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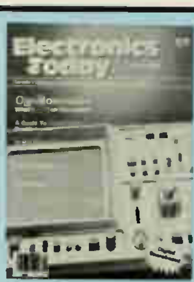

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The Hameg HM208 digital storage scope, taken as the camera fell over the table edge; it was provided courtesy of BSC Electronics and photographed by Bill Markwick.

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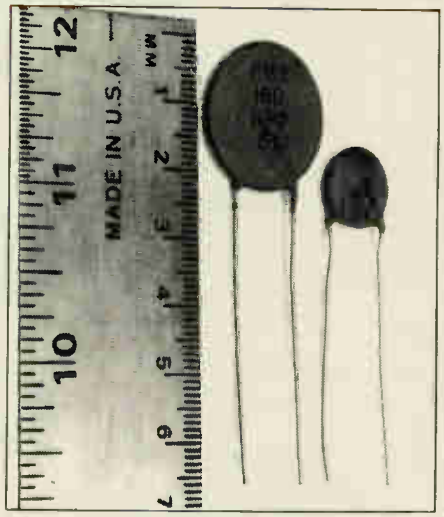

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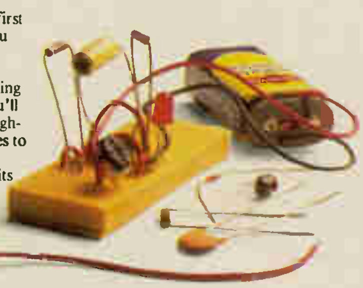

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Firstly decimal points are dropped and substituted with the multiplier: thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one nanofarad is 1000pF). Thus 0.1 uF is 100nF, 5600pF is 5n6. Other examples are 5.6pF = 5p6 and 0.5pF = 0p5.
Resistors are treated similarly: 1.8Mohms is 1M8, 56kohms is the same, 4.7kohms is 4k7, 100ohms is 100R and 5.6ohms is 5R6.

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CONNECTING LEADS

Fig. 1 A simple diagram of the internal construction of a capacitor.

Fig. 2 Some common capacitors. From front to back: a polyester, two tantalum beads, two metallized ceramics, two ceramic disc types, and two mylar film capacitors.

By Hagen Kornberger

2uF, and usual working voltages go up to 600V. Like resistors, capacitors have a specified tolerance which indicates how accurate their marked values are. Paper capacitors usually have tolerances of ±20%. Both the value and the tolerance are marked on the device's body in numerical figures.

Metallized paper capacitors use an evaporated metal film as the conductor instead of aluminum foil. The metalic film is deposited onto a former by a sputtering process. This is a technique whereby a cathode in a gas discharge tube is slowly disintegrated by bombarding it with positive ions. When this process is used to deposit metal film on an object, the object is placed near the cathode which is made of the metal to be deposited, and the tube is then evacuated to a low pressure (1 to 0.01mmHg). An anode potential of 1kV to 20 kV is then applied and the process begins.

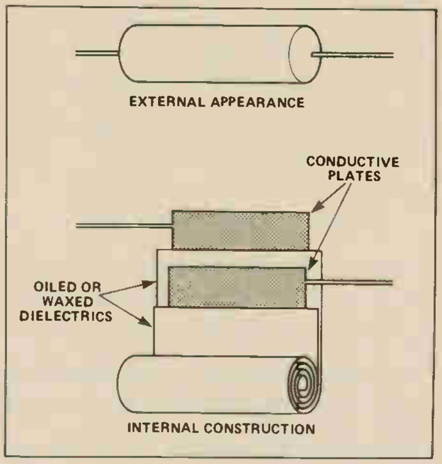


Fig. 3 This shows how the dielectric and conductive plates in the capacitor are rolled for packaging.

Mica capacitors come in a range of values from about 5pF to 50nF. As we mentioned earlier, high capacitance values are not made with mica due to the high cost.

Just as resistors are affected by their operating temperature and rated with a temperature coefficient, so are capacitors. The temperature coefficient for the average 10pF mica cap is +75ppm per degree Celsius.

Ceramic

Fig. 5 shows two low voltage miniature ceramic disc capacitors. As you might have guessed, these capacitors utilize ceramic dielectrics. These are standard general purpose low power devices and are usually available in values between 0uF01 and 1uF47. The tolerance of these components is in the order of +80%–20% and they have a working voltage of 12V. The next size up has a working voltage of 500V.

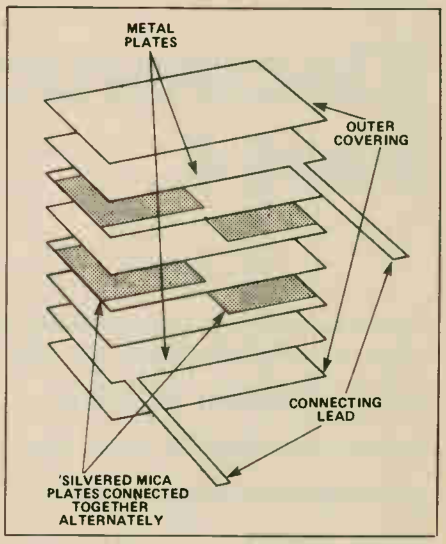


Fig. 4 A graphic illustration of the innards of a mica capacitor.

High voltage (500V) ceramic capacitors are made in exactly the same way as their low power *brothers*, except they're larger. The differences between the two types is determined by the type and dimension of the dielectric used.

Ceramic capacitors are made with dielectrics of three different values of relative permittivity. Very compact ceramic caps use high permittivity dielectrics of values up to 1200. These are however very sensitive to temperature. Medium permittivity types have negative temperature coefficients and are

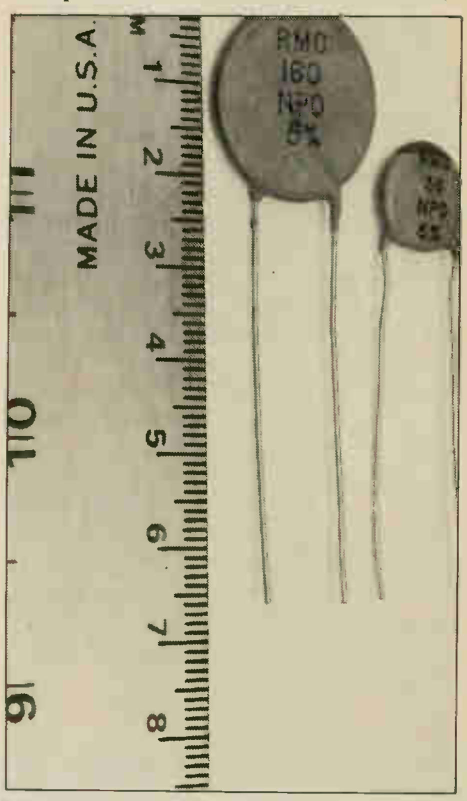


Fig. 5 Two large high voltage ceramic disc caps.

employed as temperature correcting components. Low permittivity dielectrics have a very good frequency response but a low working voltage.

Just as the mica capacitor had its conductors formed by metallization, so can ceramic components. A range of capacitances from 1pF8 to 22000pF is manufactured, with tolerances ranging from ±0pF25 to -20% — +80%. Five different temperature coefficient ranges are made according to the resistance values. The coloured blend on the top of each capacitor denotes the temperature coefficient. These values are given in **Table 2**. Capacitors of this type are generally rated at 100VDC.

Table 2

Capacitor	Temperature coefficient	Colour band
1.8 to 18pF	Zero	Black
22pF to 150pF	$-150ppm°C^{-1}$	Orange
180pF to 330pF	$-750ppm°C^{-1}$	Violet
390pF to 4700pF	(medium permittivity)	Yellow
10,000 to 22,000pF	(high permittivity)	Green

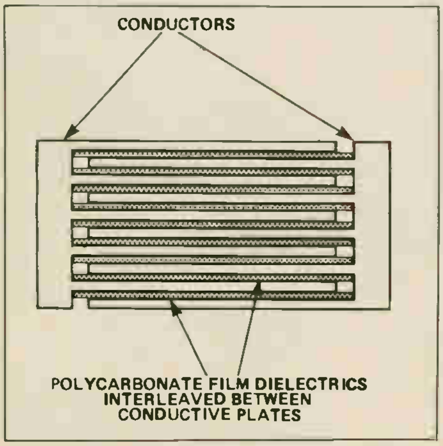


Fig. 6 This shows the internal construction of a polycarbonate capacitor.

Plastics

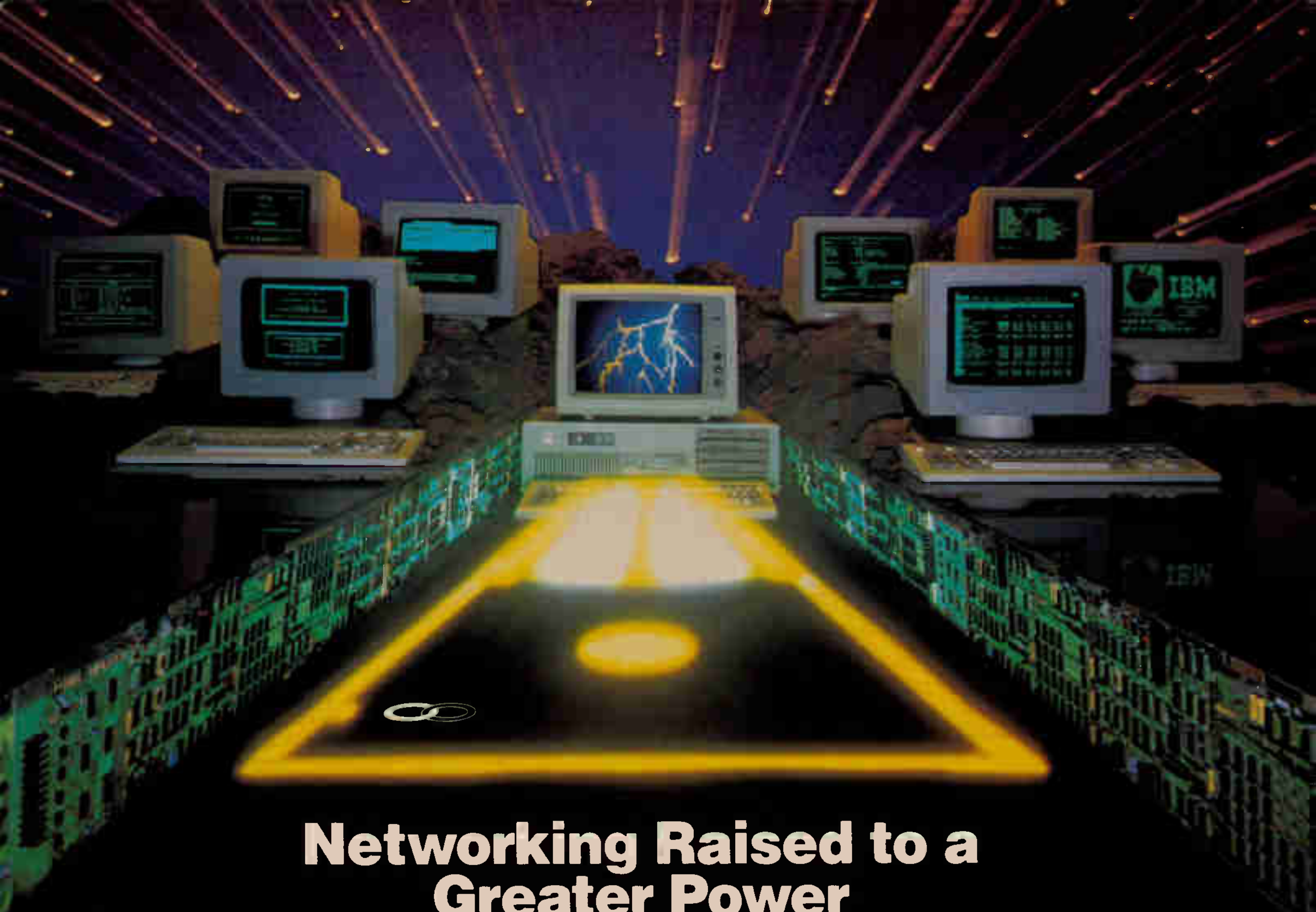
Plastic capacitors form a major component group with dielectrics fabricated from films of polystyrene, polycarbonate, and polypropylene.

A very large range of capacitances is available, running as high as 100000pF. Of course, as capacitance increases, so does the physical size of the component. A 100000pF polystyrene cap has a body 22mm long and 17mm in diameter. Like almost all plastic capacitors, this type is made by winding the dielectric and the conductors into a roll which is then sealed into a tubular or flat package.

