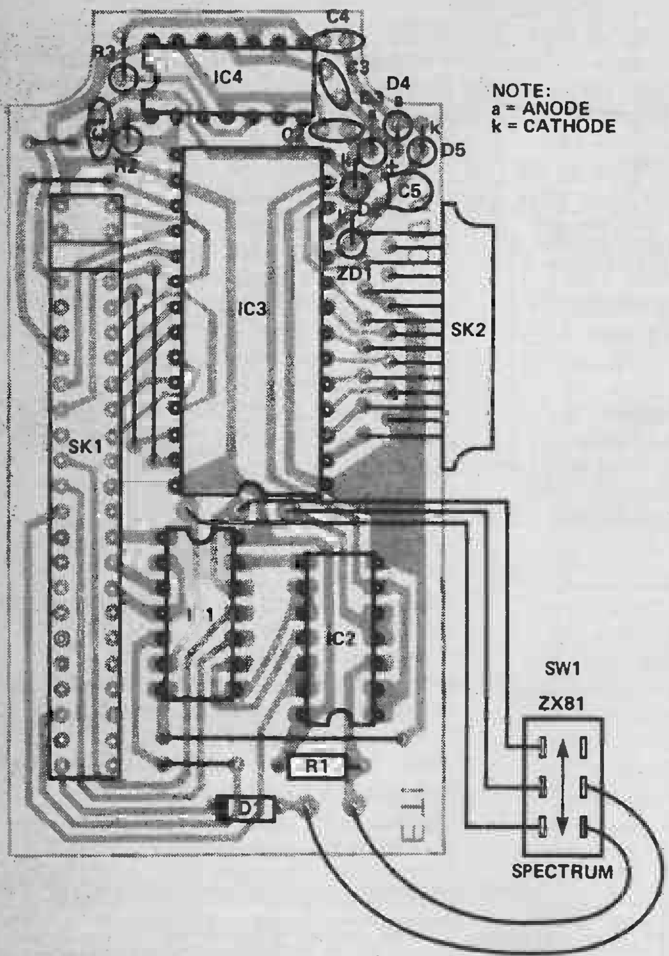
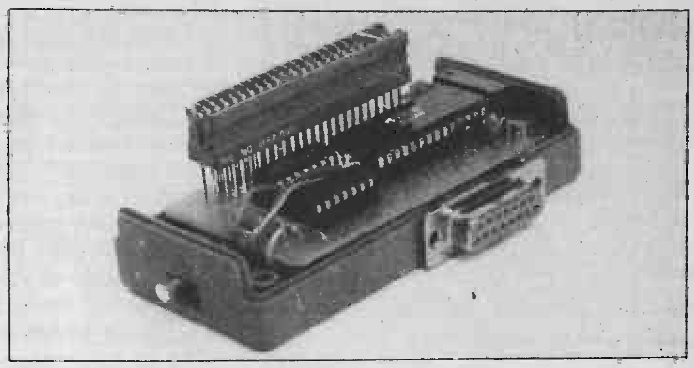
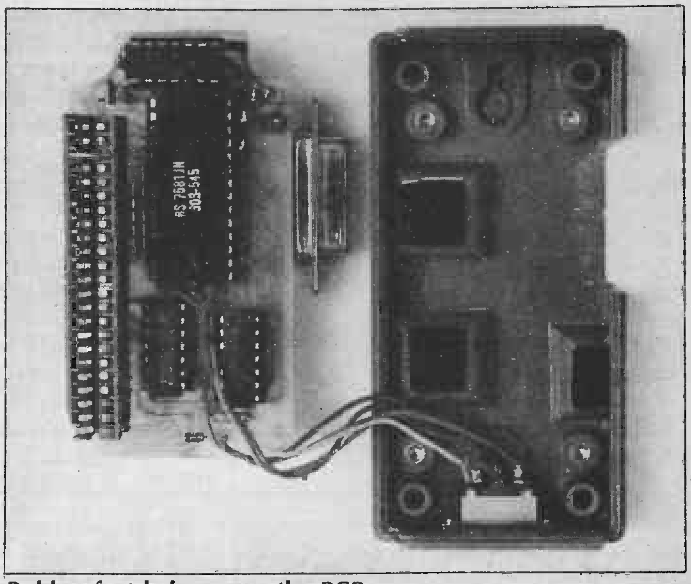


Fig. 6 Component overlay.



The socket is raised off the PCB like this.



Rubber feet help secure the PCB.

PARTS LIST

Resistors (all ¼W 5%)

R1	470R
R2	680R
R3	22k

Capacitors

C1	68p ceramic
C2-4	33n ceramic
C5	10u 16 V tantalum

Semiconductors

IC1	74LS27
IC2	74LS00
IC3	7581
IC4	40106B or 74C14
D1-5	1N4148
ZD1	10 V 400 mW zener

Miscellaneous

SW1	DPDT miniature slide switch
SK1	23-way double-sided edge connector
SK2	15-way right-angled PCB-mounting 'D' type cannon socket

PCB (see Buylines); case, Vero order code 65-2514F.

impossible, providing a small soldering bit is used.

The PCB should be filed to the shape shown in the overlay diagram, since it has to fit into the lid section of the case: the two corner pillars which take the main case bolts will also need to be filed away slightly. At this stage, a slot should be cut in the appropriate position to take the connector socket so the assembled PCB can be fitted into the lid. It should sink down until the tops of the ICs touch the inside of the lid. The edge connector should now be almost clear of the slot and the diodes and capacitors should just clear the filed-down case pillar.

By mating up the two case halves, you can find the position for an appropriate slot to be cut in the base of the case to clear the 'D' type socket. If a switch is to be fitted this should be glued, using cyanoacrylate or epoxy glue, to the side of the base section as shown in our internal photographs: the switch contacts will just clear the PCB. On our prototype we fixed three large stick-on rubber feet into the base of the Verobox; these support the PCB at the correct height, and when the case halves are screwed together, they will hold the PCB firmly in place.

The diagram of Fig. 7 shows the pinout connection for the 'D' type socket; it's a good idea to draw this along with the corresponding address locations onto an adhesive

BUYLINES

The 7581 analogue-to-digital converter chip can be obtained from Technomatic Ltd for about £8. Technomatic also stock the other semiconductors and the 'D' type connector: check their advert for prices and ordering details. The special wire-wrap 23-way edge connector for use with ZX computers can be obtained from Timedata, 57 Swallowdale, Basildon, Essex: alternatively you could get hold of a 40-way version and cut it to size as described in the main text. The PCB Service advert is on page 91 for those unable to etch their own boards. The joystick units mentioned in the text are available from Remcon Ltd, 1 Church Road, Bexley Heath, Kent (telephone no. 01-304 2055).

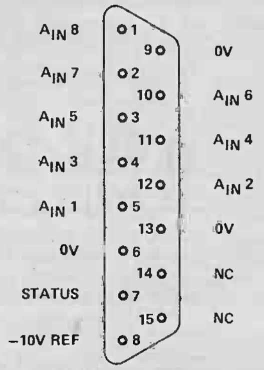


Fig. 7 Pinout for the 'D' type connector we used.

TABLE 1

CHANNEL	ADDRESS LOCATIONS ZX81	SPECTRUM
8	8199	65503
7	8198	65502
6	8197	65501
5	8196	65500
4	8195	65499
3	8194	65498
2	8193	65497
1	8192	65496

label, which can then be stuck onto the back of the box. There are two unconnected pins on the socket which could be connected (using insulated wire links) to any other two signals, say +5 V and the master clock.

Having completed the assembly, the A-to-D converter may be plugged into a Sinclair computer and tested. One of the analogue inputs may be wired up to the simple pot circuit shown in Fig. 8 and the corresponding address location can be looked at via the computer. Table 1 shows the address locations for each input; the command PEEK addr is used for the ZX81 and the command IN addr for the Spectrum. For a 0 V input the memory byte will contain 0 while

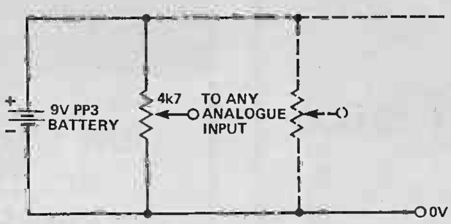
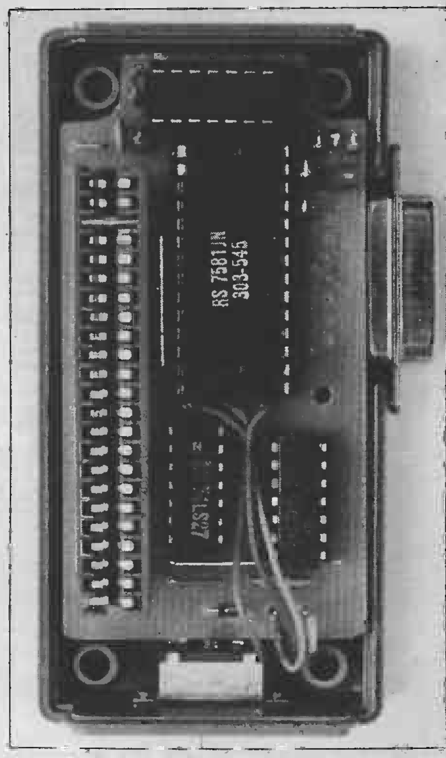


Fig. 8 How to connect pots for testing and when using the unit as a joystick port.

for the full 10 V input it will contain 255 or FF in Hex. The number (in eight-bit binary) will vary proportionately for all the voltages in between. A small program to continuously print out the value of all eight memory locations would help in the testing procedure.

After you are satisfied that the unit is working the programming options are practically limitless; eight real time voltage inputs continously available to either BASIC or machine code programs! Dedicated games players who want to use the unit to interface joysticks to the computer will find a suitable source of two-axis joysticks fitted with 4k7 pots listed in Buylines. Figure 8 shows how they should be wired up.



Using the case specified will tax your construction skills but it is possible to get everything in!

ETI

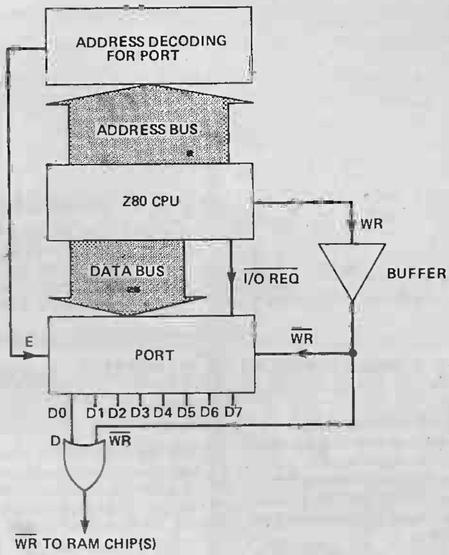
TECH TIPS

RAM To ROM Converter

A. Whitaker, Grimsby

How many times have you experimented with machine-code on an MZ-80 computer or similar system where the monitor is loaded off tape into RAM, and crashed it by accidentally re-writing the monitor? Faced with the same problem on a Z80-based system I am planning to build, I devised a method of turning RAM into ROM under software control. The idea is really very simple — after the monitor or desired language has been loaded from tape into the computer, an OUT instruction is used to program the inputs of a bank of OR gates. Whether the OR gates are inside a chip or made from two diodes and a resistor, by considering one input as an enable, we see that if the enable goes high (logic 1) the output must also go high, irrespective of the data on the other input. This can be used to disable the WRITE line going to a RAM board. When the enable input is low (logic 0) the OR gate acts as a buffer and lets the data on the other input through, so the WRITE line is unaffected. By disabling the WRITE pin on a RAM chip, the RAM is turned into a Read Only Memory — obviously this will not stop your RAM from losing its contents as soon as the power is turned off, but can prevent loss of data due to the odd bug in a user's program.

Although the basic idea was just to protect the language loaded off tape, special areas of memory can be protected by using address decoding or simply interrupting the WRITE line going to individual RAM chips. Using one of these methods, OUT statements could be used before running a program to disable most of the RAM, leaving only workspace and/or the screen (video) RAM to be corrupted by the user's program.



Modified Loudspeaker Protection Module

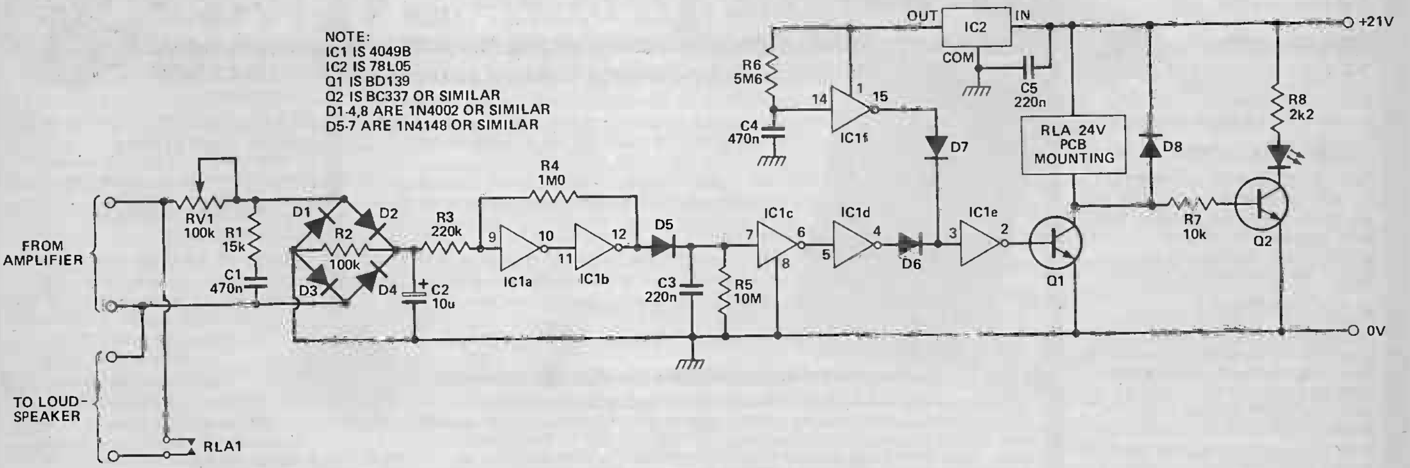
A. Caulderhead, 62 Hayfield Terrace, Denny, Stirlingshire

Having built the Audiophile 4000 system and installed the speaker protector as published in ETI July 1980, my main misgiving with this arrangement was that I had to open up the power amp case to check or change the battery; it also meant that the amplifier was connected to the speakers via two relays.