Typically, polystyrene capacitors possess temperature coefficients in the area of -160±80ppm per degree Celsius and have very low losses. This means that they are very good at holding their charge.

Other polystyrene capacitors are manufactured to very close tolerances, often as low as ±1%.

Miniature polycarbonate capacitors measuring about 10mm x 10mm x 5mm are very suitable for PCB and breadboard mounting because of their small size and parallel leads. These components range in value from 0uF001 to 1uF x10% or x5%, with a temperature coefficient of 65ppm per degree Celsius. The maximum working voltage is between 120V to 400VDC,



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Capacitor Colour Codes

Colour	First Figure	Second Figure	Multiplier	Tolerance
Black	0	0		Black = 20%
Brown	1	1	x 10^1	White = 10%
Red	2	2	x 10^2	Green = 5%
Orange	3	3	x 10^3	Black 20%
Yellow	4	4	x 10^4	White 10%
Green	5	5	x 10^5	Green 5%
Blue	6	6	x 10^6	
Violet	7	7	x 10^7	
Grey	8	8	x 10^8	
White	9	9	x 10^9	

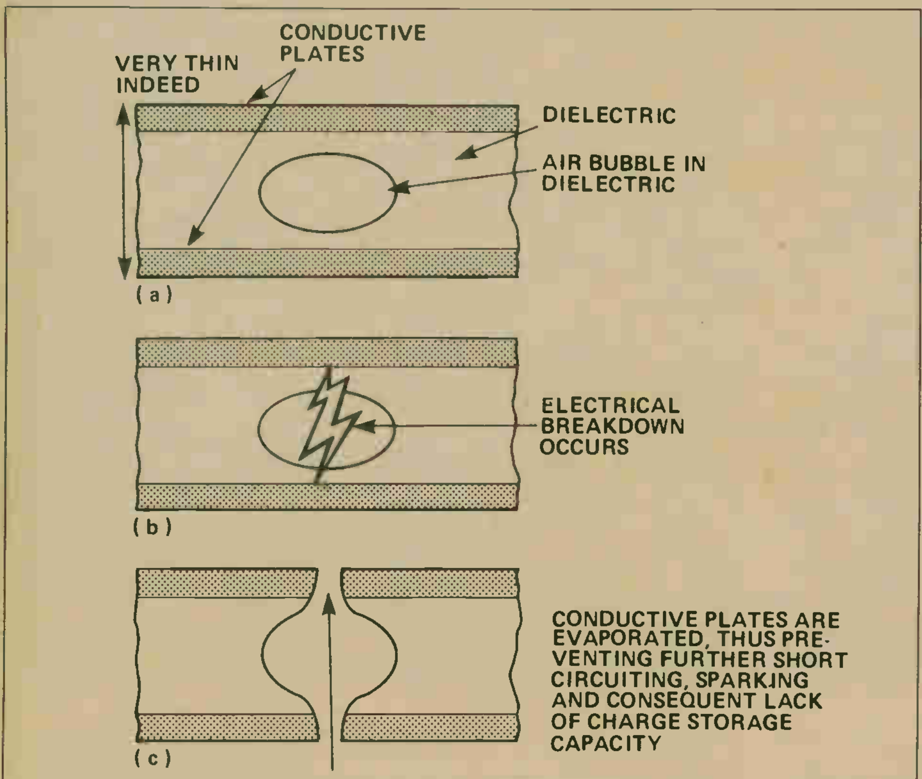


Fig. 7 A graphic representation of how a self-healing capacitor organizes itself after an electrical breakdown, so that normal functioning continues.

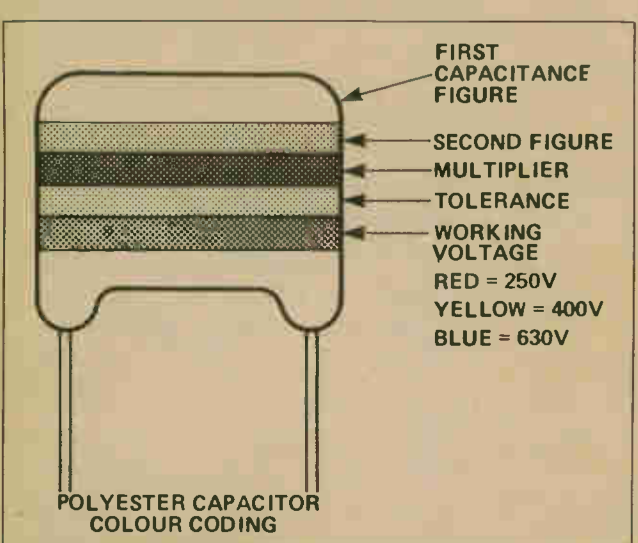


Fig. 8 A close-up diagram of the colour coding system used for many capacitors.

according to capacitance. These components are multi-layer devices constructed as in **Fig. 6**.

Self-Help

These, like many plastic film capacitors possess *self-healing* properties. This means that if the dielectric breaks down in any place, the capacitor will not be useless, but in many cases will function better than ever.

A small number of pin-holes, thin areas or air pockets in the plastic films, and these are all potential areas of breakdown. When breakdown occurs, the thin metal conductors are evaporated from around the point of breakdown. This leaves a metal free (insulated) region, and presto, we are left with a good capacitor again. As the conductive plates are made from very thin metal only a small amount of energy is used in self-healing.

During the manufacturing process, capacitors are *cleared* by subjecting them to very high voltages. This ensures that all potential breakdowns are actually *made* to happen and the capacitors are forced to self-heal at voltages higher than those to which they would be normally subjected. The healing process is graphically illustrated in **Fig. 7**.

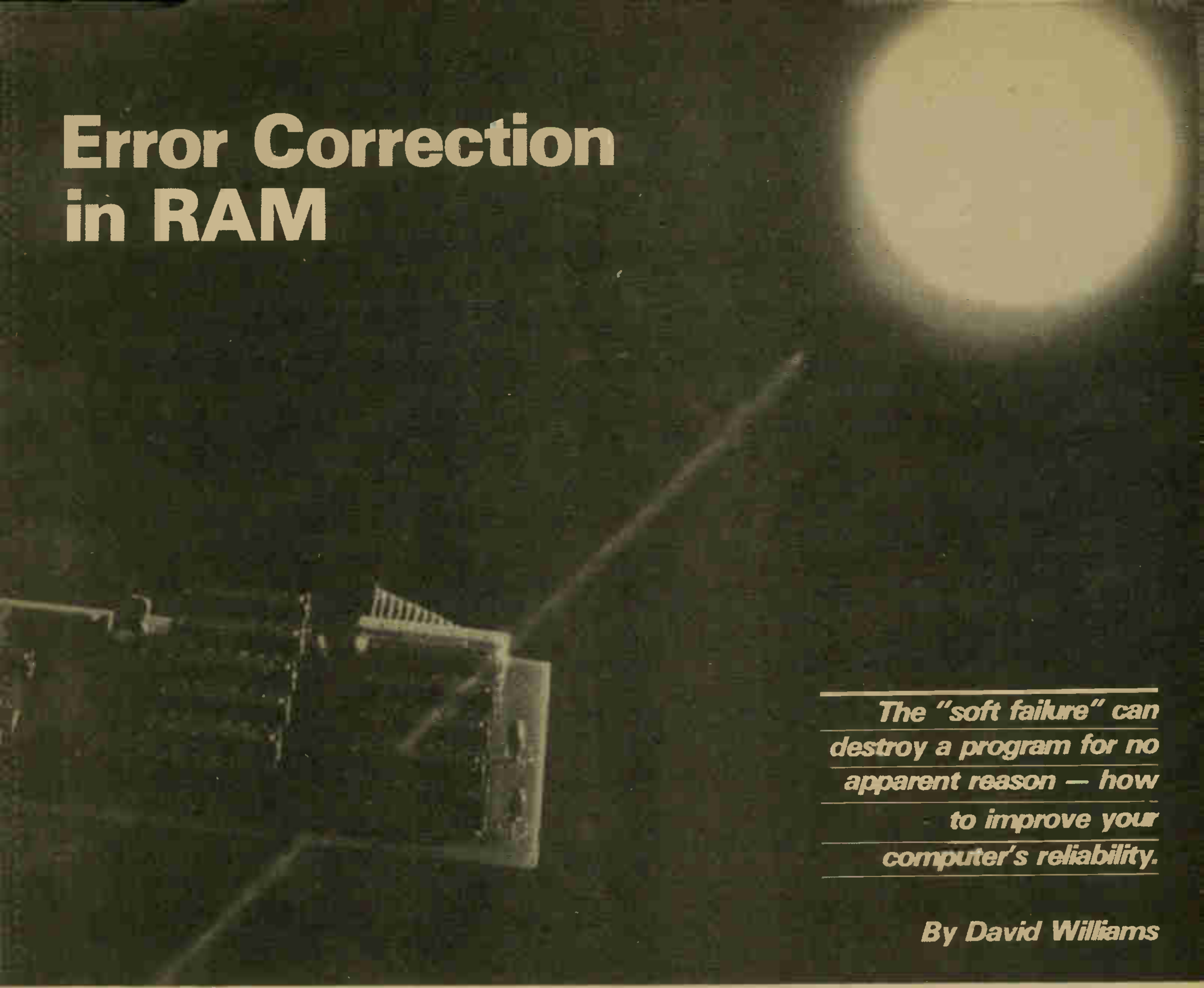
Metallized polyester film capacitors are components that use polyethylene terephthalate (PETP) dielectrics that have conductive plates metallized upon them.

Polyester capacitors have a wide operating temperature range (-40 to 100 degrees Celsius), and are typically available in values from 0uF01 to 2uF2 ±10% to ±20% with an average temperature coefficient of about 300ppm per degree Celsius.

Some polyester capacitors have their values marked on them, but others have a banded colour code system similar to that used on resistors (**Fig. 8**).

The final type of capacitor to be discussed is the mylar film type which is a general purpose plastic capacitor available in values from 0uF001 to 0uF22 ±10% with a working voltage of 100VDC. *To be continued.* ■

Error Correction in RAM



The "soft failure" can destroy a program for no apparent reason — how to improve your computer's reliability.

By David Williams

USERS OF microcomputers frequently suspect that their machines "make mistakes". Errors occur which seem not to be due to faulty hardware, illogical software or inaccurate data. A program which has run perfectly a thousand times suddenly goes wrong. All attempts to reproduce the problem, in order to locate and fix it, fail. After misbehaving once, the system behaves perfectly until, a long time later, a totally different problem makes a one-time appearance. These events are rare, occurring on average only once in hundreds or thousands of hours of microcomputer operation. Most of them are usually dismissed as being due to human errors or to faulty operations of components, such as disk drives, which are known not to be completely reliable. Since they are so rare, they are seldom thought of as serious problems. When they occur, the user simply re-boots the system and starts over.

But there are exceptions. Operators of computer Bulletin Board Systems (BBSs), for example, often leave their machines running unattended for very long periods of time. Anything which causes a system crash can inconvenience all the BBS's users until the operator discovers the situation and re-boots the system. BBS operators sometimes find that these crashes have happened at times when the even cannot be explained by a human or disk error. Many BBSs spend most of their time waiting for the phone to ring. If a crash occurs during one of these waiting periods (and many such crashes have actually been observed), its cause cannot be a human or disk malfunction.

What Happens

Some of these events cause recognizable error conditions. The computer may report a "Syntax Error" in a BASIC program. Listing the program shows that one of its lines has been somehow converted to nonsense, although the previous proper operation of the program shows that the line must initially have been correct. Many crashes, although they have not been accompanied by simple "Syntax Error" messages, have also been discovered to be due to changes in the contents of the computer's memory. Re-booting the system usually clears these problems, so they cannot be ascribed to permanent failures of the memory hardware.

These spontaneous changes in the contents of RAM are often described as "soft failures", to distinguish them from "hard failures" in which RAM fails permanently. Soft failures have no perceptible long-term effects on the computer hardware. A memory chip which has undergone a soft failure works just as well afterwards as it did before.

Deeper Causes

There are several known causes of soft failures. Some of them are incipient hard failures, in which the hardware works unreliably before (maybe) failing altogether. Bad or overheated IC chips, poor solder connections and broken PCB tracks can all cause apparent soft failures. Some people prefer to call these "intermittent hard failures". Describe them however you wish; their effect is similar to all other soft failures except that when they occur, they tend to be more frequent and predictable than those which are produced by other causes.

Some soft failures originate outside the computer. Bad electrical or electro-magnetic "noise" can sometimes make a microcomputer memory misbehave. The noise can come from voltage spikes on the A.C. power line, or from electro-magnetic fields generated by nearby equipment.