I have since built the System A amplifier and installed this modified version of the protection circuit. This uses the two spare inverters in the 4049B and gives a 2-4 second switch-on delay. The output of IC1f is at logic 1 until C4 charges up, holding IC1e's output low. Q1 is therefore turned off for this period and the loudspeakers are not connected. Q2 is biased on and LED1 lights up to indicate that the speakers are disconnected. Note that in this case, the speakers must be wired through the normally-open contacts on the relay rather than the normally-closed contacts as in the original design: this gives the added advantage that the circuit fails safe.

The whole lot is powered from the System A preamp supply, which is regulated to 5 V to power IC1.

PS. If any readers from my neck of the woods want to hear the System A they can drop a line to the above address.



Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items. ITI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for at a competitive rate.

Drawings should be as clear as possible and the text should be typed. Text and drawings must be on separate sheets. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, 145 Charing Cross Road, London WC2H 0EE.

ETI

WAVEFORM MULTIPLIER

A single VCO on a synth is, to be honest, pretty boring. Generate rich multiple oscillator sounds by hooking it up to one of our multiplier boards. Design by David Ward-Hunt.

Many synthesisers, both mono and polyphonic, utilise two or more VCOs, slightly detuned, to generate a rich chorusing sound. Chorus or phasing treatment of a single VCO can go some way towards livening up the sound, but these tend to suffer from a rather repetitive sweep and on some units a considerable amount of background noise during periods of silence — not to mention aliasing when used with high frequency high harmonic content waveforms which any decent synthesiser is capable of producing.

The beauty of using two or more slightly detuned oscillators is that in addition to producing a full chorusing sound, the problems of background noise and bandwidth are eliminated. However, multiple VCOs don't come cheap! An alternative method of achieving a 'multiple oscillator sound' is to generate additional waveforms from the existing VCO output. If each of these 'new' waveforms is out of phase with the original and with each other, then a fuller sound will be heard. However, the richness of the sound from multiple oscillators comes not from the fact that they are out of phase with each other, but from the fact that the phase difference is continually changing — the ear perceives phase *change* rather than phase difference. Therefore it is necessary not only to have additional out-of-phase waveforms, but their phase differences should be continually moving with respect to each other and the original.

A Passing Phase

The circuit described here does just that. It will accept sawtooth, triangle or sine wave inputs, though with the latter two the output will bear little resemblance to the original waveform due to the circuit action: however, they are still useful sounds to experiment with. The circuit has been used successfully to treat the VCO sawtooth outputs from a number of synthesisers including the Transcendent, Digisound '80 and PE Minisonic; it has also been used with a Korg Sigma and Roland SH02 (see the interfacing notes below). The one disadvantage of the circuit (there has to be one, doesn't there?) is that for setting-up purposes, constructors will need access to a scope or a second VCO with which to adjust the circuit to produce the correct waveforms.

The picture shows how the prototype was mounted in a Teko Alba A23 case, but this is not essential and most people will build the boards into their synth.

Using The Multiplier

The multiplier board is fed with the output from your existing VCO. With a sawtooth waveform fed to the circuit, the output is a series of six sawtooth waveforms each individually phase modulated and mixed with the original sawtooth from the VCO. One multiplier PCB (generating six 'new' waveforms) is used with each VCO. If you do have two or more VCOs each feeding a separate multiplier board the effect is outstanding, especially when the VCOs are tuned to form a chord. The output from the multiplier(s) is then fed back to the synthesiser and treated by the VCF and VCA in the normal way.

Construction

The project consists of two PCBs. The first holds the modulation oscillators for phase modulating the multiplier; the second PCB holds the multipliers and associated circuitry. The reason for splitting the project into two PCBs is that one modulation PCB is sufficient to drive up to four multiplier PCBs. (In fact there is no reason why it wouldn't drive more; however, we believe that if you intend to use more than four multiplier boards, the small additional expense of another modulator is well worth it for adding an even richer sound.)

All the components are mounted on the two PCBs with the exception of two diodes which are mounted on a switch (thereby saving two wires from the PCB to the switch). The only external connections required are the VCO input and the output from the unit plus the power supply connections (see below) which ideally should

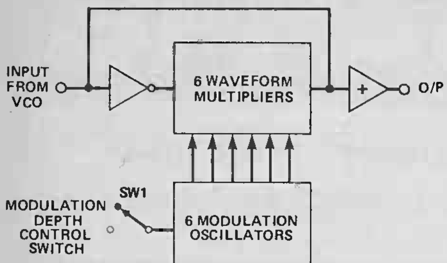


Fig. 1 Block diagram of the ETI Waveform Multiplier. Should you require an even richer sound, there's no reason why more than six multipliers shouldn't be used.

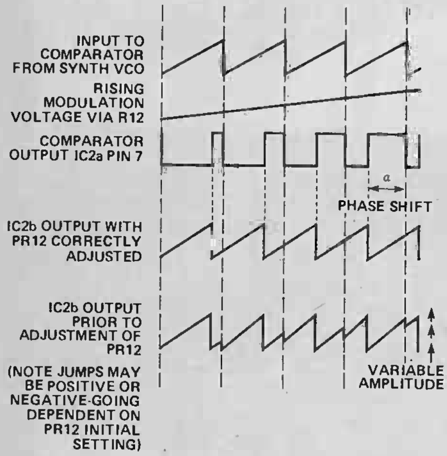


Fig. 2 The waveforms associated with various sections of the circuit. This indicates the operation of the unit and will also guide those people who are setting up the unit with an oscilloscope.

come from the same power supply as the VCO being input to the unit.

Interwiring between the PCBs should be clear from the diagram, as should the wiring up of the switch with its associated zener diodes. The switch is a DPDT with centre off and it is essential (for setting-up purposes if nothing else) to have this 'off' position (see Buylines).

A note is in order here about the component numbering. In order to make the numbering clearer and logically the same for each of the six multipliers on the PCB, each resistor or preset is designated by a two-figure number. The first figure indicates which of the six multipliers it is associated with, and the second is the 'relative number' of the component. For example, R11 is 'R1' on the first multiplier, R21 is 'R1' on the second multiplier, R35 is 'R5' on the third multiplier and so on.

With regard to the modulation PCB, though all the capacitors are of the same value, take care not to mix up the resistors associated with the two oscillators, as each oscillator should have all three of its resistors the same value. If not, the modulation output waveform will take on a pulse form at the output associated with the first op-amp in each oscillator.

PARTS LIST

MODULATION BOARD

Resistors (all ¼W, 5%)

R1-3	1M8
R4-6	2M2
Capacitors	
C1-8	100n polyester
Semiconductors	
IC1	LM324
IC2	LM1458
ZD1,2	6V2 400 mW zener
Miscellaneous	
SW1	DPDT with centre off (see Buylines)
PCB	(see Buylines)

MULTIPLIER BOARD

Resistors (all ¼W, 5%)

R1-3, 11,12,13,14, 15,16,21,22, etc to 66	100k (39 in total)
R4	18k
Potentiometers	
PR11-61	100k miniature horizontal preset (six in total)
PR12-62	220k miniature horizontal preset (six in total)
Capacitors	
C1,2	47u 16 V PCB electrolytic
C3-6	100n polyester
Semiconductors	
IC1	LM1458
IC2-4	LM324
D1-6	1N4148

Miscellaneous

PCB (see Buylines); case to suit (Teko Alba A23); sockets to suit.

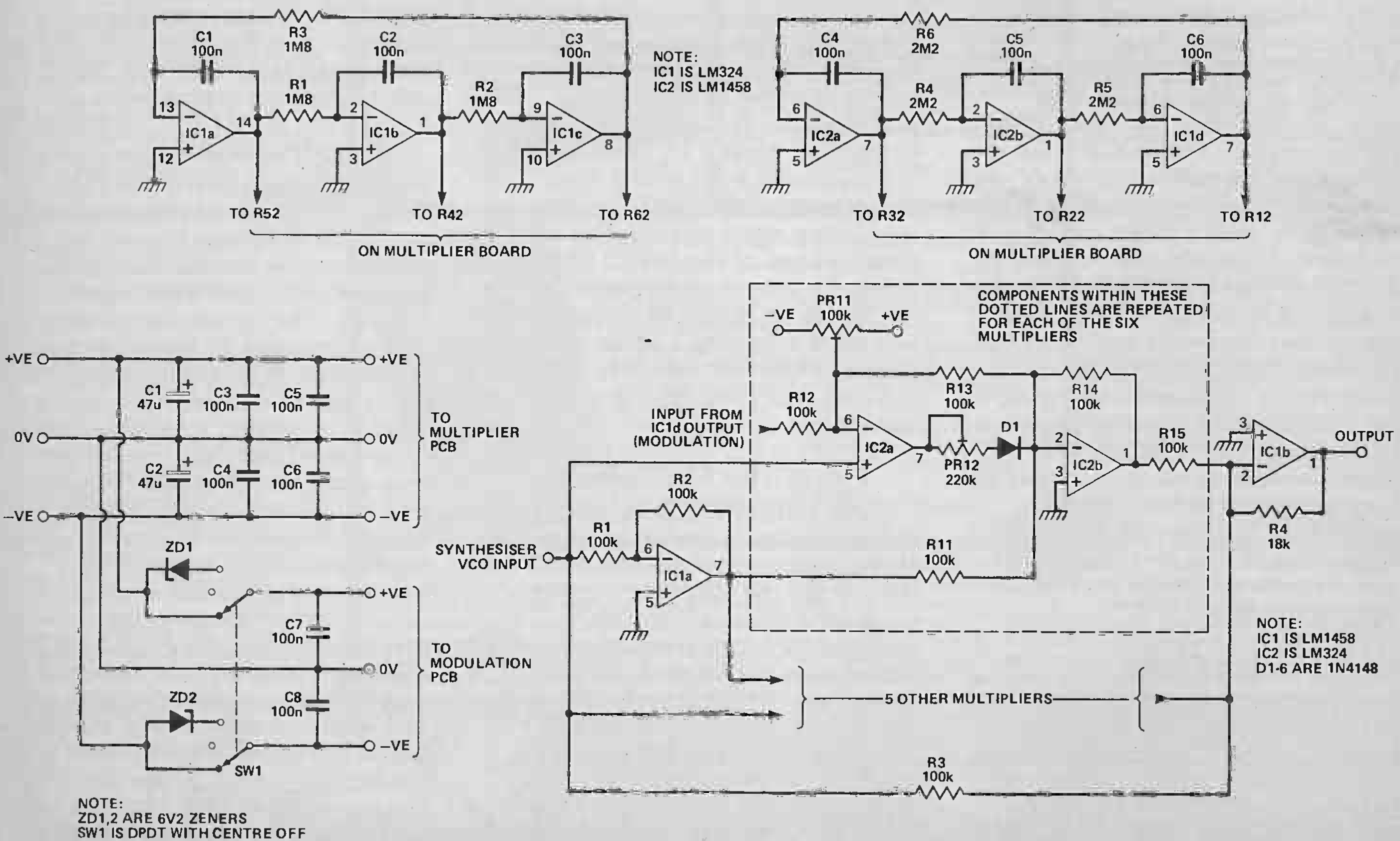


Fig. 3 Complete circuit diagram of the Waveform Multiplier.

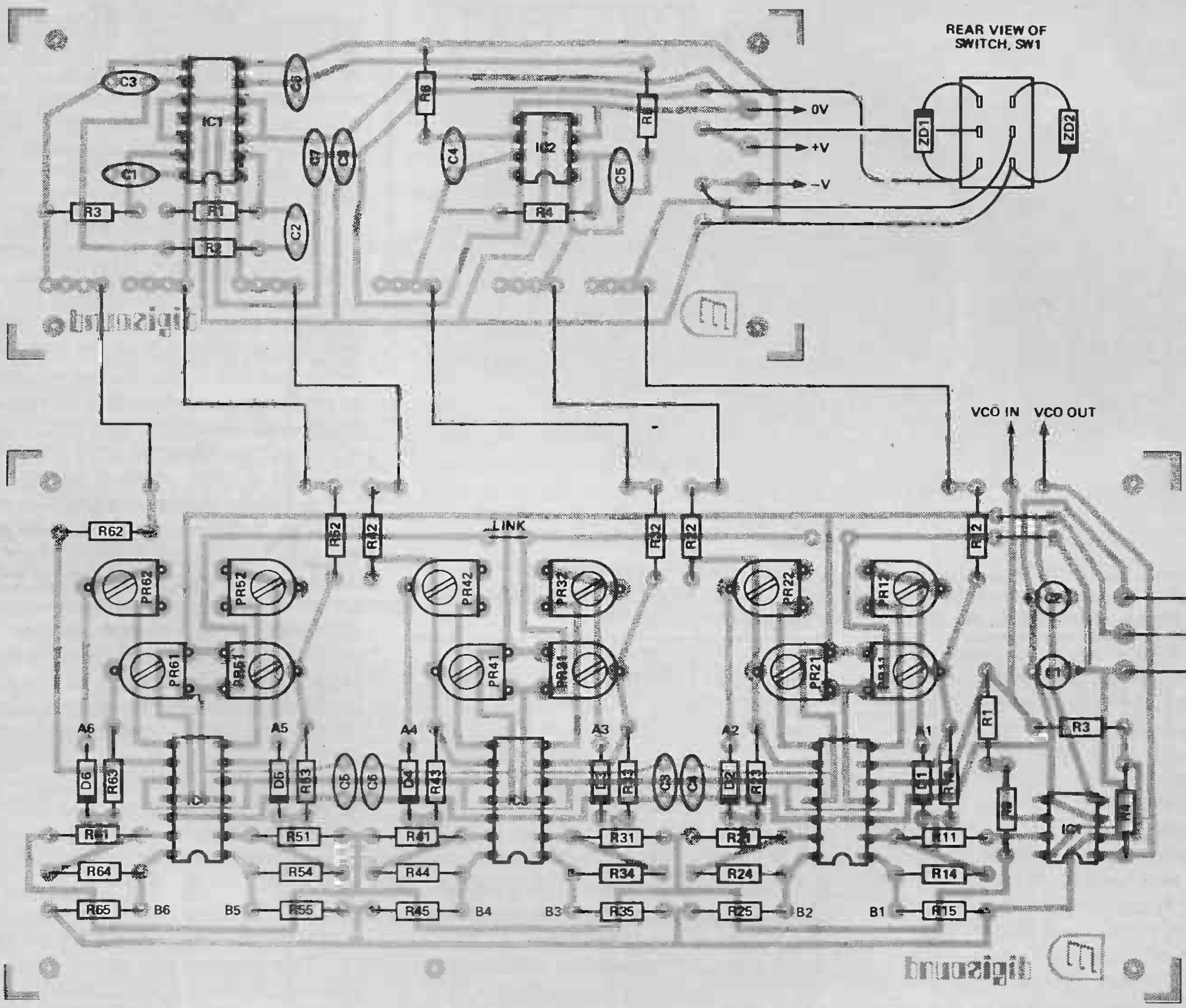


Fig. 4 Component overlays for the modulator board (top) and the multiplier board (bottom), and the interwiring required. Several multiplier boards may be driven from one modulator board.

HOW IT WORKS

The modulation oscillators are based on a standard three phase oscillator; two of these are used. Each of the three integrators in the loop outputs a waveform that is one-third of a cycle behind the others. The speed of the two oscillators is set at about 0.6 Hz and 0.4 Hz respectively. This modulation rate was found to give the best simulation of a number of oscillators running in free phase over a wide keyboard span.

It should be noted that the output of these oscillators is, in fact, a trapezoid shape waveform and it might be thought that some filtering would be required to produce a waveform more akin to a sine wave. This was tried in the development stage, but in practice the trapezoid waveform gave a better randomness to the overall output, whereas with a sine wave modulation a more definite sweep could be detected on long sustained notes.

Referring now to the multiplier circuit, the output from the synthesiser VCO is taken to IC1a configured as an inverter/buffer; the VCO waveform also goes to one input of the comparator IC2a. The other input of the comparator is fed with a voltage set up on PR11 together with the modulation voltage via R12. With a positive-going sawtooth, the point at which the comparator goes high is determined by the sum of the fixed voltage from PR11 and the modulating voltage via R12. As shown in the waveform diagram, with a rising modulation voltage the width of the pulse at the comparator's output increases. However, the comparator will, of course, always reset at the same moment as the VCO sawtooth. Thus the comparator's reset is synchronised with the original sawtooth, whereas its positive-going excursion can be voltage-controlled to any point within one cycle of the input waveform.

The output of the comparator is rectified by D1 and summed with the inverted sawtooth from IC1a via R11. These voltages (actually currents) result in a new sawtooth whose reset point is determined by the positive-going edge of the comparator. Thus, as shown in the waveform diagram, this new sawtooth is phase-shifted from the original and the amount of phase shift is dependent on the comparator pulse width. The output of the summing amplifier IC2b is taken via R15 and mixed with the other multiplier outputs plus the original sawtooth (via R3), where IC1b acts as the mixing amplifier.

Setting Up

As stated earlier in the article, setting up requires access to an oscilloscope; you should have two VCOs and some method of listening to their output, but hopefully these requirements will not be a problem for most constructors.

Once all the components have been installed, ensure that the ICs, diodes and the two polarised capacitors are correctly orientated. All the ICs should be facing the same way and the diodes mounted on the PCB should have their band pointing towards pin 1/pin 14 of the ICs. Turn all the presets to their mid-position.

The setting up procedure is reasonably straightforward, though repetitive, since each of the six multipliers has two presets which need to be adjusted; however, your efforts will be rewarded! Constructors with access to a scope will find it easier to use the scope to see the various waveforms mentioned in the text. Those of you

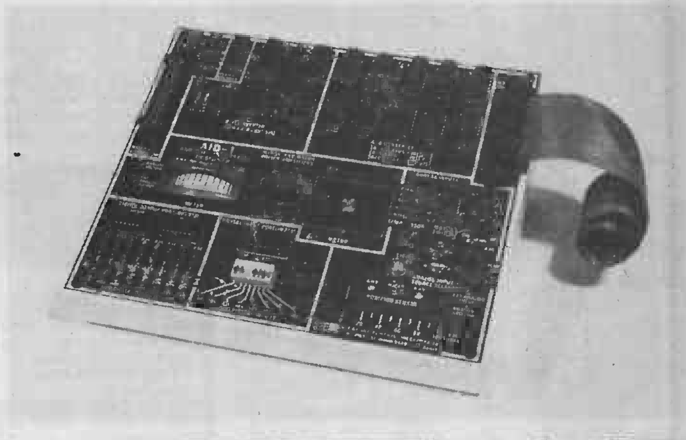
Compact Speakers with Sealed Mylar Diaphragm

New from G. English Electronics is a series of dynamic mylar audio speakers designed for use in all types of portable industrial and domestic receiving or reproduction equipment. Introduced as the DSH Series, these highly compact dynamic mylar speakers are claimed to provide sound reproduction of exceptional quality, combining good bass response with low distortion and smooth upper frequencies. They are designed for use with amplifiers of 8-ohm to 200-ohm output impedance, and have an impedance tolerance of ±20%. Their sensitivity at 1.5mm is 108 dB/mW at 1 kHz, and claimed frequency response is 20 Hz to 20 kHz. The rated and maximum inputs of the DSH Series are 30 mW and 100 mW, respectively.

An important feature of these miniature speakers is that they may be supplied with special terminations to meet individual application requirements. This means that they can be incorporated, without modification, into an extremely wide range of equipment, typically portable transceivers, headphones, domestic and office audio reproduction systems, etc. Their dimensions vary according to their rated output, from 27.1mm dia. × 14.3mm up to 45.0mm dia. × 8.2mm. G. English Electronics Ltd, 34 Bowater Road, Woolwich, London SE18 5TS. Tel: 01 855 0991.

Design Teaching Aid

The Research Machine 380Z can now be interfaced to the E & L Instruments AID-1, Analogue Interface Designer. Developed by Imperial College of Science and Technology with supporting educational text written by Edward James, the system provides an introduction to A/D and D/A conversion, and enables the student to have an understanding of the relationship between the computer and control applications. The AID-1 is complete with electric motor, sensors for temperature, position, light meter digital inputs/outputs with LED indications. Other interfaces are also available for TRS-80 and AIM 65. E & L Instruments Ltd, Whitegate Industrial Estate, Whitegate Road, Wrexham, Clwyd LL13 8UG. Tel: 0978 263030.



Shorts

●CUB miniature counters are now available with a new range of converter modules that allow count inputs to be taken from solenoids, contactors, logic sources, and sensors with triac outputs. The modules are protected against dirt, oil, water and most chemicals by PVC encapsulation. Eurovector Ltd, Wessex House, Silchester Road, Basingstoke RG26 6PX. Tel: 07356 3693.

●Motorola have announced several new products including: a plastic-packaged (T0220) 40 A (RMS) thyristor with 400 A surge capability; 'medium' current (up to 100 A!) power darlington transistors capable of switching 25k VA, the MJ10040 series; and, in the next few months, a series of gate arrays in ECL, ALS and CMOS. Motorola Ltd, York House, Empire Way, Middlesex HA9 0PR.

●Ross Electronics have launched a range of micro speakers and booster amplifiers for personal stereos. Ross Electronics, 49/53 Pancras Road, London NW1 2QB.

●Texas Instruments claim to be producing the first single-chip dual peripheral drivers with single-saturating transistors capable of outputting up to 500 mA. Designated the SN75407 (NAND inputs) and the SN75408 (NOR inputs), the 100-off price will be around 55p. Texas Instruments Ltd, Manton Lane, Bedford MK41 7PA.

●Also available from Texas is a new handbook covering information and instruction on microprocessor systems, called (original title!) 'Software Development'. The book is aimed at both software learners and experienced engineers, and Texas say that it covers the basic steps in the software development process. It costs £12.90 (plus £1.50 p&p) and is available from Texas Instrument Ltd, PO Box 50, Market Harborough, Leicestershire.

●Zilog are at it again, this time with a new data book describing their full range of microprocessor products. Available from Zilog distributors, it costs £3, which looks like a bargain for 643 pages of information. Zilog (UK) Ltd, Zilog House, Moorbridge Road, Maidenhead, Berks SL6 8PL.

●A little more expensive than the Zilog book is a new publication from Granada Publishing Ltd, PO Box 9, St Albans AL2 2NF, called the Microprocessor Data Book, by S A Money. It doesn't sound that thick at 288 pages, but believe us, when it landed on our desk it nearly carried on going — it's in a large format, so it is heavily laden with facts. If we ever manage to plough through it all, we will give you a more considered opinion on all 1.4kg of it!

●Bradford & Ilkley Community College, Great Horton Road, Bradford, West Yorkshire will be running a course to prepare for the morse examination in the Radio Amateurs 'A' Licence. The one year course will commence on 12th January, with classes on Wednesday evenings from 1900 to 2100 hrs. (Note: if other colleges are running similar courses, we and our colleagues on 'Ham Radio Today' would be most interested to hear about them with a view to publishing details.)

●New products from Raytheon Semiconductor, Howard Chase, Pipps Industrial Area, Basildon, Essex SS14 3DD: a 10-bit 85 nanosecond D to A (that's fast enough for a video signal!) called the DAC-10; and 16 and 32K PROMs and SPROMs in 24-pin 0.3" packages.

●Ground Control (they really are called that, we have the letterhead to prove it), of Alfreda Ave, Hullbridge, Essex SS5 6LT, are producing a RAM pack for the ZX81 that, they claim, eliminates the disconnection problems that can occur with other RAM packs. They claim that you can pick up your ZX81 and shake it without a crash occurring. The basic unit costs £19.95, or £24.95 with an added keyboard sounder (prices include VAT and p&p).

●Looking for a 2A or 6A high-efficiency diode with a recovery time of 25 (or 30) nS? Then contact Power Technology Ltd, Boulton Road, Reading, Berks RG2 0LT, because they've just started selling some devices made by Varo Semiconductor that may fill the bill.

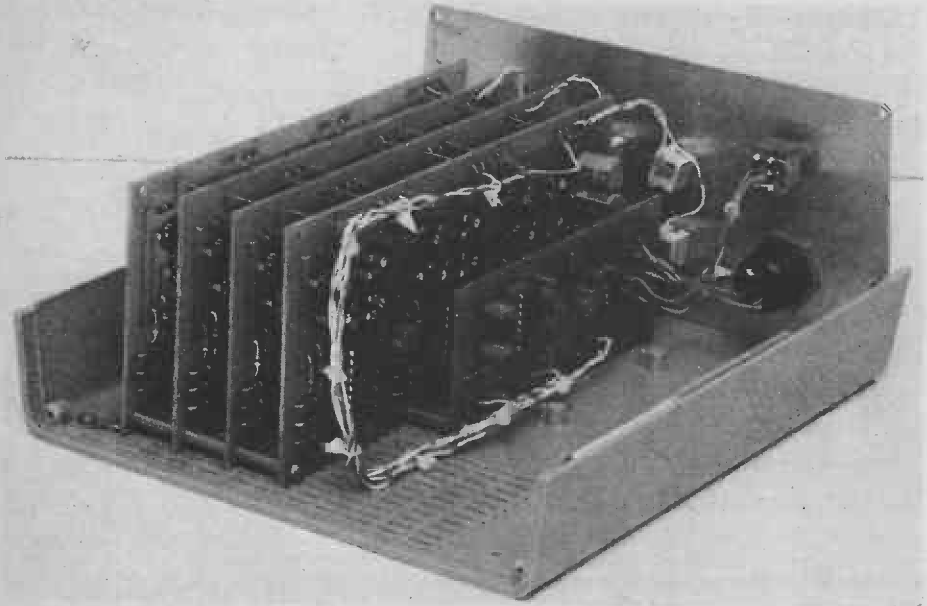
●We don't know what has gone wrong this month, as we have heard of only one new multimeter being launched — must be the time of year. This one is from Keighley Instruments Ltd, 1 Boulton Road, Reading, Berks RG2 0NL (must be next door to Power Technology), and it's called the 132. It's unusual in that it's a hand-held instrument with true RMS AC ranges and a temperature range (somebody at Keithley must have been reading Tim Orr's series on measurement techniques. . . .).

●A four-wheeled motor-driven chassis that might form the basis of a small robot (the chassis measures approx 10" × 6" × 3") is available for less than £40 from DRJ Electronics, PO Box 394, London SE6 1TR (catalogue 60p).

●Ambisonics is not dead, but are keeping a low profile of late after all the 'hype' several years ago. Minim Audio, of Lent Rise, Burham, Slough SL1 7NY, are hoping to their bit to bring it back to the public eye with their AD2 surround sound decoder module. The module costs £49.95, and will, when mounted in a 'host' amplifier, decode UHJ-encoded recordings as well as enhancing normal stereo recordings.

●The BBC has published its plans for direct broadcasting by satellite in a booklet called (wait for it) 'Direct Broadcasting by Satellite — the BBC's Plans'. A limited supply of these will be available on a first-come first-served basis from the Engineering Information Department BBC, Broadcasting House, London W1A 1AA (large A4 size stamped addressed envelope required).