Perhaps the most mystifying soft failures are those which are caused by ionizing radiation. If, for example, a heavy radioactive nucleus decays in the vicinity of a memory chip, it may cause an "alpha particle" to pass through the chip. This is a charged particle, actually a helium nucleus, which is surrounded by an intense electrostatic field. As it passes through the material of the chip, this field can move electrons from their normal positions. These electron movements can be sufficient to "flip" a memory cell from the state which holds the digit "1" to the "0" state, or vice versa. Thus the information in the memory is corrupted.

Radioactive decay is not the only source of ionizing radiation. Cosmic rays, atomic nuclei which have accelerated to extremely high energies by various astronomical processes, are common in space. When they enter the earth's atmosphere, they usually collide with air molecules, producing large numbers of "secondary cosmic rays" which are particles with lower energies than the "primaries". By the time sea-level is reached, there are few particles with sufficient energy to cause RAM soft failures, so events from this cause are relatively rare at low altitudes. However, at elevated locations and especially in spacecraft, soft failures due to cosmic rays can be much more troublesome, requiring special precautions to eliminate their effects.

Battling the Problem

The method which is normally used on spacecraft to minimize the effects of soft errors is to employ hardware redundancy. Wherever possible, three independent computers work in parallel. Their operations are frequently compared, and, if one of them is found to be in a different state from the other two, it is deemed to have suffered a soft failure. The memory of this one computer is then re-loaded with the contents of one of the others, so that the computer is restored to the presumed error-free condition.

This method of working in bureaucratic triplicate is very effective. If the comparisons among the computers are done sufficiently frequently, the overwhelming majority of errors can be eliminated. Only very rarely will events occur, such as all three computers being found in different states, which would require computation to be restarted from scratch. For most of us with our feet on the ground, the idea of using three computers to do the work of one is ruled out by economics. Usually, we just have to put up with occasional soft failures, using our human intelligence to detect them and to prevent their effects from becoming too large. However, there are occasions, especially when a computer spends long periods of time during which the contents of its memory should not change, when sufficient redundancy can be built into a single computer to allow errors to be detected and corrected. A BBS which is waiting for a phone call is an ideal system on which to do this. The rest of this article describes a method which I have used, with the help of some other system operators, to detect and correct soft errors in waiting BBSs.

Double Checksumming

Checksums are common means for detecting errors in information. For example, if two computers are exchanging information over a telephone line, they may transmit and receive the information in "blocks" of, typically, a few hundred bytes. During the transmission of a block, both computers calculate the sum of all the numbers contained in the bytes. The transmitting computer sums them as transmitted, and the receiving computer as it receives them. At the end of the block, the machines compare the two sums. Of course they should be identical. If so, the machines proceed to the next block. If the checksums are different, an error must have occurred during the transmission. In this case, the same block is sent again. Using checksums, quite accurate transmission of information is possible even over noisy phone lines which would otherwise produce many errors.

Checksums are a form of redundancy. Some extra information (the checksum comparisons) is transmitted over the phone lines, and can be used to detect errors in a transmission. By using a greater amount of redundancy, it is possible not only to detect errors but to correct them without requiring retransmission of the entire block. One method of doing this is to use a "double checksum".

The following little BASIC routine illustrates how a checksum and double checksum are calculated:

```
100 CHECKSUM = 0
110 DBLCHKSUM = 0
120 FOR INDEX = FIRST TO LAST
130 CHECKSUM = CHECKSUM
 + ITEM(INDEX)
140 DBLCHKSUM = DBLCHKSUM +
CHECKSUM
150 NEXT INDEX
```

The difference between this and a simple checksum calculation consists of the inclusion of the quantity DBLCHKSUM. After each ITEM is added to CHECKSUM, the current value of CHECKSUM is added to DBLCHKSUM. Whereas CHECKSUM ends up by containing the simple sum of the various ITEMs, DBLCHKSUM ends up with the sum of the last ITEM, plus twice the second-last ITEM, plus three times the third-last ITEM, and so on back to the first item.

Suppose that this is used in a data-transmission scheme and that, at the end of a block, the sending computer transmits its values of CHECKSUM and DBLCHKSUM to the receiving computer. The receiving machine finds that its own value of CHECKSUM is four more than the value which the sending computer calculated and that its own DBLCHKSUM is twelve greater than the sending machine's value. Obviously (unless several errors occurred), the third-last ITEM must have been garbled during transmission, and can be fixed by the receiving computer by subtracting four from the value it received. Mission accomplished! No more error!

The possibility that several errors have occurred can usually be distinguished from a single error. If only one byte is wrong, the difference between the two computers' values for CHECKSUM will be no more than 255, the largest possible error in a single byte. Dividing the difference between the two DBLCHKSUMs by the difference between the CHECKSUMs will produce an integer in the correct range, to point to an ITEM between the first and last, inclusive. Correcting this ITEM by the CHECKSUM difference will produce a number which is also in the range zero to 255, to be a valid content of a byte.

If any of these conditions is not met, the receiving computer should conclude that several errors must have occurred, and should then signal the transmitting machine to resend the block. Thus, although the system is not perfectly reliable (there is no such thing as a perfectly reliable information system), in the vast majority of cases it can be made to behave correctly, fixing one-byte errors quickly, and demanding re-transmission when multi-byte errors have occurred.

Double-Checksumming Memory

Checksums can be used in circumstances other than data transmission by telephone. Any sequence of numbers can be used to generate a checksum and double checksum. If there is reason to suspect that the numbers may be corrupted, the checksum and double checksum can be used to detect and correct any error. This is the method which I have used to find and fix RAM soft failures in waiting BBS computers. When the machine enters the waiting state, almost all of its RAM is scanned by a routine which calculates a checksum and double checksum of the numbers the RAM contains. The checksum and double checksum are stored. At frequent intervals during the waiting state, the same area of RAM is scanned again. If the new values of the checksum or double checksum differ from the stored ones, the system attempts to find and fix a one-byte error. If, however, it finds that the discrepancies cannot be accounted for by an error in a single byte, it calls another routine which automatically re-boots the entire system from disk.

It is not possible, in a practical system, to include all of the computer's RAM in the scanned area. There are some bytes which are frequently changed during the normal operation of the machine, even in a waiting state. If these bytes were scanned, the changes in them would be interpreted as soft failures, so the system would wrongly try to "fix" them. The small area of RAM in which the checksum and double checksum are calculated and stored must also be left out of the scanned area, since these operations would cause discrepancies for the next scan. Nevertheless, in the system I have implemented, more than 98% of the RAM is scanned, reducing the probability of a fatal soft failure by a factor of about fifty.

Machine Language

There are difficulties involved in writing a routine in BASIC to calculate a checksum and double checksum of the contents of memory. Such a routine would be very slow, taking several minutes to scan the RAM. Also, it would be difficult to make the scan exclude the RAM in which the checksum variables are calculated and stored by BASIC while still including the variables belonging to the main BBS program, which should be protected from soft failures. For these reasons and others, I decided to use machine language for the routine which calculates the checksums and corrects any errors.

In fact, in my system, the entire "wait for a phone call" program is in machine language and resides in an EPROM. During the waiting state, the BASIC interpreter is not used at all. The machine is extremely insensitive to any changes in RAM, so soft failures are very unlikely to cause a crash. The program in EPROM alternates between two routines. For approximately one minute, one of these routines examines an input line for a signal which would indicate that the phone is ringing. If this signal is received, the routine branches back to BASIC and the main BBS program takes over. Otherwise, at the end of each minute, the memory-checking routine is called. This scans most of the RAM and responds to any errors, as described above. At the end of the memory check, the system goes back to the first routine. If the phone rings during the memory check, the caller has to wait until it is complete. This is not a significant problem, since the entire check takes less than two seconds at machine-language speed. The only circumstance in which a user would have to wait for a longer period is if the memory check shows a re-boot from disk to be necessary. This involves several minutes during which the phone will not be answered. However, this is far preferable to the probable alternative: a complete crash of the BBS.

The Hardware

The memory-checking EPROMS have been installed in three identical microcomputers, aged but reliable Commodore PETs. Prior to this installation, the ROMs in these machines had already been modified in several ways to make them more suitable for running BBSs. For example, after power failures or if various error conditions occur, the modified operating systems in these machines cause the BBS to be automatically re-booted from disk and put online.

The machine language source code shown in the listing is, of course, specific to computers which use the 6502 microprocessor or other very closely related chips. Since many readers will not be interested in these particular machines, I do not intend to dwell on the details of the coding here. I should point out, however, that I have removed almost all coding which would work only on a PET. The original program, for example, contains Commodore-specific coding which prints a message on the screen if the memory-checker finds and corrects a one-byte error. This coding is not shown in the listing, so the program as printed will not indicate to its user that it has done a one-byte correction. The only coding left in the listing which would not work on all types of 6502 machine is the jump to address $C436 in line 960. In a normal PET, this jump would cause the machine to clear the stack and then to drop into direct mode with an "Out of Memory Error" message. (The fact that the stack is cleared explains why I have not troubled to ensure that this jump is made at any particular stack level.) The modified operating systems in the PETs which have actually been used with this routine do more. The exit to direct mode is automatically followed by a re-boot from disk. This is the route which is followed if the memory-checker finds a situation which indicates that more than one byte of RAM needs correction.

Results

The memory-checking EPROMs have been installed in the three BBS PETs for practical reasons. Like the other modified ROMs in the computers, they are intended to reduce the number of system crashes. They are not primarily intended to provide information to myself or to anyone else. If a one-byte error is corrected, a message appears on the screen which can be seen by anyone who happens to be present. However, in normal BBS operation, this message soon scrolls off the screen and is permanently lost. If nobody is around when an error is automatically fixed, nobody ever knows about the event. Likewise, a re-boot from disk can pass unnoticed unless someone happens accidentally to observe it.

In their primary purpose, the EPROMs seem to be very successful. In approximately ten thousand machine-hours since they were installed, there have been no crashes of the systems in which they are fitted. Previous experience suggests that several crashes would have occurred in that much time without the modified ROMS.

Observed Events

On approximately twenty occasions, the computers have been observed to make corrections to their memories. Three of these occasions involved re-boots from disk; the remainder showed the screen message as single-byte errors were fixed. During the waiting state, a substantial portion of a BBS computer's memory does not contain useful information, so some of these corrections were probably made to errors which would not have proved fatal if they had been left unfixed. Nevertheless, the observed events support the idea that several crashes would have occurred if the error-fixing EPROMs had not been fitted.

The events which have observed have not occurred equally often in the three computers. One computer has not displayed any memory fixes. Four events have been observed in a second machine, including two of the three re-boots from disk. All of the remaining events, eighty percent of the total, have involved the third computer.

```
100 *=$7000
110 wkspc=$20
120 permspc=$83e9
130 ptr=$5e
140 flg=$83e8
150 quot=$60
160 lopg=2
170 hipg=$7f
180 erout=$c436
200 strt  lda  #lopg
210       sta  ptr+1
220       lda  #0
230       sta  ptr
240       tay
250       ldx  #7
260 11    sta  wkspc,x
270       dex
280       bpl  11
290 12    lda  (ptr),y
300       clc
310       adc  wkspc
320       sta  wkspc
330       bcc  p2
340       inc  wkspc+1
350       bne  p1
360       inc  wkspc+2
370 p1    clc
390 p2    adc  wkspc+3
400       sta  wkspc+3
410       lda  wkspc+1
420       adc  wkspc+4
430       sta  wkspc+4
440       lda  wkspc+2
450       adc  wkspc+5
460       sta  wkspc+5
470       bcc  p3
480       inc  wkspc+6
490       bne  p3
500       inc  wkspc+7
510 p3    iny
520       bne  12
530       inc  ptr+1
540       lda  ptr+1
542       cmp  #hipg+1
545       bne  12
550       ldx  flg
560       beq  p4
570       ldx  #7
580 13    lda  wkspc,x
590       sta  permspc,x
600       dex
610       bpl  13
620       lda  #0
630       sta  flg
640       rts
650 p4    ldx  #7
660 14    lda  wkspc,x
670       cmp  permspc,x
680       bne  p5
690       dex
700       bpl  14
710       rts
720 p5    sec
730       ldx  #0
740       ldy  #8
750 15    lda  permspc,x
760       sbc  wkspc,x
770       sta  wkspc,x
780       inx
790       dey
800       bne  15
810       lda  wkspc
820       beq  erex
830       pha
840       lda  wkspc+1
850       cmp  wkspc+2
860       bne  erex
870       cmp  wkspc+6
880       bne  erex
890       cmp  wkspc+7
900       bne  erex
910       pha
920       cmp  #$ff
930       beq  p6
940       cmp  #0
950       beq  p7
960 erex  jmp  erout
970 p6    ldx  #7
980 16    lda  #$ff
990       eor  wkspc,x
1000      sta  wkspc,x
1010      dex
1020      bpl  16
1030      inc  wkspc
1040      lda  #0
1050 p7   sta  quot
1060      sta  quot+1
1070      ldx  #24
1080      stx  wkspc+1
1090 17   clc
1100      ldx  #0
1110      ldy  #5
1120 18   rol  wkspc+3,x
1130      inx
1140      dey
1150      bne  18
1160      bcs  erex
1170      lda  wkspc+6
1180      sec
1190      sbc  wkspc
1200      tax
1210      lda  wkspc+7
1220      sbc  #0
1230      bcc  p8
1240      stx  wkspc+6
1250      sta  wkspc+7
1260 p8   rol  quot
1270      rol  quot+1
1280      bcs  erex
1290      dec  wkspc+1
1300      bne  17
1310      lda  wkspc+6
1320      ora  wkspc+7
1330      bne  erex
1340      sec
1350      lda  ptr
1360      sbc  quot
1370      sta  ptr
1380      lda  ptr+1
1390      sbc  quot+1
1400      cmp  #hipg+1
1410      bcs  erex
1415      cmp  #lopg
1420      bcc  erex
1430      sta  ptr+1
1440      pla
1450      tax
1460      pla
1470      ldy  #0
1480      clc
1490      adc  (ptr),y
1500      pha
1510      txa
1520      adc  #0
1530      bne  erex
1540      pla
1550      sta  (ptr),y
1560      rts
```

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The 6502 assembler for error correcting in RAM.

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This book educates educators, on the various ways computers, especially microcomputers, can be used in the classroom It describes microcomputers, how to organize a computer-based program, the five instructional application types (with examples from subjects such as the hard sciences, life sciences, English, history, and government), and resources listings of today's products The book includes preprogrammed examples to start up a microcomputer program, while chapters on resources and products direct the reader to useful additional information All programs are written in the BASIC language

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Large Digital Scoreboard

Do your achievements go unnoticed? Build this big, bright display board and make sure that everyone knows the score.

By Ken Wood

THIS SCOREBOARD has been designed for use in a gymnasium or other large area and uses regular light bulbs to provide a large, bright display easily visible from a distance. The scores or other numerical information are normally entered from thumbwheel switches but the system could also be adapted to accept data from a microcomputer. The basic model has a four digit display which could be used to show a two-digit score for each of two teams, but the number of digits can easily be increased to suit other applications.

The Circuit

The heart of this project is a digit driver module. This uses a 7447A, BCD to seven segment decoder, to drive a digit composed of regular 15W decorator light bulbs via seven triacs. The BCD information in fed serially through a shift register, and used to drive the display.

One module is used per digit in the display, and they are chained together so that they form a long shift register of four bits per digit. The control logic is isolated from the 120V line by an opto-isolator module at the start of the chain, and only one o these is needed for the display.

Third module is a power supply. This provides two separate 5V supplies, one for the circuitry in the display drivers and theother for circuitry isolated from the 120V supply by the opto-isolator module. The supplies shown only offer up to 100mA, so for displays with lots of digits a different regulator may be needed.

Finally there is a controller module. This takes data from up to four thumbwheel switches and turns it into a serial stream to send to the display drivers. It also takes 120V zero crossing pulses from the power supply and uses them to time the serial transmission. This allows the display to be updated while the displays are off at the zero crossing point of the AC cycle.

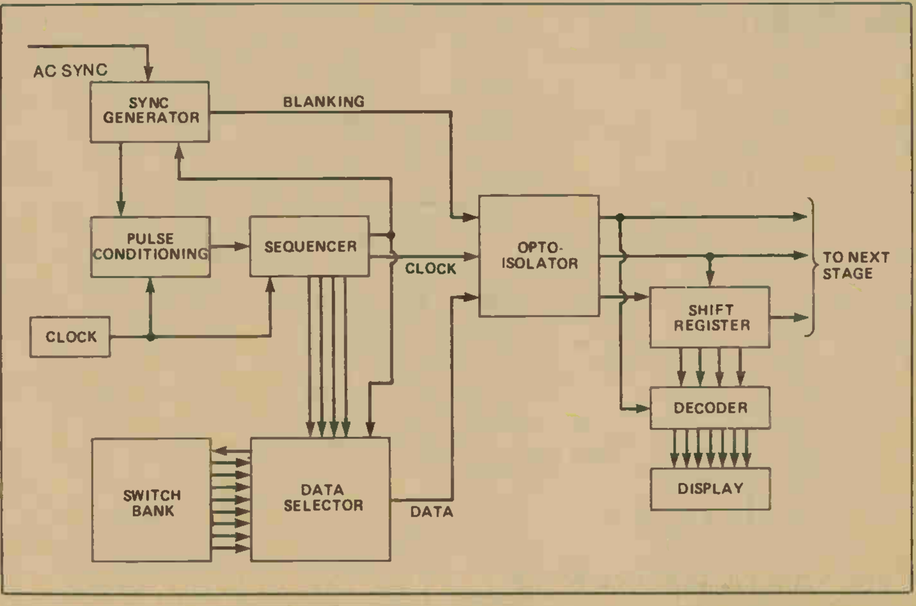

Fig. 1 Block diagram of the complete system.

How it Works

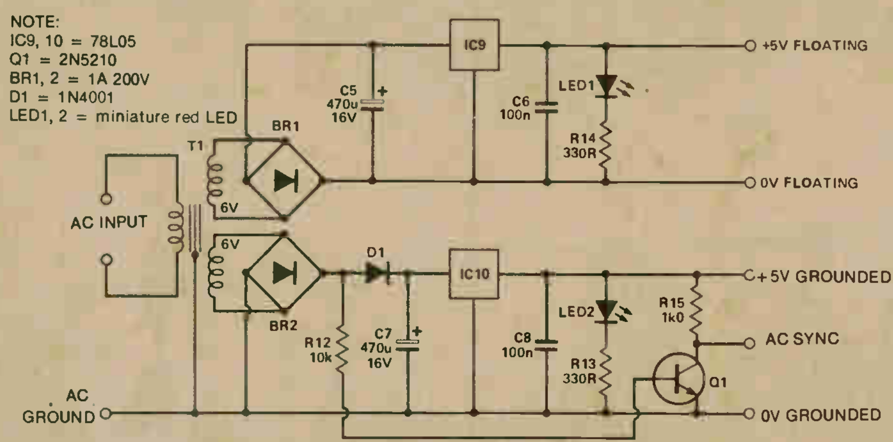

Fig. 2 Circuit diagram of the power supply. Note the use of separate grounded and floating +5v supplies. The controller operates from the grounded supply.

The power supply is in two sections, each of which has a bridge rectifier and a smoothing capacitor followed by a voltage regulator (ICs 9 and 10). C6 and C8 cut out any high frequency spikes and protect the regulators from oscillation. Each section is also fitted with an LED and current limiting resistor as a visual check of operation.

The section that supplies power to the control electronics has its 0V connected to ground as a safety precaution, and also provides AC sync pulses to the controller module. The bridge rectifier BR2 is isolated from the smoothing capacitor with a diode D1, so full wave rectified AC waveform appears at the junction between D1 and R12. This is fed to TR1, which is driven hard on for all but the brief interval when the waveform is at less than 0.7V, 100 times a second.

The AC sync pulses are not necessarily at the zero crossing point of the AC because of the phase shifts that can occur through the transformer. To overcome this, they are fed into a monostable IC1a which is trimmed so that its output is truly at the AC zero crossing point. This is fed into a second monostable whose output is gated with the controller blanking output to hold the triacs off for a period into the AC half cycle. This achieves the dimming function.

IC2a, 2b, and 3a produce a square wave clock at about 50KHz. It is also used to control the operation of the remainder of the module.

IC4a, 4b, and 6a produce a pulse lasting for exactly one clock period at each AC crossing. This is used to reset IC7, a four bit counter. The counter controls IC8, an eight input multiplexer, to sequence through the bit inputs from the thumbwheel switches. Output D from the counter selects one switch bank or the other via IC2d.

When the counter reaches 15 the carry output goes high and the counter is inhibited via IC2e. This means that after each AC zero crossing, the data bits from the thumbwheel switches appear in turn at the serial data output and via IC2f and 5c at the shift data output to the digit drivers.

The beginning and end of this sequence is detected by IC3b which produces an envelope signal while data is coming out of the controller. The signal is made available to an external controller via IC6, and also gates the shift data and shift clock outputs to the digit drivers. It is also fed into the blanking signal so that, even with a very short period set for the monostable IC1b, the triacs cannot come on while data is being transmitted.

The three control signals connected to the digit drivers are fed through an opto-isolator circuit to prevent any AC potentials from reaching the control circuits, thereby making the unit completely safe for connection to a home computer for example.

Each of the three channels is identical, so reference will be made to one channel only. An emitter-follower transistor Q2 drives the LED in the opto-isolator IC11. The opto-isolator transistor, biased by R19 to improve its high frequency response, is buffered by a Schmitt trigger (IC14a and R25), and a final output buffer IC14b drives the output.

IC15 is a four bit shift register, which converts the serial data to parallel at its outputs. The fourth output passes serial data on to the next driver module in the chain, thus with four digit drivers each gets its new data after sixteen clocks. The parallel BCD data is decoded by IC16 to form the segment drive to each of seven triacs.

The blanking signal drives Q5 which switches off the outputs of IC16, preventing the possibility of a digit being displayed while the shifting process goes on and allowing the display to be dimmed.

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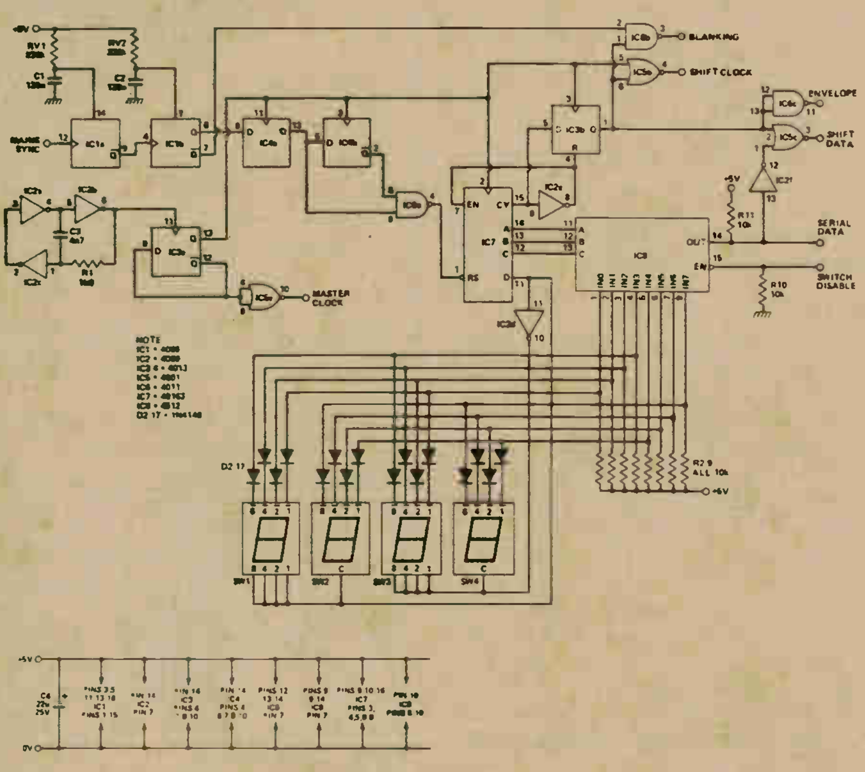


Fig. 3 Circuit details for the controller.