●Connectors' Corner — we seem to have more new connectors this month than anything else. Semiconductor Specialists (UK), of Carroll House, 159 High Street, Yiewsley, West Drayton, Middlesex UB7 7BX have introduced the '400' range of dual-beam (thought they were 'scopes) DIP sockets; BFI Electronics Ltd, 516 Walton road, West Molesley, Surrey KT8 0QF have a new snap-in connector range called the Series 600 that's already in use in the French telephone industry; BICC-Vero Connectors, Parr St, St Helens, Merseyside have introduced the M50 series fixed-pitch (1.27mm) flat-cable connecting system with a wide range of different connectors; and finally, Davico Industrial Ltd, Charles Street, West Bromwich, West Midlands have issued what they claim is the definitive catalogue of electrical terminals, connectors and cable ties. ETI



A view inside the prototype showing how it is configured to provide four independent channels driven by one modulator board. Miniature jack sockets are used for input and output (see also the lead photograph).

without a scope will be using your ears rather than your eyes, so make sure you have some means of listening handy. Either an amplifier and speakers, or headphones of reasonable quality will do, but remember we are listening to a 'raw' signal so don't stick it straight into your favourite hi-fi amp!

The first step is to power up the circuit and apply a VCO sawtooth waveform running at about 500 Hz (for ease of listening — so with a scope it doesn't matter). Ensure that the modulation switch is in the off position. Attach a lead to the output of IC1b (junction of pin 7 and R2). This should be outputting the VCO sawtooth (inverted). Next move the scope probe or audio lead to the junction of D1 and PR12 (marked A on the component overlay). This is the comparator output from which we want to get an approximate square wave output. At first you may hear no sound at all, but as PR11 is rotated you should hear a square wave break in with the pulse width varying as you turn the preset. Adjust PR11 for an approximate 50% duty cycle. (For those unfamiliar with this sound, adjust PR11 for the 'loudest' sound. When the duty cycle is less than about 30% or more than about 70% a 'thin' spiky sound predominates, so set PR11 midway between these two — an accurate 50% is not important.) Repeat this step on each of the five other multipliers.

With the comparators now set up, we need to adjust the presets on the comparator outputs so as to give a smooth sawtooth waveform. PR12 is the preset associated with this adjustment. Attach your lead to the output of IC2b (junction of pin 1 and R15 — point B on the overlay). Until PR12 is correctly adjusted the sawtooth will contain a jump in it as shown in the waveform diagram. Using a scope, all you need to do is turn PR12 until this jump is smoothed out. Without a scope you will need two VCOs in order to accomplish this adjustment.

First, slow down the VCO which is connected to the circuit, to its lowest setting (somewhere around one cycle per second is fine). Now attach a lead from the aforementioned junction of pin 1 and R15 (point B) and run it to the FM input of your second VCO. If you now listen to the output of this second VCO it will be frequency-modulated by the sawtooth wave that we need to smooth out. So all you need to do now is turn PR12 until this second VCO gives a smooth upward frequency sweep followed by a sudden return to the starting frequency. This may sound difficult to perform but in fact it is surprising how easily the ear can detect any jumps in the modulating waveform. However, if you are unsure of what a VCO sounds like when it is being frequency-modulated by a slow running sawtooth, listen to this effect on its own before trying to set up PR12. Again this adjustment is carried out on each of the six multipliers.

With all the multipliers now set up, speed up the VCO connected to the circuit, attach a lead to the output and you should see/hear a multiple sawtooth waveform. Now switch the modulators on (either setting of SW1) and you should hear a 'phasing' sound as the modulation builds up. Finally, check that the two 'on' positions of SW1 give different depths of modulation.

If, when the modulation switch is set to 'full' you find you can hear a distinct pause or break in one of the new waveforms, this indicates an incorrect setting of the preset associated with the comparator. To determine which one needs a finer adjustment, check each of the six multipliers by attaching an audio lead or probe to point B and adjust PR11, 21, 31 etc as appropriate, so that even with full modulation depth the comparator (and thus the sawtooth) remain within the range of one full cycle of the original sawtooth.

Interfacing Notes

The original circuit was developed for a Digisound 80 modular synthesiser; this has ±15 V supplies and a positive-going 0–10 V VCO output. However, the circuit is fairly tolerant of a wide range of conditions and can be adapted to almost any synth with possibly some small additional components. The most likely problem concerns the ratio of the VCO output amplitude when compared with the voltage supply rails. The minimum and maximum supply voltages to the circuit described are ±5 V to ±16 V. Bearing in mind these two limits, the waveform to be treated should be equal to or greater than one-third the sum of the voltage rails.

If the input waveform does not meet these requirements the obvious course is to add an op-amp to the front end of the circuit to bring the waveform up to the required level. For instance, with the PE Minisonic, which is pretty much a worst case, the power supply is ±9 V, the VCO output is 1 V peak-to-peak. In this case a simple ×6 amplifier would do, but so as to allow plenty of headroom a ×8 amplifier was made up. **ETI**

BUYLINES

A kit of parts for this project, comprising glass fibre PCB and all electronic components, is available from Digisound Ltd, 14-16 Queen Street, Blackpool, Lancs FY1 1PQ. The prices, inclusive of VAT and postage, are £10 for the multiplier and £6.05 for the modulator. Housing the project is entirely up to you and most people will simply fit the boards inside their synth, but we put ours into a Teko Alba A23 case to match the rest of the Project 80 modules. If you want to do likewise, the case is available from West Hyde, Unit 9, Park Street Industrial Estate, Aylesbury, Buck.

CONFIGURATIONS

And so to op-amps, the most venerable members of the linear IC family. Ian Sinclair traces their ancestors, descendents and lifestyle.

Before the reason for the name becomes shrouded in the mists of history, perhaps it's just as well to look at the origins. Operational amplifiers were designed for analogue computers, which are machines used for solving mathematical equations. They do so, not by using binary arithmetic as digital computers do, but by connecting up a network of components which represents either a mathematical relation or an equation. In the case of a mathematical relation (eg, $y=x^2$) the circuit will have an input, x, and an output, y, that will vary according to the relationset up and according to the value of x. Equations can be either ordinary (eg, $x^2+4x+3=0$) or differential (eg, $d^2y/dx^2+x=0$); the circuit will be connected in a loop, and in the case of the ordinary equation it will give an output that represents the solution (or one of the solutions) to the equation. The solution to a differential equation is itself a mathematical relation (in the case of the example given above, $y=A\sin x+B\cos x$), so the circuit will have an input and an output (the coefficients of the equation, A and B, will be determined by the initial values of the circuit voltages, but that takes us a bit beyond the present scope of this article).

An essential part of representing a mathematical operation in electrical terms is an amplifier with very high gain whose frequency response can be modified by using negative feedback. Typical operations that can be simulated by amplifiers of this sort include the mathematically important ones of differentiation and integration (Fig. 1), and the amplifiers which were designed for these purposes very reasonably became known as operational amplifiers.

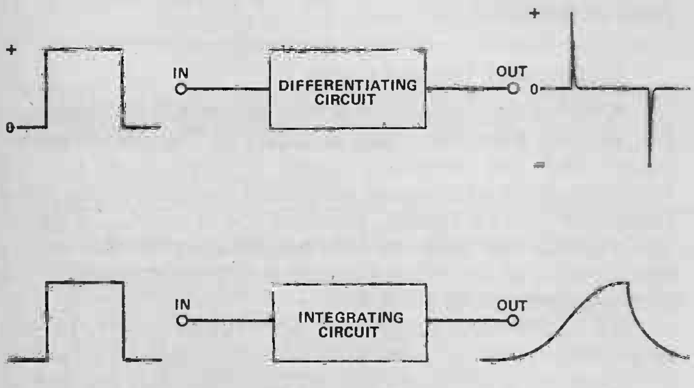
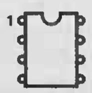
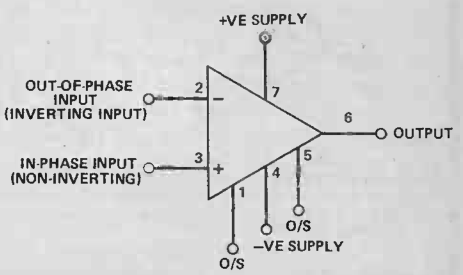


Fig. 1 The operations of differentiation and integration performed on a square wave.

The Perfect Specimen

The specification for a perfect operational amplifier was that it should have infinitely high gain, infinitely high input resistance, zero output resistance, and as much bandwidth as was needed — it was particularly important to have the gain maintained right down to DC. Analogue computers are still produced, though they don't have the importance they once had, and the operational amplifiers which were once made using valves, and then transistors, are now made as ICs. The requirements are still pretty much the same, because our definition of an operational amplifier nowadays is as a high gain DC-coupled amplifier whose behaviour can easily be controlled by using negative feedback. Since the behaviour (gain, bandwidth, shape of gain-bandwidth curve) is so easily modified by the use of negative feedback, the operational amplifier is the nearest thing we have to an all-purpose amplifier, and that's why operational amplifiers were among the first linear ICs that were produced.





MAXIMUM RATINGS

POSITIVE SUPPLY = +18V
NEGATIVE SUPPLY = –18V
DIFFERENTIAL INPUT = ±30V
COMMON-MADE INPUT = ±15V
LOAD CURRENT = 10mA
OPERATING TEMP. = 70°C
STORAGE TEMP. = 140°C
DISSIPATION = 400mW

TYPICAL CHARACTERISTICS

INPUT RESISTANCE = 1M0
OUTPUT RESISTANCE = 150R
OPEN LOOP GAIN = 10,000+

Fig. 2 Part of the specification for the 741 op-amp.

To start with, consider the typical specification of one of the best-known op-amps, the 741. This is illustrated in Fig. 2, to show how close we can get to the ideal specification. One point of importance is the bandwidth. If you use a 741 at its full gain, you must expect the bandwidth to be very severely limited — less than 100 Hz at maximum gain. Some care has to be taken if 741s are used in audio circuits, because in some feedback circuits that include filtering the chip may be working at a very high gain at the ends of the bandwidth, even though its midband gain is low.

Offset Problems

Getting down to configurations, the main point about op-amp circuits is how to bias them. Very few applications call for the 741 to be operated as a differential DC amplifier at full gain, but for these applications a balanced power supply is needed. Additionally, some form of input offset balancing will be needed. This is necessary because there are bound to be some very small mis-matches between the resistors and transistors that make up the two input circuits (see later). The gain of the op-amp is so high that any imbalance will be amplified up, so that with both inputs tied to zero, the output of the op-amp will not be zero by quite a margin.

Manufacturers usually specify typical and maximum *input offset voltage* and *input offset current*. These are the *differences* between the input voltages and the input currents (with both inputs very close to zero volts) needed to obtain an output voltage of zero. With the 741 and many other op-amps there are offset trim connections that allow you to trim out the voltage offset. A circuit for the 741 is shown in Fig. 3. However, the input currents will still be slightly different, and there may be the odd circuit

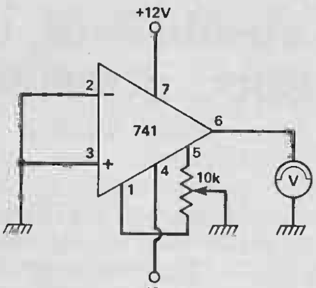


Fig. 3 Using the offset adjustment to balance out the internal currents.

for which this will need to be taken into account.

The offset adjustment will have to be repeated at intervals, because the settings *drift*. The effect of temperature and time conspire to make the output voltage change (drift) away from zero, so that an op-amp at full gain is a rather unstable device which needs frequent checking. Fortunately, we seldom need to make use of the full gain of the op-amp, and most of the circuit configurations make use of feedback bias circuits.

Figure 4 shows one of the most common bias methods. The circuit uses a balanced power supply, and bias is obtained by connecting a resistor between the output and the out-of-phase or inverting input (marked as –). The in-phase or non-inverting input (+) is connected to earth, so that the output voltage will be almost zero, just enough to apply the correct offset voltage (which is usually less than a millivolt) to the inverting input. The gain of this circuit depends on the resistance of the signal source. If we represent this as a resistor in series with the input, R1, then the gain is simply –R2/R1 (the – sign indicates that the signal is inverted).

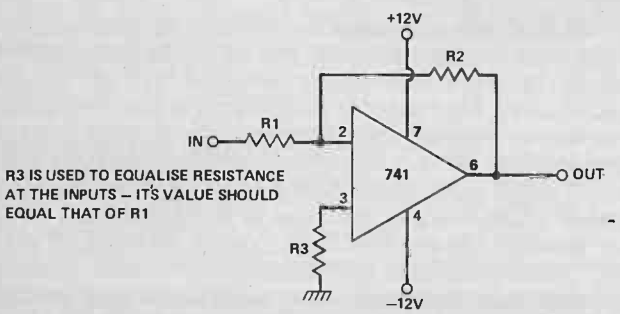


Fig. 4 The feedback bias system in a circuit which uses the out-of-phase, or inverting input for signals.

This circuit is DC-coupled throughout, but if we do not need DC gain, then a single-ended supply version can be constructed, as indicated in Fig. 5. Capacitor coupling must then be used to avoid shorting out the bias voltage, choosing capacitors with low leakage, and the supply voltage must be adequate — the quoted minimum voltage across the chip is 3 V.

When this configuration is used, the inverting input voltage remains practically constant when a signal is applied. When a balanced power supply is used, in fact, the inverting input is virtually at earth voltage, and this 'virtual earth' effect means that signals applied to the input terminal (one end of R1) are flowing through R1 to a point

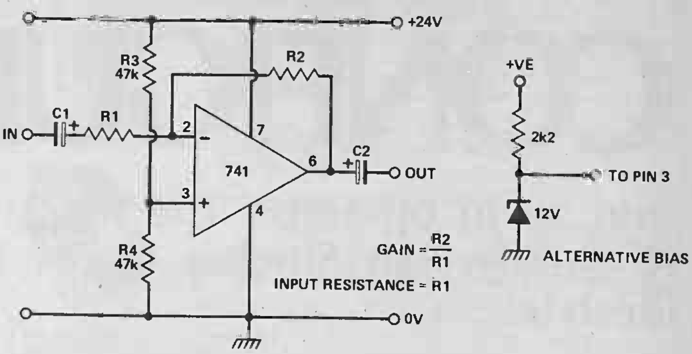


Fig. 5 A single-ended power supply version of the Fig. 4 circuit.

which is as good as earthed as far as signals are concerned. This makes the input resistance of the circuit equal to the value of R1, and it limits the application of the circuit to some extent, because if the input resistance is to be reasonably high, then the feedback resistor R2 will have to be of an unreasonably high value to achieve a modest gain. If the feedback resistor has too high a value (in the megohm region), then the bias currents at the input of the chip, typically 200 nA, will cause voltage drops which we can't ignore without making our calculations go considerably astray. The input resistance of the op-amp itself is large, but the use of negative feedback to the same input as the signal makes the input resistance low because of the 'virtual-earth' effect.

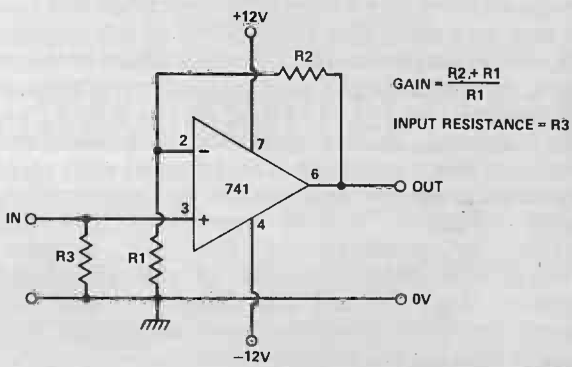


Fig. 6 Using signal input to the in-phase, or non-inverting input of the 741.

Improved Impedances

Another configuration of the op-amp is illustrated in Fig. 6. This time the input is taken to the non-inverting input, and the inverting input is used only for the feedback. In this balanced version of the circuit, the input resistance can be higher, because the resistance R3 does not control the gain of the amplifier, and the source resistance is of no interest unless it is unusually high. The gain is given by (R2 + R1)/R1.

It's quite straightforward to combine the biasing arrangements of Fig. 5 with the non-inverting circuit of Fig. 6. However, a word of caution: all those resistors and all those capacitors combine to form low-pass filters, and at frequencies around their cut-offs, these will all produce considerable phase-shifts, and this may lead to what you've designed as an amplifer actually turning out to be an oscillator!

Slewing About

The 741 type of operational amplifier has a lot a merits, but it is a design which is now showing its age. Much more recent designs have, in particular, wider bandwidths, and are impressively better in one respect — slew rate. The slew rate of an operational amplifier is the maximum rate-of-change of output voltage expressed in volts per microsecond, and it affects large signals (which change by a greater voltage) more than small signals. The point is that if the maximum rate of change of voltage is 1 V/us, then a 10 V change would need 10 us, and a 10 V signal is limited to one tenth of the bandwidth of a 1 V signal. The effect in practical terms is that the useful bandwidth of the amplifier for sine waves depends on the amplitude of the waves, and the shape of output for a square wave input also depends on the amplitude of the wave.

Slew rate limiting is caused by stray capacitances within the chip. When voltages change, these stray capacitances have to be charged or discharged, and the amount of current which flows in the input stages is very small, not enough to allow these capacitances to be charged or discharged quickly. All amplifiers suffer from this to some extent, but slew rate is much less of a problem for discrete component circuits whose circuits are not DC-coupled and which can therefore use large currents and small values of load resistors. The typical slew rate of the 741 is 0.5 V/uS, and this is rather poor in comparison with more modern designs such as the Motorola MC1741S, which has a slew rate of 15 V/uS.

The other feature of the 741 which causes problems is that the peak amplitude of signal output must not be allowed to approach the supply voltage limits, because the internal biasing is no longer effective if this is done. This restriction can be quite irksome if the op-amp is to be used with low voltage single-ended supplies, and an alternative for such applications is the current difference amplifier (CDA), of which the best known example is the National Semiconductor LM3900N. This chip is an operational *current* amplifier whose internal circuitry, though remarkably similar to that of the 741, allows operation at output voltage levels very close to either ofthe supply voltages.

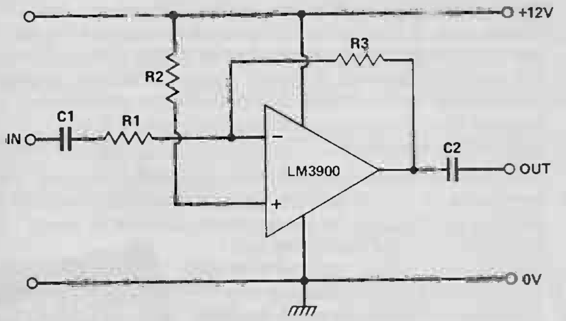


Fig. 7 A typical LM3900 circuit.

The design principles for CDAs are very different from those used in the 741. The output voltage depends on the difference between the *currents* at the two inputs, and the circuits that use these chips are distinguished by large resistor values. In the circuit of Fig. 7, for example, if we aim for an output voltage which is half of the supply voltage, then, remembering that the current through R3 must be the same as the current through R2, the value of R3 must be half of the value of R2. Since the input currents are very low, these resistor values have to be high, and values of several megohms are common. The voltage gain in the circuit shown is R3/R1, as for the 741 type of amplifier, but the voltage swing at the output can reach very close to the supply voltage limits. Current difference amplifiers are used mainly in circuits which operate at the lower ranges of frequency because of the effects of stray capacitances on the very large value bias resistors. **ETI**

PROGRAMMABLE POWER SUPPLY

We hear a lot these days about computing power but here it is, literally. With this PSU plugged into a suitable port on your micro you can control your voltage and current bit by bit. There's manual control, too. Design by Phil Walker.

This versatile piece of equipment is basically a programmable power supply. It allows you to set the output voltage and/or current to very close limits by means of your computer keyboard without actually touching the unit itself. Even more useful, in some cases, is that a sequence of voltage and/or current levels can be programmed in advance. The unit has a range of 0–25V5 in 100 mV steps and 25 mA to 1A6 in 25 mA steps.

The prime controlling element in the power supply section is an LM317 integrated voltage regulator device. In this project it is used as a high-gain self-protecting power transistor. In order to get the rated output from the device under all operating conditions, two power rails are used. The lower one, 17 V, is used while the required output is less than 12 V, the higher supply rail of 34 V is used when the required output is greater than 12 V. The purpose of this configuration is to keep the dissipation in the LM317 as low as possible. This is necessary because the LM317 will not allow the full 1A6 output to flow if there is more than about 17 V across it.

The reduced power dissipation in this circuit arrangement allows us to have a constant current output characteristic over the whole range instead of a 'foldback' limiting circuit.

The handsome face of the ETI Programmable power supply.

Construction

The project was constructed in the specified Newrad case, but it's a fairly tight fit and it may well be easier to use the next size up (S2/38) to allow more elbow room. Construction of the PCB is straightforward so long as polarity of components is observed where relevant. We used PCB plugs and sockets for the digital input as this is most convenient. IC8, Q3, D4 and D5 are mounted on the heatsink and wired through a grommet in the rear panel. It makes things easier here if some PTFE insulators are used to hold the diodes and connecting wires. Use insulating mica washers with heatsink compound under IC8 and Q3 to conduct the heat away while preventing unwanted short circuits. Together with the heatsink, the mains switch, fuse, mains cable and control input socket are all mounted on the rear panel.

It will help considerably if the front and rear panel components are fitted and wired as far as possible before the chassis is finally fitted. Make sure, however, that you leave enough room to insert the chassis afterwards. Note that R4, 25, 27 to 31 are mounted on their associated front panel components, though we did find room on the PCB for R4 after the prototype was completed, and it is shown thus on the overlay.

The transformer, main capacitors, bridge rectifier and PCB together with D6 and R26 are mounted on the chassis supplied with the case. Some solder tags and tagstrip will be useful for mounting the smaller components and connecting to the capacitors. The large capacitors used in the prototype were mounted horizontally using two clips each.

BUYLINES

Not too much in the way of unusual components for this project: the ZN428 and D-range connector may be hard to track down but Technomatic can supply both parts. The case we used is available from Newrad Instrument Cases Ltd, Tiptoe Road, Wootton, New Milton, Hants BH25 5SJ, telephone New Milton 615774; the PCB can be obtained, as usual, from our PCB Service as advertised on page 91. The optional DVM module, the DPM05, is stocked by Lascar Electronics, Oakland House, Reeves Way, South Woodham Ferrers, Chelmsford, Essex CM3 5XQ, telephone 0245 329797.

Setting Up

Having constructed the project and checked for wiring errors very carefully, put RV1 and RV2 to minimum, close SW3 and set SW2 to local. Switch on and check that the voltages on C1, C2 and C7 are +34, +17, and −34 (± 5 V or so). If not, check the wiring again. Now make sure that the +5V and −5 V

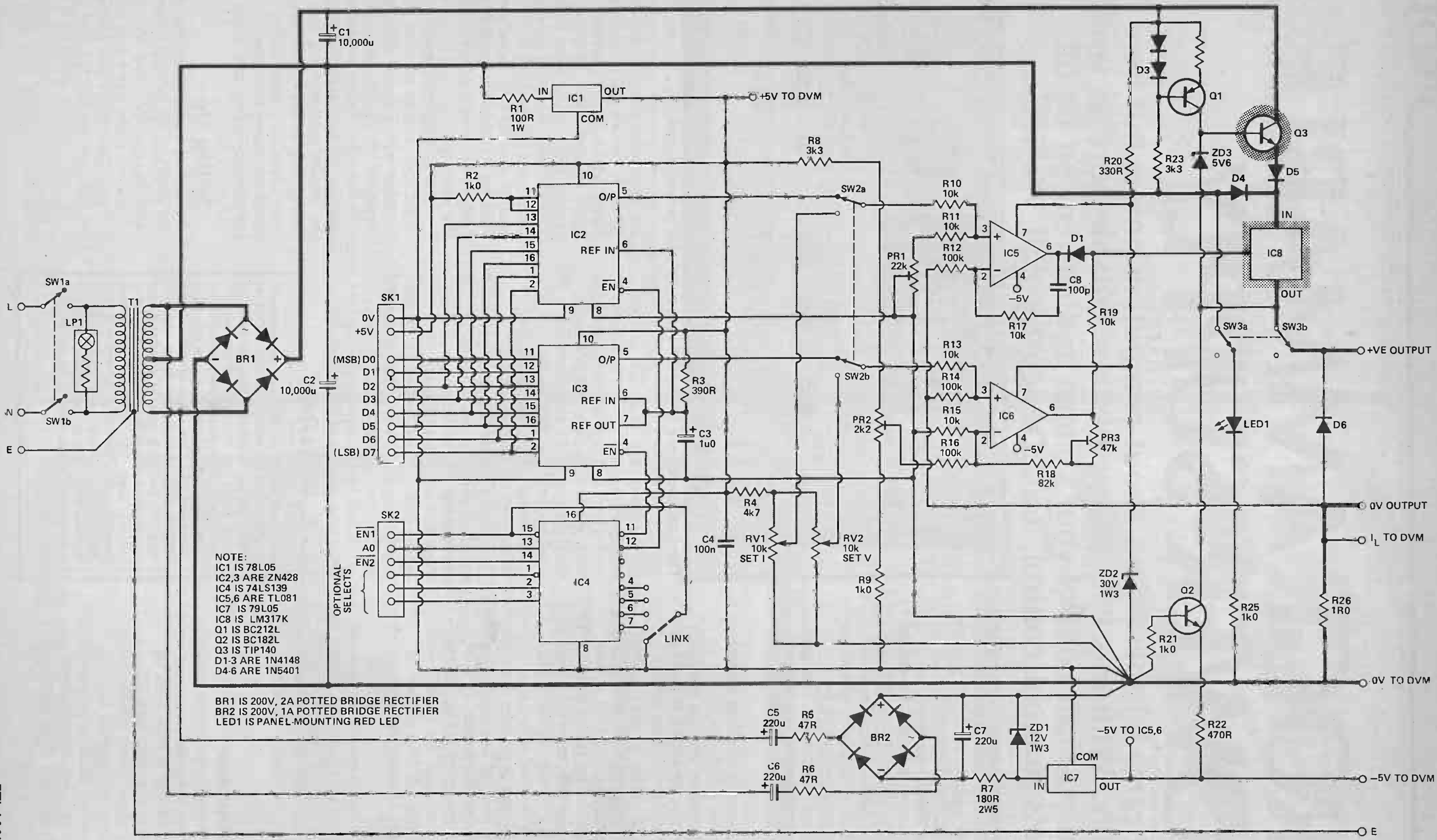


Fig. 1 Circuit diagram for the power supply. The heavier tracks carry the high current. Note the central earthing system.

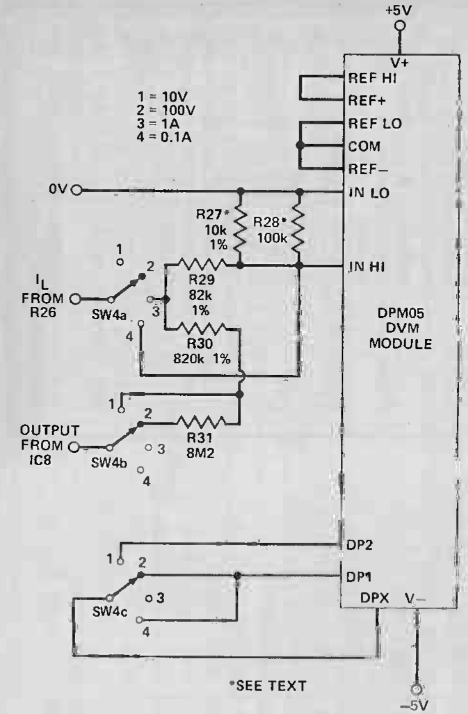
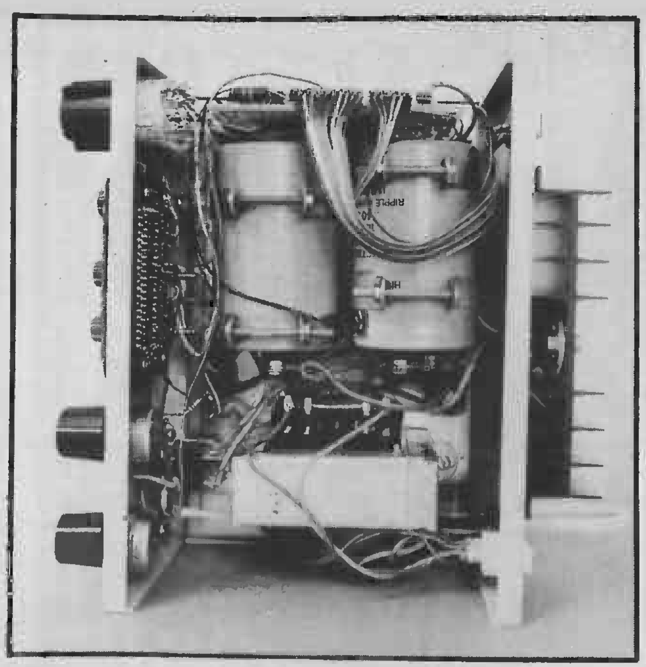


Fig. 2 Circuit for the optional DPM.