How it Works

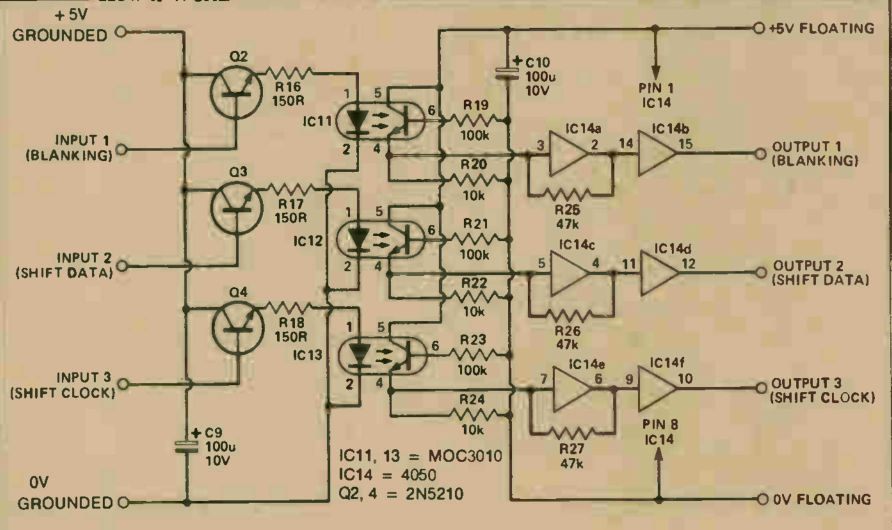
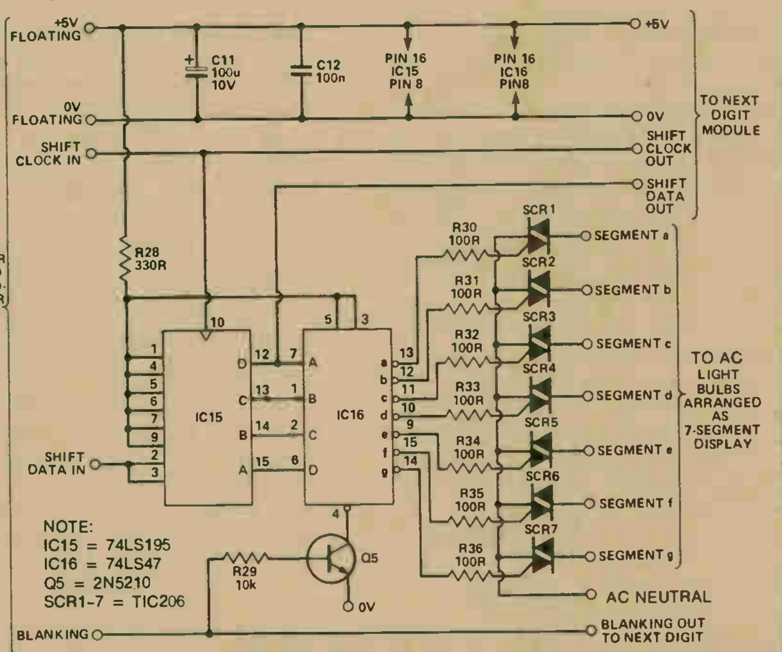


Fig. 4 Circuit of the opto#isolator module.



The controller also provides connections so that the display can be driven by a special purpose external controller, or by a simple I/O port on a home computer. In the case of a display with more than four digits, this is probably the easiest way to enter data and the circuitry for the thumbwheel switches can be omitted.

Construction

The box should be built first, and this is probably the trickiest part. It's not possible to give exact details and dimensions because these will vary according to the size of the digits and the number required. Fig. 6 shows the arrangement used in the prototype and this should be a used only as a guide.

The circuit boards are all single sided except for the controller which is double sided. The leads of the components on the controller board are used to bridge between tracks on each side of the board; components should be soldered on the top side as well as the bottom. Unfortunately this rules out sockets for the ICs.

Printed circuit board pins are used for the flying lead connections to the power supply (except the 120V into the transformer), the isolator module, and the display drivers. In the case of the display drivers, no flying leads are used for the triac-to-lamp connections. The pins should be installed first, followed by the wire links, the resistors, capacitors, and the semiconductors. Be careful with the ICs, some are CMOS types. Leave the power supply, transformer, and triacs for the time being.

The triacs on the digit driver modules are mounted with a small heatsink sandwiched between them and the board. This is a length of aluminum strip, details are given in Fig. 9. The heatsink also provides the extra two mounting points for the board. Each triac is bolted to the board through the heatsink with a mica washer and bushing to insulate the tab. Silicone grease should be used between the tab and the aluminum to improve heat transfer.

Two of the pins on each triac are bent down to pass through the board, while the centre pin is bent up for a flying lead connection to the lamps. Only after the triac-heatsink assembly has been completed should the triacs be soldered to the board.

CASE AND CONTROL PANEL

D2-17 .... 1N4148
FS1 .... panel-mounting fuse holder and 3A fuselink
LP1 .... panel-mounting mains neon
SK1 .... 7-pin DIN socket or other multipole connector to choice
SW1-4 .... BCD ten position thumbwheel swtich with true and inverse outputs
SW5 .... DPST toggle or other mains on-off switch

15W light bulbs, lampholders as required; wood, brackets, etc, for enclosure; coloured filter for front of display; small aluminum panel for the controls and nuts and bolts to mount; cable ties or spiral wrap or similar, stand-off pillars, nuts and bolts for mounting PCB's; ribbon cable, writing etc. The thumbwheel switches are available from Electro Sonic, 1100 Gordon Baker Rd., Downsview, Ontario (416) 494-1555.

POWER SUPPLY

Resistors
(all ¼W 5%)
R12 .... 10k
R13,14 .... 330R
R15 .... 1k

Capacitors
C5,7 .... 470u 16V radial electrolytic
C6, 8 .... 100n 5% polycarbonate

Semiconductors
IC9, 10 .... 78L05
Q1 .... 2N5210
D1 .... 1N4001
BR1,2 .... 1A, 200V (General Inst.)
LED1,2 .... miniature red LED

Miscellaneous
T1 .... 6-0-6V, 500mA mains transformer, chassis mounting

PCB; 1mm terminal pins; ground tag; nuts and bolts for mounting transformer. The bridge rectifiers are available from Active Components.

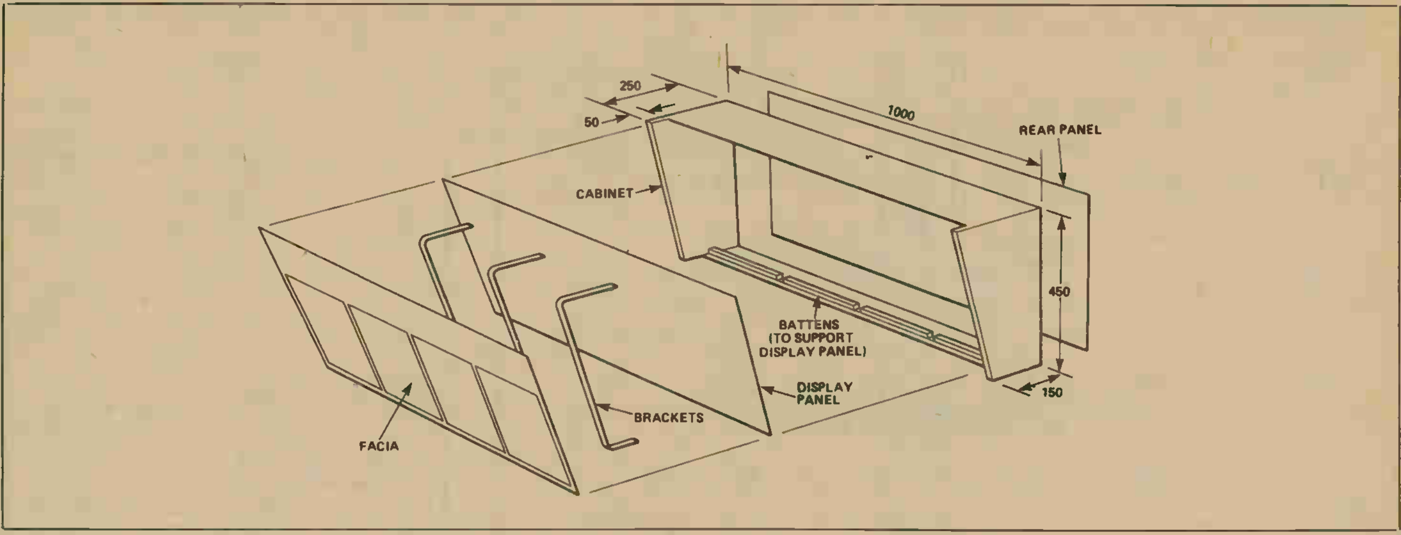


Fig. 6 Details of the cabinet used for the prototype.

The bulb sockets can be mounted on a wooden panel which is also used as the chassis for the PCBs. Mount the PCBs with standoff pillars and keep the interwiring neat by using spiral wrap around the cables. Make sure suitable cable is used for the AC supply to the lamps, between the lamps and triacs, and the returns from the digit driver boards.

The supply, return, and ground wires have been taken to a central supply point rather than chaining them from point to point. This includes the power supply module as well as each display. Remember that quite a bit of AC voltage and current is present throughout much of the wiring; wire it for safety.

The diodes associated with the thumbwheel switches are integral with the switches themselves, and the arrangement shown uses the inverse data outputs. If the switches used do not have inverse outputs, turn all the diodes around, swap the common connections for the two pairs of digits and alter the pull-up resistors on the controller module so that they pull down to 0V. If a display of less than four digits is required, simply omit switches and diodes starting with SW1, then SW2, etc.

Any convenient connector can be used for the outlet to the external controller. A seven pin DIN socket has been used in the prototype. The external controller can interrogate the thumbwheel switches by intercepting the serial data and control signals. It can inject data in place of the switch data by driving the switch disable input to a logic 1 (3.7V +), at which point the output of IC8 goes high impedance and can be driven externally.

If the switch inputs are never going to be used, the controller module may be dedicated to external control by omitting IC4,7, and 8, as well as R2 to R9. The copper track on the component side of the board leading to IC3 pin 1 should be cut (close to the IC only) and a wire link soldered between the pad of IC8 pin 15 and IC5 pin 2. This allows the external controller to generate the envelope signal. IC6 pins 5 and 6, and IC3 pins 4 and 5 must be wired to 0V to protect their CMOS inputs.

Setting Up and Use

Boot up the power supply with its outputs disconnected, if all is well, the LEDs should light to show that something is getting through. Check that both outputs are producing 5V.

Very little intermediate checking can be done on the rest of the circuitry so be careful while poking around the digit

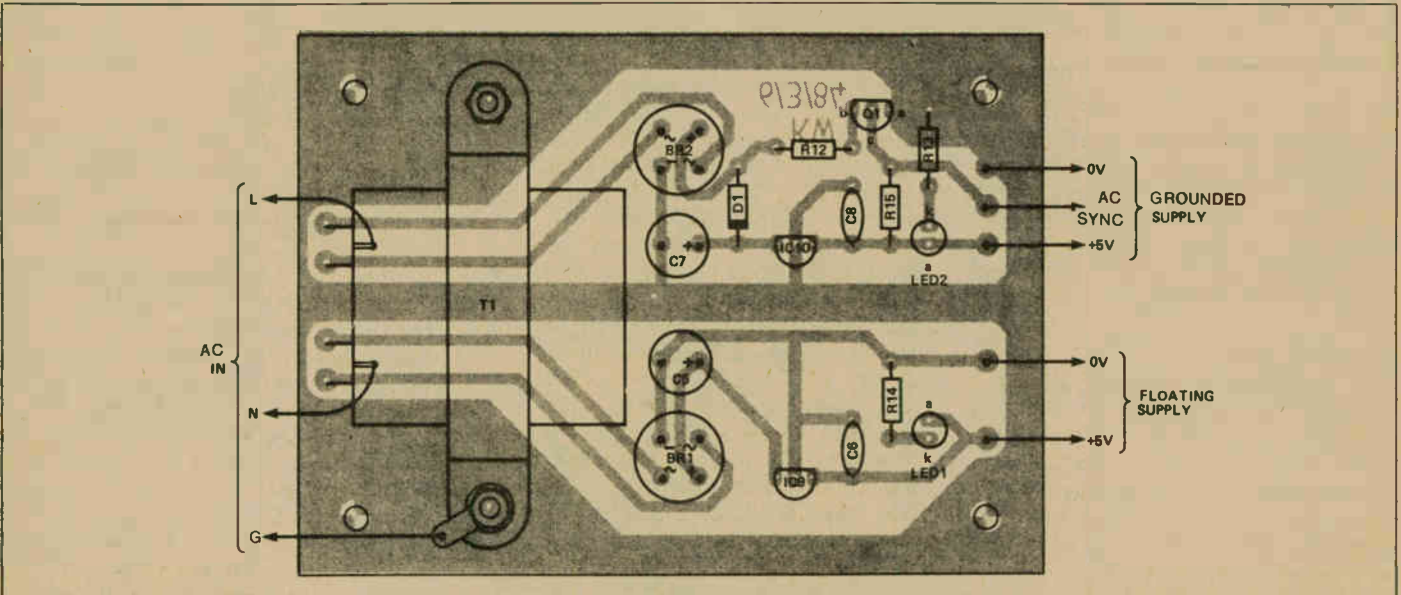


Fig. 7 Component overlay of the power supply board. Note the ground connection to the frame of the transformer and the AC connections taken directly to the transformer, not to the PCB.