This is how we packed everything into the case specified in Buylines but it's pretty tight! You may wish to use the next size up.

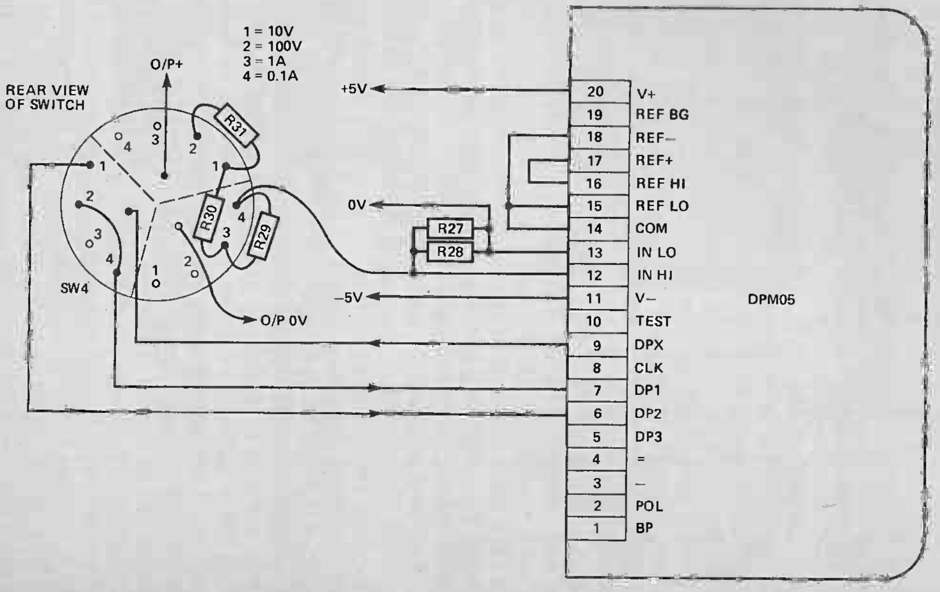


Fig. 3 How to wire up the range switch and its resistors to the DPM.

HOW IT WORKS

POWER REGULATOR STAGE

The 12-0-12 V from the transformer is rectified by BR1 and smoothed by C1 and C2. This is connected to give a 0 V rail, a 17 V and 34 V positive supply rails. Also driven from the transformer, BR2, C5, C6, C7, R5 and R6 act as a full wave voltage doubler to provide a negative supply rail for the control circuitry.

The 17 V rail is connected to the input side of the LM317 via D4 while the 34 V rail is connected to the same point via Q3 and D5. Q1, R24, D2, 3 and R23 form a simple constant current source which tends to turn Q3 on. ZD3 acts to maintain the base of Q3 at 5V6 above the output level. By emitter follower action in Q3, the input to the LM317 will be maintained at about 5V6—1V8 higher than the output terminal. However, this is only true while D5 is forward biased, ie while V_{OUT} × (5.6 — 1.8) is greater than 17 V. When the output voltage is less than the level required, current will no longer be supplied via Q3 and D5 but will come via D4.

AUXILIARY SUPPLIES

The op-amps are supplied from +30 V and —5 V to enable them to cover the output voltage range while staying within their absolute maximum supply capability. These voltages are generated by a resistor and zener diode combination for the 30 V supply and an IC regulator for the —5 V supply. This latter device is preceded by a resistor and zener diode combination to drop the output from the voltage doubler circuit down to a safer level. The logic circuitry is supplied with +5 V from IC1.

THE VOLTAGE REGULATOR CIRCUIT

IC8 is the main regulator device in this project; it is treated as a self-protecting transistor except that its 'base' voltage is about 1V2 below the output level. The current into or out of this terminal is very small. IC6 is connected as an amplifier with a gain of 10. It also removes the effect of the current sense resistor R26 on the final output, and allows the output to be set to 0 V out for 0 V in by means of PR2.

The input to IC6 is selected by SW2 and is a 0 to 2V55 variable DC level from either RV2 for local (manual) control or from IC3 for remote (programmable) control. The output from IC6 goes via R19 to the common terminal of IC8: the voltage at this point determines the output voltage from the unit.

THE CURRENT REGULATOR CIRCUIT

IC5 is the circuit element which detects the voltage generated by the output current flowing through R26. This voltage is compared with the current limit input voltage selected by SW2 and if the current limit is exceeded, the output of IC5 is driven towards the negative rail. This eventually pulls the common terminal of IC8 low enough via D1 to stabilise the current at its preset limit.

R10, 11 and PR1 set the sensitivity of the circuit while R12, 17 and C8 reduce the high frequency gain of the circuit to help stability.

THE PROGRAMMABLE INPUT SECTION

IC2 and 3 are eight bit A-to-D converters with internal latches, although only six bits of IC2 are programmable as greater resolution was not felt to be usable without greater complexity in the current limit circuit. This also means that the unit is not completely off under any circumstances. All eight bits are available in IC3 for setting the output voltage. R3 and C3 supply the reference voltage generator in IC3 which in turn supplies the D-to-A converters in both IC2 and 3. Address decoding and device selection is available in IC4 which is a dual 1-of-4 selector. Two outputs from one section of this IC drive the enable inputs of the DACs and the three inputs to this section can be used on their own with external address decoding or in conjunction with an output from the other section (selected by a suitable link on the PCB) if required.

THE PANEL METER MODULE

This optional part of the circuit allows the user to monitor the output voltage or current from the unit: SW4 is used to select the mode and range required. R27 to 31 form a divider network to scale the meter to the correct measuring range. The module used has a nominal input of 100 mV for a reading of 1000. It also has provision for selecting the decimal point position and this is made use of by a section of SW4. It is necessary to use +5 V and —5 V to supply the meter as it will not read correctly if the input terminals are at or near the negative supply. The module has its own internal band-gap voltage reference and if accurate resistors are used for the divider network a highly accurate readout will be obtained.

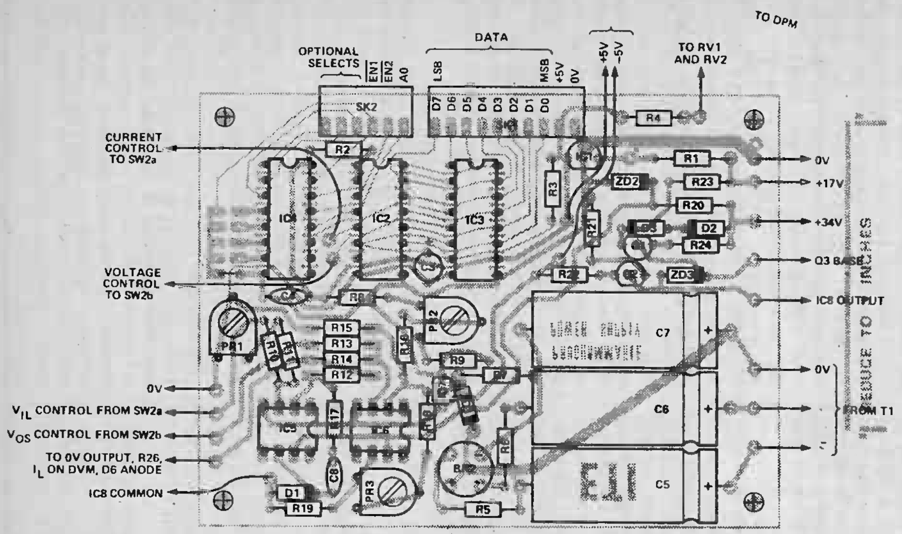
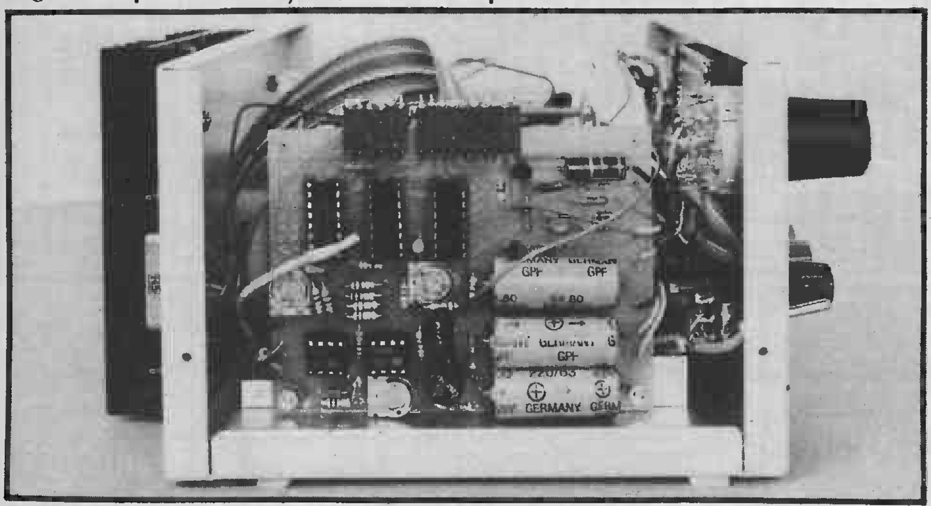


Fig. 4 Component overlay. Note some components are mounted off-board.



A side view showing the construction of the PCB.

rails are correct on the PCB. If not, check component polarities and placement. Rotate SW4 through all its positions and check that it reads at or somewhere near zero in all positions. With SW4 in the 10 V range (or a 10 V meter connected at the output) adjust PR2 for 0 V output. Connect a voltmeter to RV2 wiper and adjust RV2 until it reads 2V55 with respect to the 0 V rail. Adjust PR3 until the output reaches 25V5 (SW4 in 100 V position).

Now connect the voltmeter to RV1 wiper and adjust RV1 until it reads 2V55. Turn RV2 to minimum and connect an ammeter to the output terminals. Advance RV2 a little and a current of between 1 and 2 amps should flow. Adjust PR1 until this current is 1A6.

If all these steps have been accomplished without smoke, the supply should be operational. The only thing left to check is the digital control section. Connect all the data inputs on SK1 to 0 V and connect $\overline{EN1}$ to 0 V using the link indicated beside IC4 in Fig. 4. Now, with A0 at 0 V take $\overline{EN2}$ low momentarily. Repeat this with A0 high. Now check that the outputs from IC2 and 3 are at 0 V (IC2 will be 30 mV or so positive). Set SW2 to 'remote' and readjust PR2 if necessary.

Set all the data inputs to +5 V and latch in this new information using A0 and $\overline{EN2}$ as in the previous paragraph. Readjust PR3 and (with care) PR1. The unit should now be ready for use. Note, when doing the above procedures it may be advisable to provide pull-up resistors on unconnected inputs.

The A0 line selects the voltage D-to-A converter when low and the current D-to-A converter when high. $\overline{EN1}$ could be the select line while EN2 would be the R/$\overline{W}$ on 6502-type systems, or $\overline{WR}$ on the Z80 etc. For most applications it is advisable that there should be some means of isolation between the control processor and this unit to prevent earth loops and other undesirable effects; this may well be in the form of opto-isolators. Pads are provided to allow the $\overline{EN1}$ link to be repositioned to use the other section of IC1 and gain extra decoding capability, should this be necessary.

PARTS LIST

Resistors (all ¼W, 5% except where stated)

R1	100R 1 W
R2,9,21,25	1k0
R3	390R
R4	4k7
R5,6	47R
R7	180R 2W5
R8,23	3k3
R10,11,13, 15,17,19	10k
R12,14,16	100k
R18	82k
R20	330R
R22	470R
R24	120R
R26	1R0 2W5
R27*	10k 1%
R28*	100k
R29	82k 1%
R30	820k 1%
R31	8M2 5% or better

*R27 and R28 may be replaced with a single 9k1 1% resistor

Potentiometers

RV1,2	10k linear
PR1	22k miniature horizontal preset
PR2	2k2 miniature horizontal preset
PR3	47k miniature horizontal preset

Capacitors

C1,2	10,000u 25 V can electrolytic
C3	1u0 35 V tantalum
C4	100n ceramic
C5-7	220u 63 V axial electrolytic
C8	100p ceramic

Semiconductors

IC1	78L05
IC2, 3	ZN428
IC4	74LS139
IC5,6	TL081
IC7	79L05
IC8	LM317K
Q1	BC212L
Q2	BC182L
Q3	TIP140
D1-3	1N4148
D4-6	1N5401
ZD1	12 V 1W3 zener
ZD2	30 V 1W3 zener
ZD3	5V6 400 mW zener
LED1	panel-mounting red LED
BR1	200 V, 2 A potted bridge rectifier
BR2	200 V, 1 A potted bridge rectifier

Miscellaneous

SW1	two-pole mains-rated on-off rocker switch
SW2	two-pole miniature changeover toggle switch
SW3	two-pole on-off toggle switch (5 A @ 30 V)
SW4	three-pole four-way rotary switch
FS1	20 mm 1 A fuse
T1	0-12, 0-12 V, 50 VA mains transformer
LP1	mains neon indicator

PCB (see Buylines); DPM05 LCD DVM module (see Buylines); PCB plugs and sockets if required (one off 10-way and two off three-way); 15 way D-range connector (see Buylines); three off screw terminals; three knobs; can capacitor clips; tag strip; transistor mounting kits and heatsink compound for LM317 and TIP140; heatsink (2.0° C/W); cable and hardware; case, Newrad type S2/37 (see Buylines).