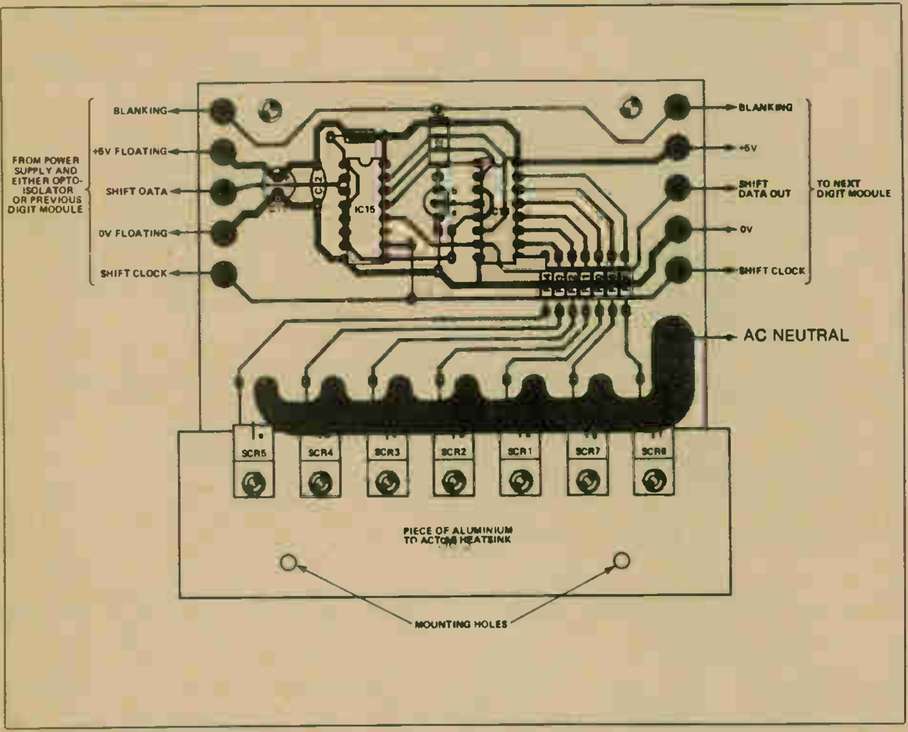


Fig. 8 Component overlay of a digit driver board. The lamp connections are made directly to the centre pins of the triacs.

DIGIT DRIVER MODULE

Resistors
(all ¼W 5%)

R28	330R
R29	10k
R30-36	100R

Capacitors

C11	100u 10V radial electrolytic
C12	100n polycarbonate

Semiconductors

Q5	2N5210
IC15	74LS195
IC16	74LS47
SCR1-7	TIC206

Miscellaneous

PCB; 1mm terminal pins; nuts and bolts, mica washers and insulating bushes for triacs; heatsink (see text); IC sockets if desired — 2 off 16 pin DIL.

driver areas as these are ripe with AC voltages.

Make the set-up adjustments with a single bulb plugged in somewhere, and arrange for the display to show all 8s. Set RV1 on the controller module fully anticlockwise and RV2 fully clockwise. Switch the unit on and the lamp should be at full brightness. Using an insulated screwdriver so that AC hum does not affect adjustments, slowly turn RV1 clockwise until the lamp suddenly goes dim, and stop there. Now turn RV2 anticlockwise and the lamp should increase in brightness. The lamp may now be set to the desired operating brightness.

If the display is to be run at full brightness, either because you need that much light or because you want to keep RF interference to a minimum, continue to turn RV2 anticlockwise until the lamp suddenly goes out then turn it back to the point where the lamp comes on again.

The display is now ready for use, so switch off and install all the lamps. Keep a few spare triacs on hand as well because when bulbs blow they tend to take the triac with them. Running the display at a reduced brightness should help a little.

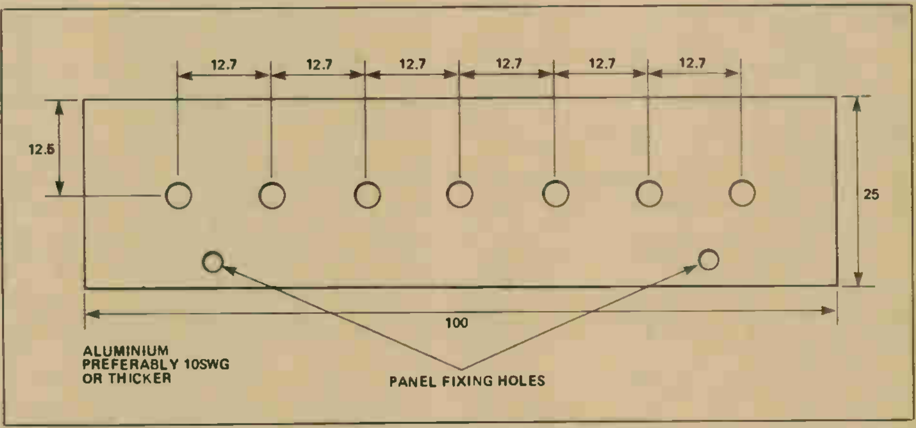


Fig. 9 Drilling details of the heatsink for the digit driver board.

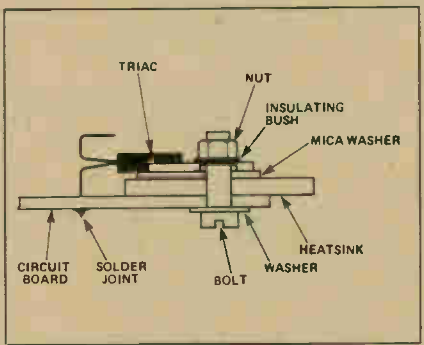


Fig. 10 Mounting arrangements for the triacs.

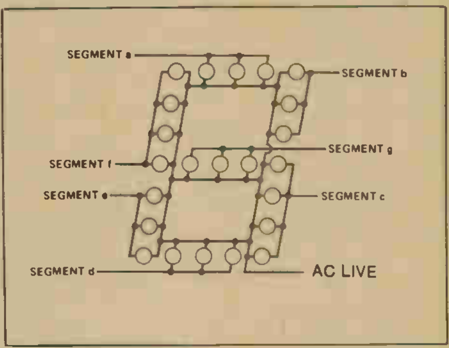


Fig. 11 How the lamps are connected to form a seven segment display.

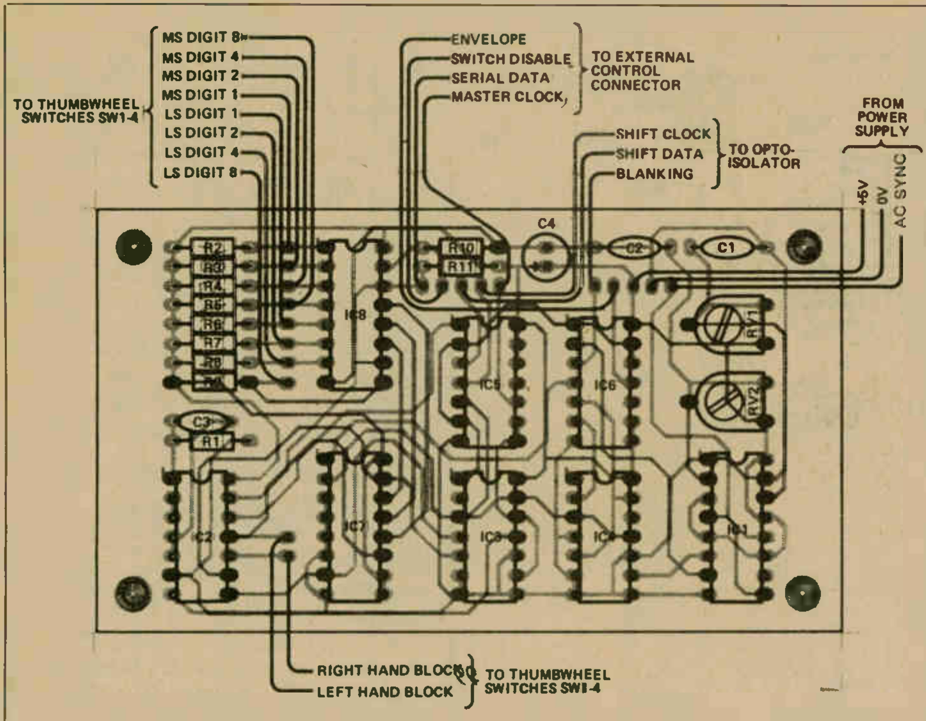


Fig. 12 Component overlay of the controller board.

CONTROLLER MODULE

Resistors
(all ¼W 5%)

R1	1k8
R2-11	10k
RV1,2	220k miniature horizontal preset

Capacitors

C1, 2	120n 5% polycarbonate
C3	4n7 5% polycarbonate
C4	22u 25V radial electrolytic

Semiconductors

IC1	4098
IC2	4069
IC3,4	4013
IC5	4001
IC6	4011
IC7	40163
IC8	4512

Miscellaneous
PCB

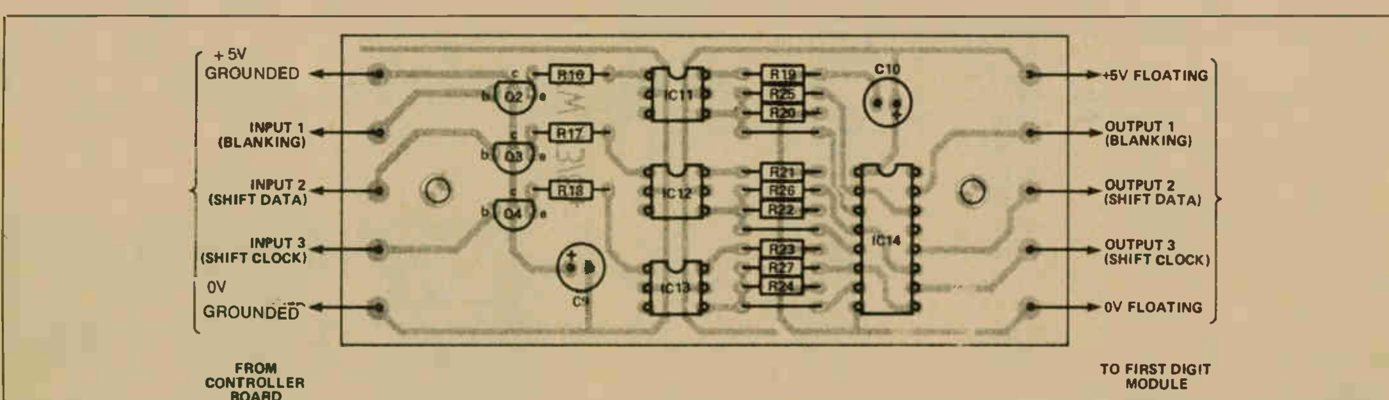


Fig. 13 Component overlay of the optoisolator board.

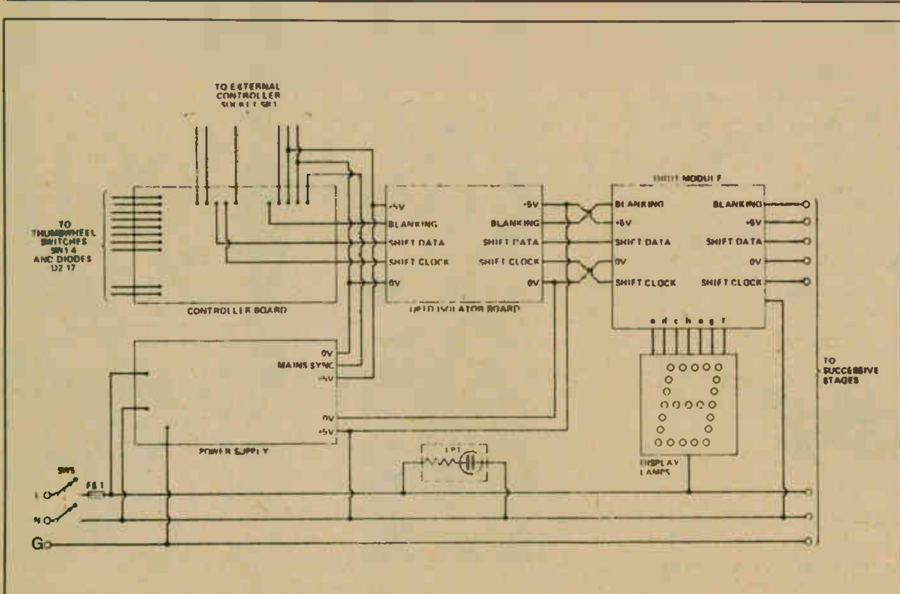


Fig. 14 Interconnection of the boards.