ETI

TRON

All photographs © 1982 Walt Disney Productions

One of the most imaginative and innovative films for some time has just been released, and it uses computers in a way never seen before. Peter Green has seen the film; now read the article.

Far above the infinite Sea of Simulation which resembles shifting, multicoloured graph paper, a jewelled ship flies on butterfly wings down a channel of pure light. Its path takes it over gridded fields populated by strange spiderlike creatures and through vast canyons with faceted, metallic cliffs that pulse with an eerie, sombre light.

A group of crouching warriors are surrounded by skeletal 'blueprints' which solidify into futuristic lightcycles and speed forwards toward each other, trailing impenetrable coloured walls in their wake. The cycles snap into right-angled turns, courting collision and slowly covering the playing area with a complex maze of walls. Suddenly a warrior miscalculates a turn: he is destroyed in an explosion of light and his wall disappears with him.

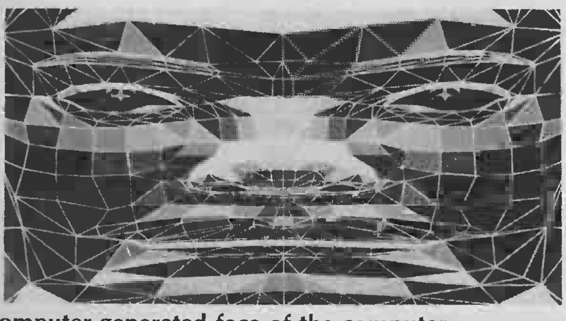
A huge battleship thunders across the landscape, the ultimate weapon of the tyranny that has taken over this world. Slowly, along a plane that sweeps over the craft from front to rear, it fades into a transparent, skeletal outline that continues on its journey towards a distant citadel as if nothing had happened.

This is the world of *Tron*. It is like no film you have seen before. And it was made as no film has been before — or will be again.

Game For A Death

Most of the standard subject matter for science fiction has been done to death — albeit in a pretty spectacular manner, given the skills of the modern special effects team. *Tron* is fresh and different because its director has combined two modern phenomena that have become big business: the use of high-res computer graphics for leisure, in the guise of video games, and the use of high-res computer graphics as a tool for industry. One forms the backdrop to the plot for the film, the other the means of its making. Most of the film takes place in an imaginary world inside the computer, and all the major actors have two roles, one on either side of the video screen.

Tron starts in the real world, where Flynn (Jeff Bridges, playing the sort of laconic rogue I first warmed to in *Thunderbolt and Lightfoot*) is running a seedy videogame arcade, and beating everyone else's maximum score to boot. Flynn used to be the top programmer at ENCOM, a communications conglomerate, until he wrote five crack videogames. An unscrupulous colleague, Dillinger (David Warner), steals the games from the company computer, presents them as his own, and on the strength of their success gets promoted to Managing Director; Flynn gets the elbow.



The computer-generated face of the computer.

A trifle miffed at this, Flynn spends his evenings on a home computer terminal upstairs from the arcade, trying to break into the ENCOM computer and gather evidence of Dillinger's dirty work. Unfortunately for Flynn the whole system is now being run by the artificial intelligence of Dillinger's Master Control Program (MCP), which monitors the intrusion and shuts down all access by group seven users (Flynn's security rating). This has the added bonus to the MCP of preventing Alan Bradley (Bruce Boxleitner) from completing work on TRON, an independent security program that would monitor the ENCOM computer and reveal the embarrassing fact that, no longer under Dillinger's control, it is tapping into the computers of other companies, not to mention the Pentagon and the Kremlin (most readers will have spotted that TRON is the BASIC command for TRace ON). Other ENCOM employees to have their work halted are Gibbs and his assistant Lora (Cindy Morgan), who've been working on a project to disassemble objects with a laser, store the information in a computer, then reassemble it ("Beam me up, Scotty").

Alan and Lora guess that Flynn's been meddling, pay him a visit, get the whole story and decide to help him. That night they break into ENCOM; Flynn will forge a new security access so that Alan can complete his work on TRON. But Flynn is using Lora's terminal, right next to the experimental laser; the MCP fights back by disassembling Flynn and sucking him inside the computer. Flynn wakes up in an alternative universe where the inhabitants are 'Programs', electronic alter-egos of the 'Users' who wrote them. The cruel tyrant ruling this world is the MCP, aided by his henchman Sark (Warner again), who flies around in his giant carrier putting down rebellion. Any program that's useful is absorbed by the MCP; the rest are trained as gladiators and fight on the Game Grid, where videogames become a life-and-death reality. Flynn is sentenced to fight until he dies, and finds he needs all his skills to stay alive against the complex games that he himself has written.

Here Flynn meets Tron (Boxleitner), mightiest of the warrior programs and still fighting for the Users against the MCP. Tron is adept in the use of his 'identity disc', which doubles as an information store, and a personal weapon à la Frisbee. Tron and Flynn manage to escape from the Game Grid on their lightcycles and being a long journey to sabotage the MCP. Separated from Flynn by Sark's tanks, Tron meets Yori (Morgan again), a simulations program, who helps him steal her Solar Sailer project. Meanwhile Flynn has stolen a Recognizer, a vehicle used by Sark's guards. Tron manages to contact Alan Bradley via an input/output tower and his identity disc is coded with the information required to destroy the MCP. Eventually the trio meet up again on the home ground of the MCP and prepare for the final battle that will decide all their fates.

The Pong Plot

As you can see, the plot is innovative to say the least. So are the techniques used to film it. And the whole thing is the result of the drive and vision of the director, Steven Lisberger. I spoke to him during his recent visit to London to promote the film and though we started talking about *Tron*, he ended up leaping from subject to subject like a gazelle. For example, if you're planning to play Zaxxon, the new arcade game that's been appearing in pubs over here, be gentle with it — apparently the joystick is badly designed and machines are breaking down regularly in the USA.

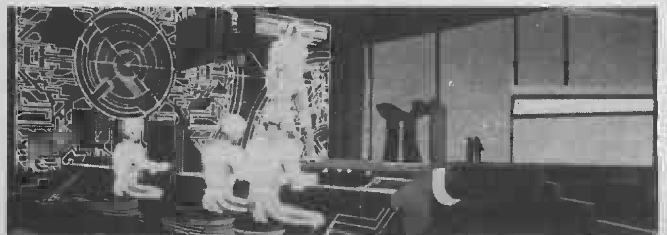
Lisberger first conceived *Tron* in 1977 while he was directing a couple of animated TV specials called Animalympics: the inspiration was the lowly Pong, father of arcade games as we know them today. Originally the film was to have been animated entirely by computer, and as Lisberger began checking into the techniques he met many people in the industry who gave him ideas for the plot. The theme of the parent company ripping off the inventions of its employees was one, inspired by stories from people it had actually happened to.

By 1980 Lisberger and his producer, Don Kushner, had honed the script into its final form and were hawking it around the major studies. The screenplay now contained extensive scenes using live actors and conventional animation, all of which had to be carefully combined with the computer-generated footage. Within a week of being offered the project, Walt Disney Productions had, in keeping with their tradition of gambling on the success of some pioneering technique, expressed an interest and put up $50,000 for test footage.

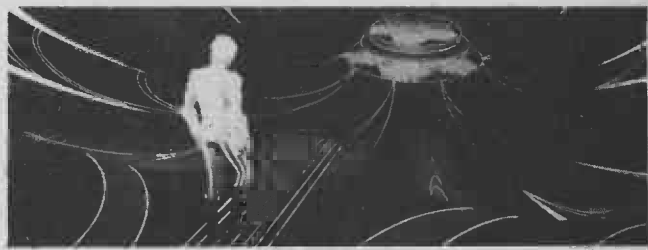
Lisberger And Chips

The computer-generated sequences in *Tron* occupy about 20 minutes of the 75 spent in the fantasy world — primarily they are scenes involving the lightcycles, the tanks and Recognizers, the Solar Sailer, Sark's carrier and the face of the MCP. Three main companies were involved in the work: Digital Effects Inc, who did the opening shot of a man forming out of energy and Flynn's 'pet', Bit; the Mathematical Applications Group Inc, or MAGI; and Information International Inc, known as Triple-I or III for short. MAGI and III use completely different approaches to computer image generation and worked on separate areas of the film.

The MAGI Synthavision system (you may have seen it used in the film *Demon Seed* on TV recently) is unique in that it uses subroutine programs; a selection of about 50 solid geometric shapes are stored in the computer as building blocks. To generate the required images, the basic shapes may be added or subtracted from one another until the correct result is obtained. For example, to make the lightcycle you might start with a pair of



The spacious control room of Sark's battlecruiser.



Tron approaches the platform of the I/O tower.

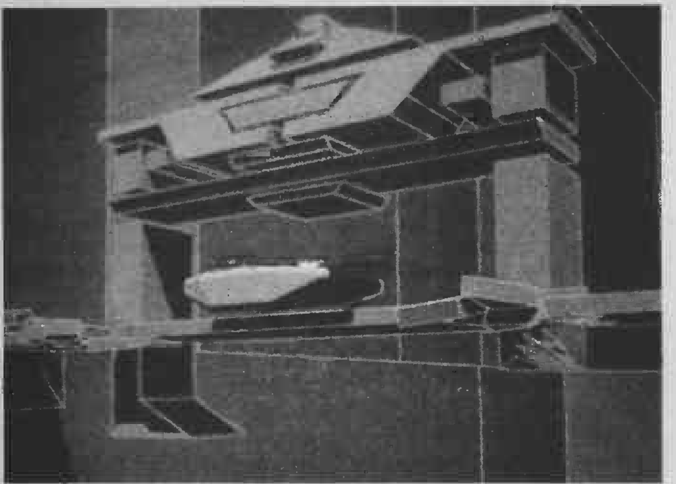
spheres and remove cylindrical cores to give the tyre shapes, then add a smaller central sphere for the hubcap. MAGI were responsible for the lightcycles, tanks, Recognizers and so on. The company uses a Perkin Elmer System 3240 computer for the graphics calculations, using two megabytes of MOS memory and two 80 megabyte disc drives. The pictures are actually generated on a monitor by a second computer, a Celco DFR 4000. As MAGI are located in New York, all their work for the film was sent down the telephone lines via modem to the Disney Studios in California, where the animators studied the results on their monitors and called back with any corrections needed.

III uses a completely different system, in which the blueprints for the required object are digitized on a 40" by 60" Taylos graphics tablet and fed into a custom-built one-off computer they call the Foonley F-1. The computer uses the digital information to define the points of the surface, which is then coloured and shaded. This method is better for complex, irregular shapes because it doesn't rely on regular-shaped, geometric building blocks. Hence III are responsible for the 'human' face of the MCP as it communicates with Sark, and also the delicate Solar Sailer.

Eventually, when the scenes have been choreographed to the satisfaction of the animators (and using computers means that changes to the action can be made in only 20–30 mintues), the images are transferred to movie film by photographing them frame by frame from the screen of a high resolution cathode ray tube. The resulting quality is superb: each frame can contain up to two million pixels and the resolution of some of the images is 2000 lines, higher than that of the film stock being used. So don't try looking for the little squares, because you won't see them.

Seeing Things In Black And White

Equal care and quality went into the filming of the live action scenes, and equally innovative techniques were used. All the denizens of the computer world wear costumes with constantly flickering bands of light — none of which existed in reality. The actors' costumes were white with black patterns and were filmed on black-and-white film against black backdrops. The film was 70mm — rare in itself these days — and provided big negatives for the post-production work. In fact both MAGI and III had to change their equipment to VistaVision. Once the actors had been filmed, the special effects team made a series of 'mattes' and 'reveals' for each frame of film. These are masks and countermasks that allow various sections of each negative to be lit separately from below by coloured lights and rephotographed on colour stock to give the finished film frame. Most frames had to be rephotographed at least 12 to 15 times (and some as many as 45 times) to produce the required effects using eye reveals, face reveals, costume reveals and so on. The live action was then combined with backgrounds which had been either computer-generated or drawn by conventional animators. Of the 1100 special effects shots in Tron, over 700 involve composite shots with actors.



L-driver Flynn crashes his Recognizer into a bridge — a remarkable piece of special effects work.

This may seem like a stupendous amount of effort but the quality of the result is worth it. Normally a film shot using the conventional 'blue screen' matting techniques gives spaceships and actors with a noticeable line round them. This is the system where the actors or spacecraft are filmed against a bright blue background, which can then be photographically 'removed' and replaced with a different background, such as a star field or planet. Even Star Wars, which used a greatly improved version of this technique, had scenes in which it was possible to 'see the join'. Since *Tron* doesn't have any mattes in the conventional sense, there are no matte lines. Conventional matting will also give errors in perspective, since it's almost impossible to merge film of models shot at different locations and different times and get things dead right. *Tron* uses no models: everything exists only in the computer's memory and the perspective is always perfect.

One particular scene demonstrates this well. Recognizers are composed of various elemental blocks and Flynn has stolen a wrecked one by using his User powers to hold it together. But his steering's not too good and the machine hits a bridge, sending the component blocks twisting and tumbling in all directions. Flynn exerts his will and draws them together from their random trajectories, spinning and rotating back into place with perfect precision. This scene alone would have taken a team of conventional animators years to perfect.

The Digital Editor

Even the level of technology used in *Tron* is only the beginning. The next step is to scan the live action footage and digitize it so that it, too, may be completely manipulated within the computer. The live action can be coloured, distorted, combined with other objects, again without matte lines. In effect the computer will become a digital film printer and the optical printer will become obsolete. According to Lisberger, this sort of equipment will arrive in a couple of years — just in time for *Tron II*, perhaps?

Looking even further ahead, I asked how soon he thought it would be before computer graphics could simulate real scenes, such as the Star Trek episode "Court Martial" in which a disgruntled crewman fakes the computer log tape to incriminate Kirk. "I've seen sample reels where objects are indistinguishable from photos, but to simulate people will take a long time — 10–15 years," he estimates.