ISOLATOR MODULE

Resistors
(all ¼ W 5%)

R16-18	150R
R19,21,23	100k
R20,22,24	10k
R25-27	47k

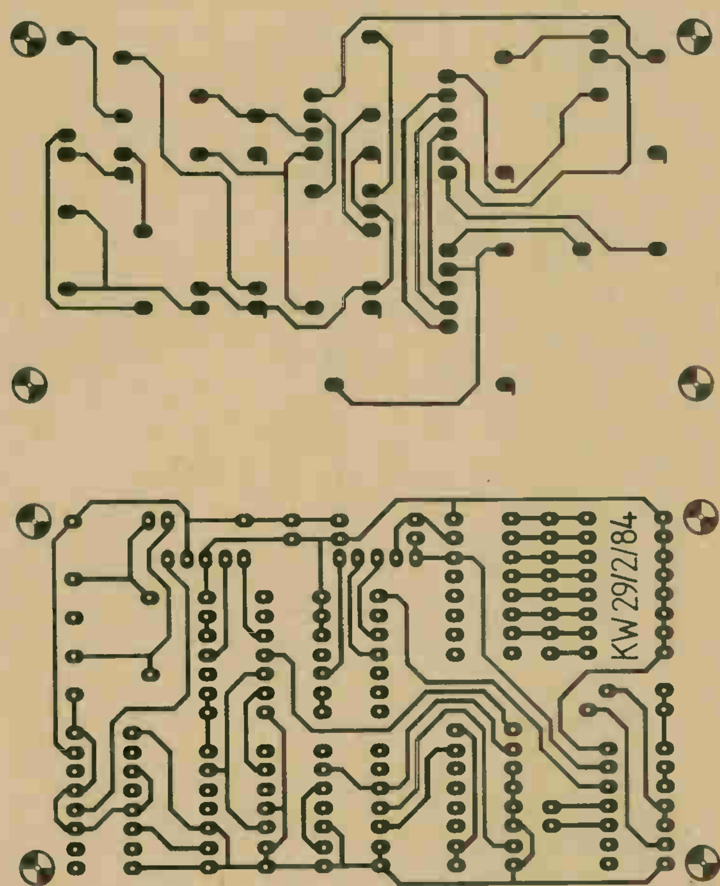
Capacitors

C9,10	100u 10V radial electrolytic

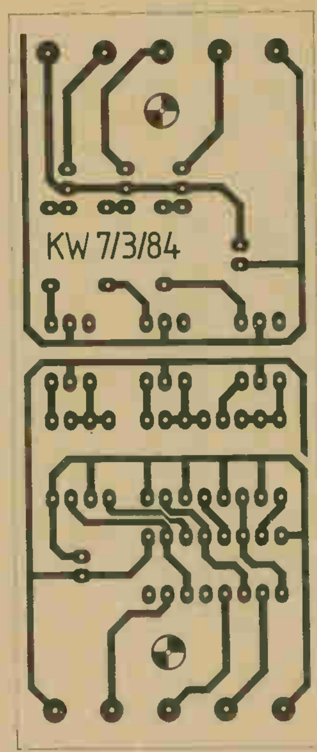
Semidconductors

Q2-4	2N5210
IC11-13	MOC3010 opto-isolator.
IC14	4050

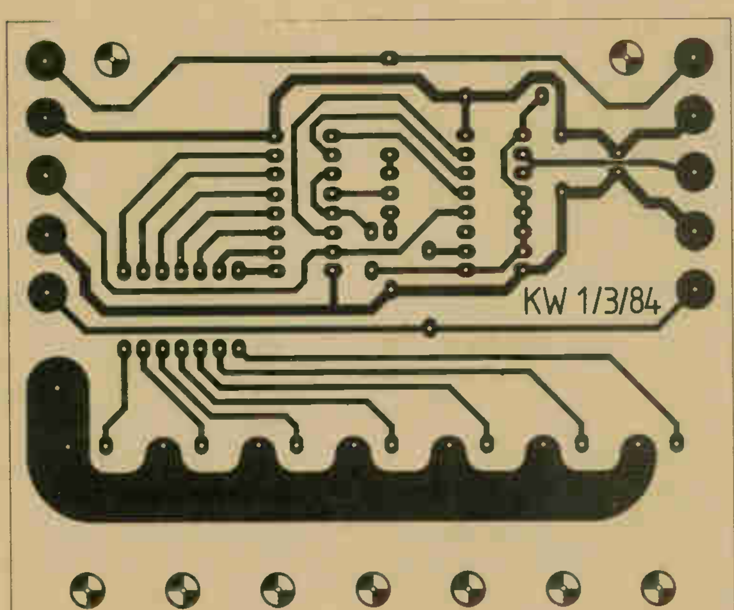
Miscellaneous
PCB; 1mm terminal pins; IC socket if desired — 1 off 16 pin DIL



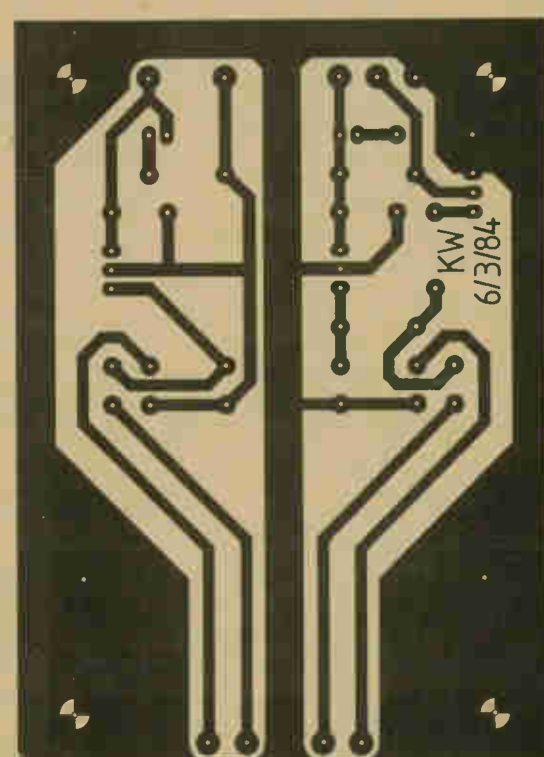
The top and bottom patterns for the scoreboard controller module.



The pattern for the scoreboard opto-isolator module.



The digit driver board pattern for the scoreboard



The power supply board pattern for the scoreboard. ■

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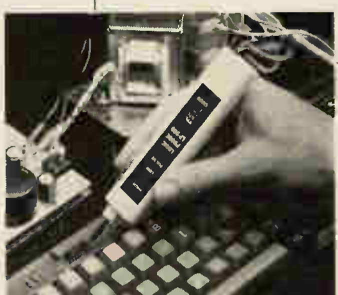

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PHILIPS Test & Measurement

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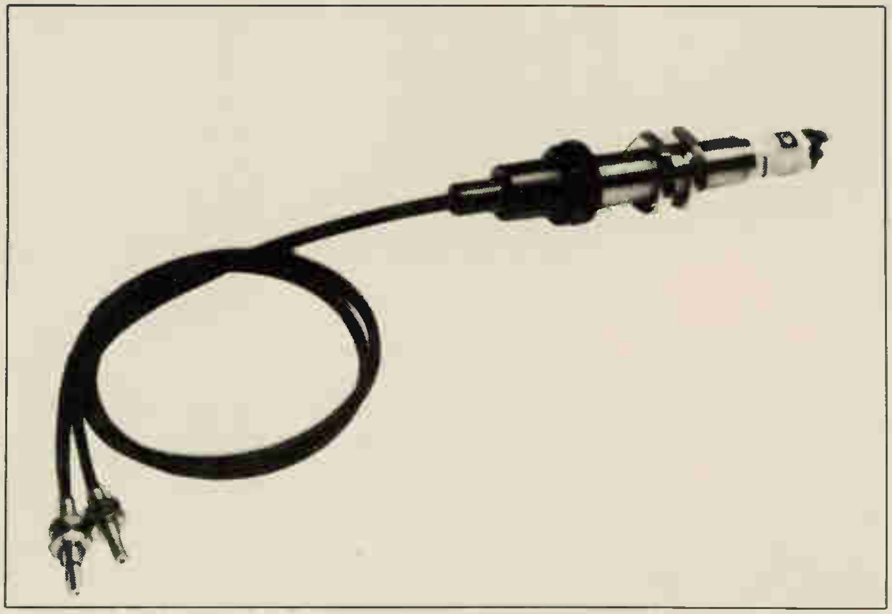
PHILIPS

continued from page 6

Compact Fibre Optics



Electro Corporation has announced a new line of Photo-Trol pulsed LED photoelectric switches for target detection in industrial applications. The control head is 1/2 inch in diameter and the optical diameter of the fibres only .040 inch. No electrical energy is present in the head or cable, making them ideal for hazardous locations. Models are available in through-beam, retro-reflective or proximity modes. They're stocked by Atlas Electronics, with branches in Montreal, Ottawa, Toronto, Winnipeg, Calgary, Vancouver and Tuktoyuktuk; their head office is 50 Wingold Avenue, Toronto, ONtario M6B 1P7, (416) 789-7761. Circle No. 45 on Reader Service Card

Zentronics, 8 Tilbury Court, Brampton, is now distributing United Chemi-con aluminum electrolytic capacitors. UCC have a broad base of capacitors ranging from general purpose, tantalum replacement, power supply, high CV and computer grade. They're at (416) 451-9600

Circle No. 46 on Reader Service Card

The president of Apple Computer, John Scully, announced recently that the company would "open up" the architecture of the IIc and Macintosh to third-party vendors. This would encourage hardware and software developers to come up with expansions for both machines. The IIc, in particular, could use more memory and the ability to run CP/M.

Miniature TV

Zenith Electronics has introduced its most portable television set ever, the black-and-white model BT044S, weighing only two pounds and sporting a four-inch diagonal screen. It's said to fit easily into a briefcase, purse, totebag or palm, and has UHF/VHF 69 channel capability. It runs on household AC, your 12V car battery, or four alkaline C cells. It also has a jack for signals from a VCR or video camera, making it an ideal field monitor. From Zenith dealers.

Circle No. 47 on Reader Service Card

ComputerLand Canada Inc., Canada's largest computer retailer with 63 stores, has introduced a national, toll-free hotline to answer customers' software questions. The hotline, offering bilingual service, is available for the duration of each maintainence contract purchased, or for up to 30 days with each software purchase. Good stuff. Few things must be as frustrating as spending a bundle on software that doesn't seem to do what you want.

Circle No. 48 on Reader Service Card

According to the joint program of Statistics Canada and the Electrical and Electronic Manufacturers Association of Canada, shipments for May totalled $12.7 million. Exports were $498 million, up about 9 percent from a year ago, and imports were $1041 million, also up slightly. There were 108,000 people employed in the industry, up .8 percent over last year. In other words, no drastic changes so far.

Other facts: the electrical energy made available up until April was 147,072 gigawatt/hours. The top three imports were semiconductors, parts of semiconductors, and tape decks.

Prices: compared to 1971, major appliances are 2 1/2 times more expensive, radio and TVs twice as expensive, small appliances twice, and lighting fixtures 3 1/2 times.

The Lexicon 1200C mentioned in the last issue is used for the compression or expansion of the running time of video and audio program material, allowing split-second timing adjustments without editing. We omitted the fact that Lexicon products are available from Deltech Communications Equipment Inc., 300 Steelcase Road, Unit 11, Markham, Ontario L3R 2W2 (416) 649-2674.

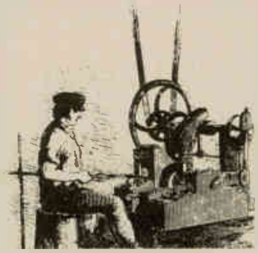
Circle No. 49 on Reader Service Card

100 and 1000 Years Ago in Electronics Today

Electronics Today

October, 1885: "Can the many readers of Electronics Today really justify to their compatriots the usefulness of the endless hours of diversion provided by coils of wire and battery jars filled with peculiar liquids? While we, the staff, enjoy these pastimes as well, we must answer in the negative. It would appear that the invention of electricity will not prove of use to society, and regretfully must be ranked with other idle fantasies, such as the flying machine or the transmission of animated photographs through the ether.'

'While the staff of Electronics Today makes every effort to ensure accuracy, things occasionally do go wrong. The printed circuit for last month's Electrical Health Stimulator and Perspiration Suppressor was accidentally omitted and appears in this issue along with apologies for those inconvenienced.'



'Work is progressing in Southern California towards the miniaturizing of relays. The relay, at present an unwieldy coil and frame, can be used as the most basic form of 'memory', since it 'remembers' its electrical state until power is interrupted. Researchers claim that the relay could be made as small as six inches to a side, and dozens of them mounted in a framework no larger than the average living room, giving a 'memory' capability of hundreds of states. At present, we find this concept to be unrealistic; aside from having no conceivable use, it can no doubt be shown that miniaturization to this extent is simply not physically possible.'