After *Tron*, our discussion turned to the videogames that the film is based on. Lisberger is a videogame buff and feels that they are a Good Thing for society. "This technology is here to stay, and the kids who are playing these games now will grow up into adults who are familiar with it. This has got to be helpful to their development". But he's less happy about the way the big money-spinning games like Space Invaders and Pacman are licenced by the Japanese, who rake in the millions of dollars of profit each year. "It doesn't say much for American enterprise" he comments sadly. His opinion of Atari suing left, right and centre over Pacman copyright infringement is that it's a load of b*ll***t, and he feels they're really just testing out laws which are too vague. "I think the tendency in future will be towards more lenient copyright laws, but big companies like Atari will probably still try to bring lawsuits against smaller companies just to be a nuisance. It's scary that the threat is more powerful than the law itself."

Raiders Of The Lost Arcade

I wish I'd said that; but it's what *Tron* was dubbed in the USA when it was released. Oddly enough, when I first saw the film the only two actors I'd heard of were Bridges and Warner: since then Bruce Boxleitner and Cindy Morgan have appeared on the ITV network in a series called *Bring 'Em Back Alive*, which is a thinly-disguised rip-off of *Raiders*, even down to the theme tune — and what's more, one of the characters is called Flynn! The incestuous plagiarism of the US film and TV industry never ceases to amaze me . . .

I also spotted a few cinematic references in *Tron*, although Lisberger is as much a film buff as he is a video buff and these are obviously a homage to some great classics. The most blatent one is Alan Bradley's poster reading "GORT KLAATU BARADA NIKTO", the famous line from *The Day The Earth Stood Still*. Flynn's journey across the electronic landscape when he is atomized by the MCP echoes Bowman's journey over the weird planet at the end of *2001*, and surely the scene when the Solar Sailer escapes from its hanger, pursued by Sark's giant warship and watched by the helpless guards on the ground is straight out of *Star Wars*? Perhaps I'm wrong, but in any case *Tron* has sufficient action and witty dialogue of its own. For example, when Dillinger reminds the MCP that he programmed it, it replies "I've gotten 2,415 times smarter since then": though I did cringe a bit when Sark orders the destruction of an electronic barrier with the words "Bring up the logic probe!"

Tron is already showing in London and will be on general release by Christmas. It cost $22 million to make and has already grossed $30 million in the USA, salvaging the reputation of Disney which suffered badly from the appalling *Black Hole*: a film which Lisberger admits might make people wary of *Tron*. Other problems he was worried about were Britain's poor cinema audiences — "Your TV is too good" — and the imminent release of *ET*. However, there are queues outside the cinema down the road from us and *Tron* is already the top film after being out for a fortnight, so Lisberger's fears are probably unfounded.

Strangely enough, *ET* is the sort of film that Disney themselves might once have made, although Lisberger isn't too impressed with it. "*Tron* has a moral, that we have to watch out for big business and guard against its excesses. I don't know what sort of message you could take home from *ET*, except maybe be kind to your pet". I'll buy that; and I'll also buy a ticket to see *Tron*, despite sitting through two press showings already. It's brilliant, and I thoroughly recommend it. It establishes computers as a powerful new tool for the cinema industry, and Lisberger as a major young talent to join the ranks of Spielberg, Lucas et al.

END OF LINE.

ETI

PROGRAMMABLE STAGE LIGHTING

Tis the season to be jolly, and put on pantos. And make yourself a nervous wreck trying to control the stage lighting. This programmable lighting control unit should solve your problems. Design by David Colven and Ian Cleverley.

Is your lighting of Christmas productions a pain? Is your director always shouting at you in the lighting gantry about a missing spot, wrong light level or jerky fades? Do you need three hands with six fingers each during complex scene changes? Worry no more, here is a circuit that does it all for you.

Over many years of school productions the authors have come to the conclusion that a system capable of remembering scene changes and fading stage lights at pre-set rates would be a great boon. The 'computer' we developed even (eventually) met the exacting standards of our stage director.

The unit will control up to 16 light channels of up to 2 kilowatts maximum each. It can pre-set each channel to one of 16 different light levels and fade each channel up and down at 32 different speeds. Up to 99 different scene changes can be programmed into the unit as

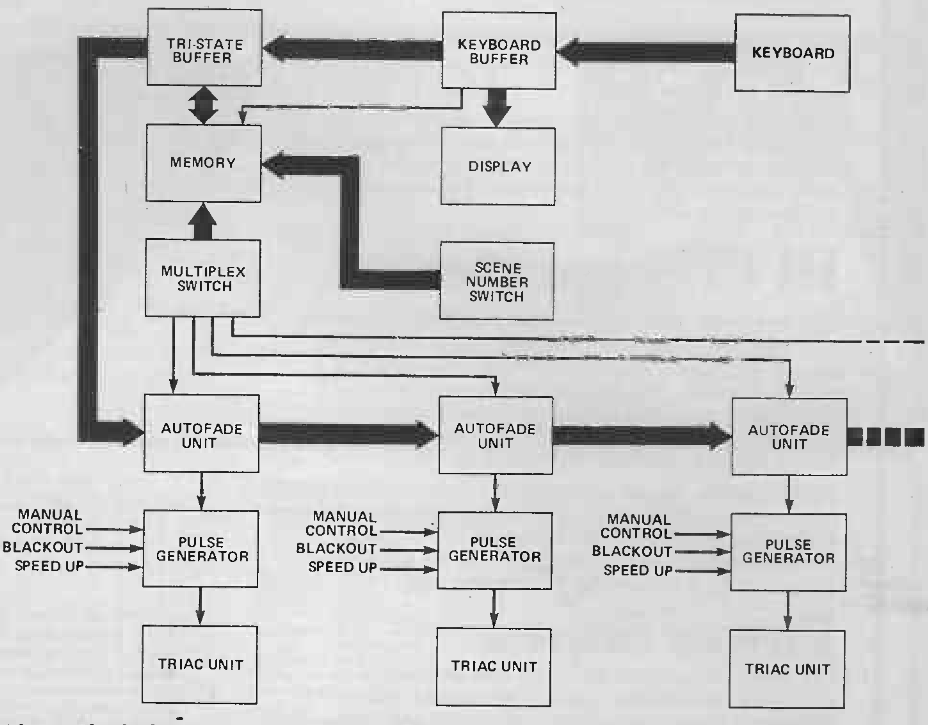


Fig. 1 Block diagram of the stage lighting unit. Up to 16 auto-fade/pulse generator/triac units may be controlled.

HOW IT WORKS — KEYPAD AND BUFFER

The various output lines are normally held low by resistors R1-4. When any numbered key is pressed the strobe line (KS) is taken high by one of the diodes D1-8, which triggers monostable IC1a via Q1. The monostable is necessary to debounce the keyboard. At the same time the other diodes in the keypad, D9-20, encode the numbered key into parallel binary on lines KD0—2. This parallel data is presented to the inputs of the dual two-bit latches IC6-9. Each successive key-press/monostable pulse clocks on IC2, a 4017 decade counter whose outputs go high in turn and provide the latching pulse to the required latches. The latching pulses are fed to IC6-9 via AND gates IC3a-d, 4a, whose other inputs are taken from the output of IC1a via R5,C3. These components delay the latching pulse until IC2's outputs have had a chance to settle, avoiding any problems due to double latching. One point to note is that the first digit of the light number is temporarily stored in IC8 by the first key-press before being transferred into IC6 by the second key-press.

The data must be input in a fixed order and the contents of the buffer are decoded and displayed on seven-segment common anode displays by IC10-13.

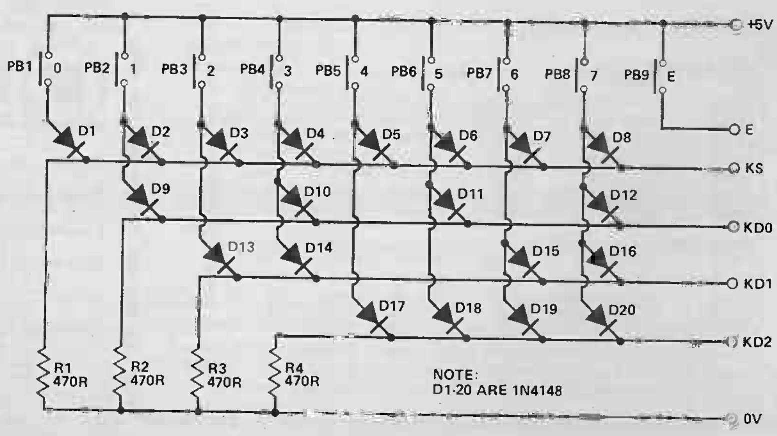


Fig. 2 Circuit diagram of the keypad unit.

described, but this can easily be extended by using extra memories and addressing circuitry to meet any requirements without theoretical limit. Eight different light levels have been found to be quite sufficient for stage use, and fade times of up to about one minute are possible. Longer fade times can be accomplished by programming in multiple scene changes. Individual blackout, master blackout, manual operation and fade speed-up controls are available.

The Light Fantastic

The light control circuits themselves are designed in such a way as to be easily driven from a microcomputer with two eight-bit user output ports. We felt, however, that the expense of a microcomputer dedicated for some weeks to this single purpose could not be justified; in any case, we had enough hardware problems without adding software ones as well.

All the lighting changes are stored in RAM (a 6116 2K × 8 low power memory) and are stored in octal. This cuts down on the complexity and expense of the circuit and makes the most efficient use of the store. It is worth it even if it means spending some time teaching your director or lighting man about number bases!

One final virtue of this unit is that by using external control voltages, one can produce many special effects and you could easily have a 32 kW, 16-channel sound-to-light unit!

Module Mode

A modular design has been used for ease of construction and these modules are housed in two units. The main control console contains the memory section, separate auto-fade units for each light channel, the phase switching pulse generators and the power supply. The front panel controls include a calculator-sized keypad for programming the information and a pair of rotary switches for selecting the scene number: the manual override controls, blackout and speed-up switches are also located on this unit.

If a touch of luxury is desired, there's no reason why the keypad and scene select switches shouldn't be mounted separately in a small hand-held unit so that the lights can

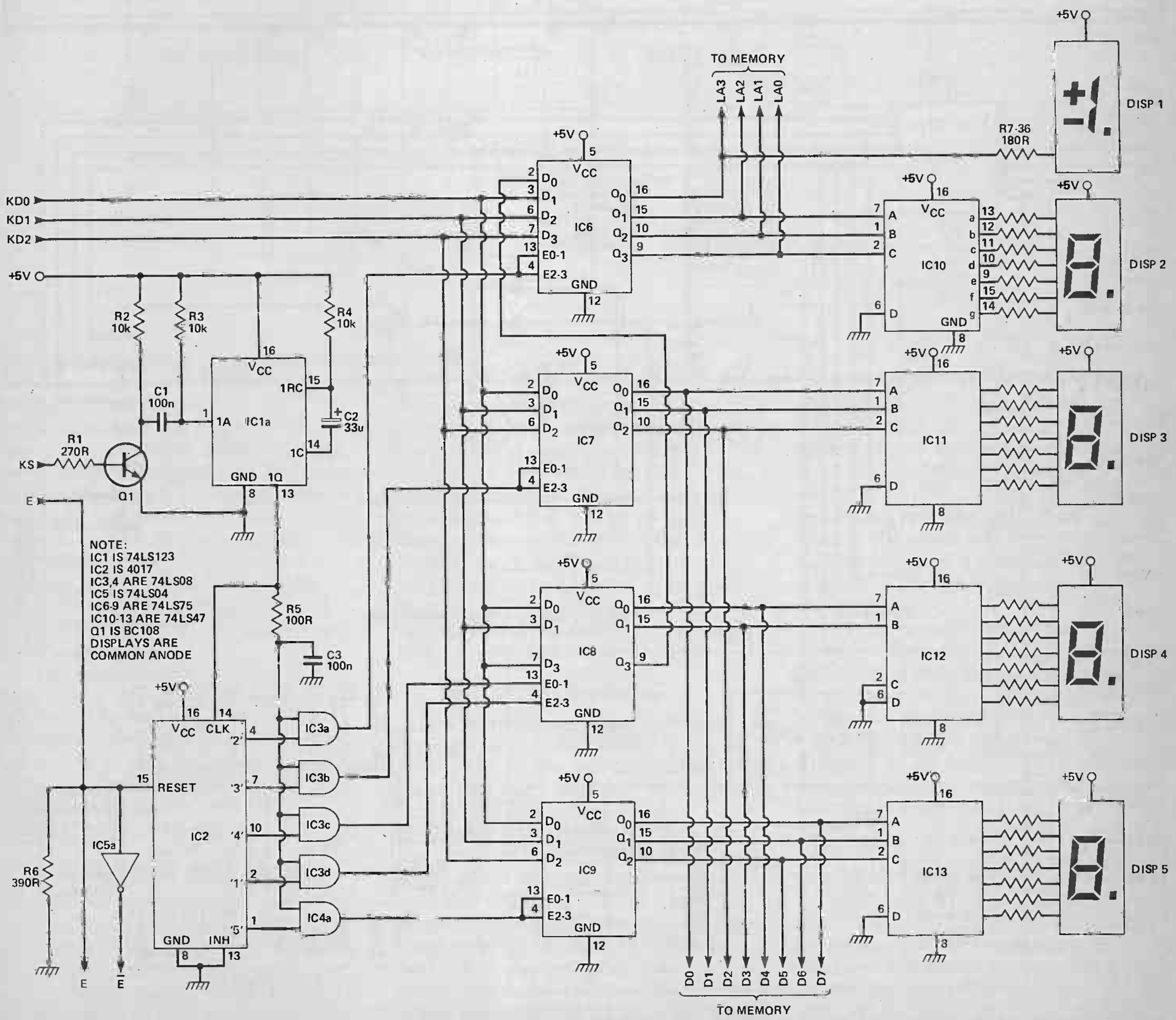


Fig. 3. Circuit diagram of the keyboard buffer and data display circuitry.