Electronics Today

October, 985: "Verily, ye Len Fynkler and Companny have prefented a new machine Tool, yclept ye OK-11 Wirewrap Tool from OK Induftries. Cleverly yclad in black ABS Plaftik, ye compact Tool is defigned for ye Production and ye R&D, handling Wire from 22 to 34 AWG. Much Time will be saved over ye previous way of faftening ye Wire with ye blow of an Axe."

"In sooth, ye Goblins do wreke Havok in ye Nyght in our Office; yea, ye Printed Circuit for Ye Electryfyed Broadfword inddeed was omitted from laft Month. It appeareth this Iffue wyth Apologia moft profufe."

"Ye alchemifts do difturb ye Brain and quicken ye Temper: verily, they do infift that ye entyre Drawbrydge could be ufed for a 'Memory' in that it doth 'remember' one of ye two State, forsooth, ye 'up' or 'one', and ye 'down' or 'zero'. Ye Drawbrydges are to be 'miniaturised', God a-willyng, and mounted in ye 'Memory Banks' to keep afresh ye 'Data'. Suche Foolery and wafting of Tyme doth bode ille for ye Induftry."

PC ATE

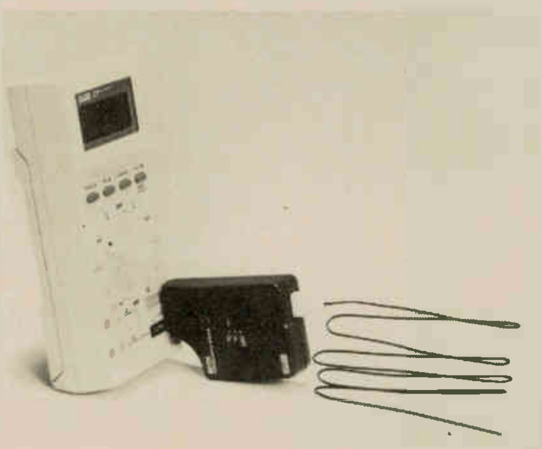
Ate what? If you have an IBM PC or HP 150, you can build yourself an Automated Test Equipment setup with Hewlett-Packard's new PC Instruments test modules. The interface card and software allow the computer to control and display test results from up to 15 of the stackable modules. Modules available so far are: a digitizing scope, a multimeter, a function generator, a universal counter, a digital I/O interface, multiplexer, a D/A converter, and a relay actuator. Contact Hewlett-Packard (Canada) Ltd., 6877 Goreway Drive, Mississauga, Ontario L4V 1M8, (416) 678-9430.

Circle No. 51 on Reader Service Card

DMM Temperature Module

Instant temperature measurements are possible with the Fluke 80TK thermocouple converter. It has an output of 1mV per degree, giving a direct readout on any 3 1/2 digit multimeter having a 10 megohm or greater input impedance. Various probes are available for different applications, giving a range in total of -40 to 927 degrees C. Powered by a 9V battery, the converter is switchable from Celsius to Fahrenheit. From Allan Crawford Associates, Test and Measurement Division, 5835 Coopers Ave., Mississauga, Ontario L4Z 1Y2, (416) 890-2010.

Circle No. 50 on Reader Service Card



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All three machines are in the Toronto area, at low altitude, so few cosmic ray induced soft failures are to be expected in any of them. In other respects, however, the computers' environments differ substantially. They are in three separate buildings. The machine on which no memory corrections have been observed is supplied with A.C. power through a commercially manufactured filter which, according to its maker, removes virtually all spikes and other forms of noise from the A.C. waveform. In contrast, the computer in which the most errors have been observed is surrounded by many other items of electrical equipment and, until recently, was supplied with "raw" A.C. without any filtering. Interestingly, no memory corrections have been seen on this machine in the most recent 1,000 hours or so of operating time. This corresponds roughly with the fact that an A.C. spike filter has recently been installed in its power line. The machine which has twice re-booted its BBS from disk is one which is suspected by its owner of having some kind of intermittent hardware problem. If this is the case, it is not surprising that the errors it produces tend to be of the multi-byte variety.

Conclusions

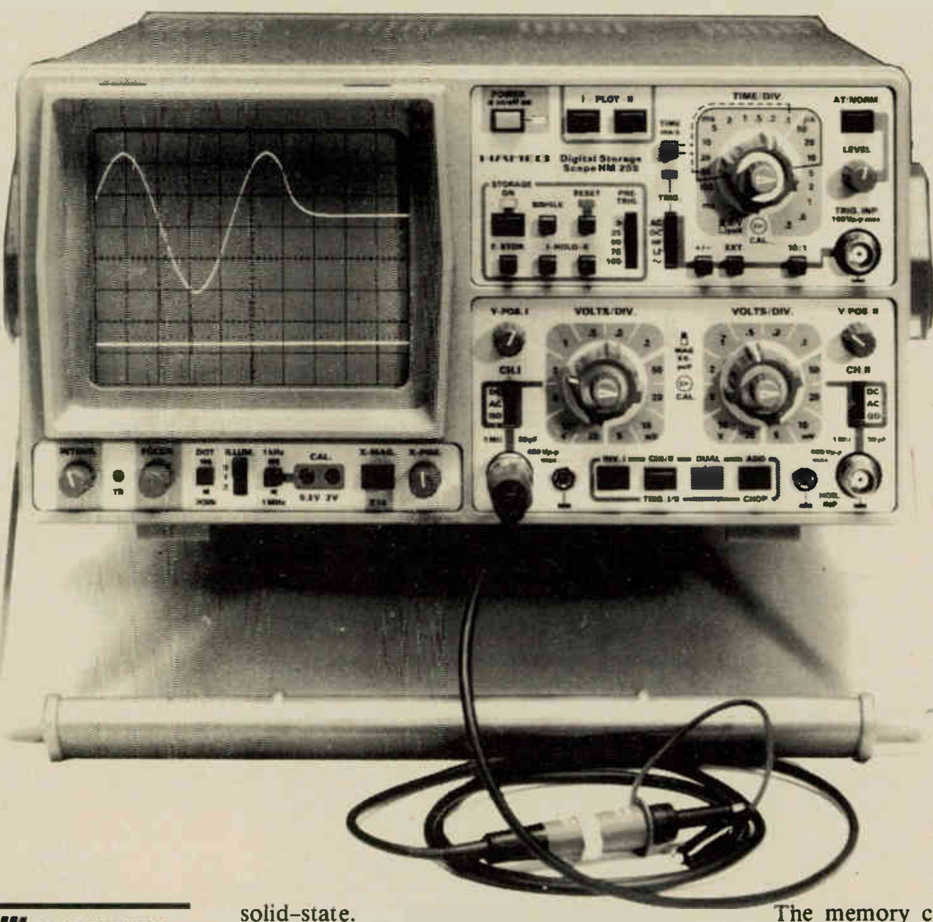
Any conclusions which are drawn from these observations must be very tentative. They may not apply to types of computer other than the PET, nor in other geographical locations, particularly places at high altitude.

It does appear that the most frequent cause of memory soft failures in our BBS computers has probably been electrical noise. The difference in the error rates between the most and least error-prone computers is far greater than might reasonably be ascribed to chance, and the only difference between them which seems to be a likely cause is the "dirtiness" of their electrical supplies.

The double-checksum technique of finding and fixing memory soft failures has been effective under the real-life conditions I have described. Its inclusion into other suitable systems is probably desirable.

The author is grateful to David and Richard Bradley and to Patrick Cole, the owners and operators of the Bradley Brothers' BBS, for having participated in this investigation. The BBBBs may be contacted, in Toronto, at (416) 487-5833. The BBS which the author operates is not a publicly accessible system.

Oscilloscopes



A look at oscilloscopes and the various features provided by low-cost solid-state technology.

By Bill Markwick

AS THIS article was first taking shape, I was doing some testing with my 1970s vintage storage oscilloscope. It was the high-tech of its time, being stuffed with all sorts of discrete transistors, and featuring an analog storage capability in the CRT. This worked by flooding the phosphor coating with electrons to keep the display refreshed, allowing storage of signals, or accumulated signals, for hours. It did its job all right, but the sensitive coating eventually burned a bit, especially with bright, repetitive signals; there's now the hazy ghost of a sine wave on top of anything else you happen to be looking at. It also suffers from spreading ("blooming") of the trace if you turn the intensity up too high. In addition, it cost a king's ransom and generates a remarkable amount of heat for something that's solid-state.

The advent of low-cost digital and analog electronics has changed all that. Although discrete transistors are still used quite a bit for optimizing various characteristics, ICs are a natural for such functions as triggering circuits, and reduce power consumption in the bargain. A/D converters and inexpensive memories have replaced the analog phosphor as a storage device; not only do they eliminate the analog bugs, but they allow you to store waveforms in memories for later comparisons. On the scope on our cover, for instance, both the 1KHz pulse train and the 60Hz electrical noise were being displayed from the digital memories.

Circle No. 52 on Reader Service Card

Hameg HM 208

The oscilloscope on the cover, photographed as seen by someone who's nodding out on the testbench, is a dual trace, 20MHz storage scope with a 20MHz digitizing rate. This means that you can capture signals from extremely low frequencies to 20MHz, or 10MHz with both traces being stored. The Roll mode allows the scope to function as a chart recorder, with the signal running from right to left with continuous trace.

The memory consists of a 4096 by 8-bit block, divided into storage for channels 1 and 2, plus two backup memories of 1024 points each. The two backups can be used as a single, doubling the resolution to 2048 points.

Other features include four pre-triggering settings to allow the trace to start ahead of a particular event, X-Y operation with storage to display very low frequency transfer curves, Lissajous figures, etc., and an output for sending the stored waveforms to a chart recorder. Vertical sensitivity is 5mV/cm to 20V/cm.

The HM208 costs $2750, FST included, from BCS Electronics, 980 Alness St., Unit 7, Downsview, Ontario M3J 2S2, (416) 661-5585.

Circle No. 53 on Reader Service Card

Duncan 6022

A general purpose 20MHz scope is the Duncan 6022, featuring dual traces, 5mV/cm sensitivity, a post-deflection-accelerator tube for linearity, and a built-in component tester. This latter item is no end of use to the troubleshooter, particularly if you come across a doubtful semiconductor; it consists of a 9VAC supply current-limited to 2mA. The AC is ap-

continued on page 42

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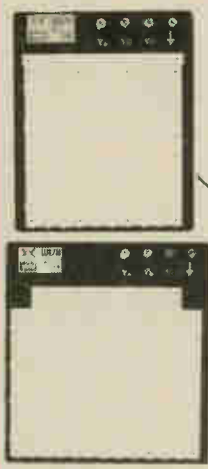

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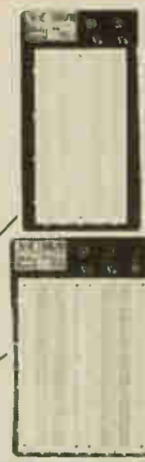

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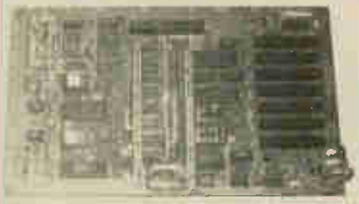

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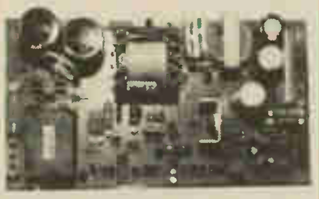

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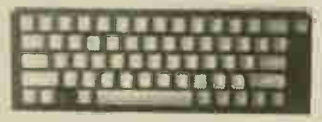

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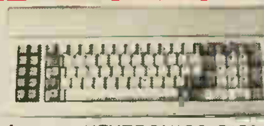

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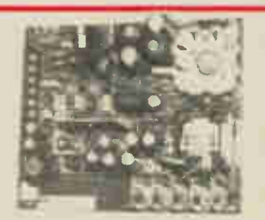

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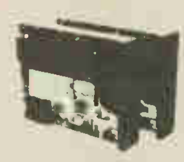

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A Guide to Transformers

Some theory and some rules of thumb for getting acquainted with power and audio transformers.

By Bill Markwick

THE TRANSFORMER is usually just one of those black boxes that you don't have to think about much; it sits in your chassis supplying power or changing signal levels to suit the circuit. Once in a while, however, you may decide to build a project or do a replacement and you can't find the exact model you need.

There are enormous numbers and types of transformers for various purposes; we'll be looking at the two largest categories: power and audio transformers. Here's a brief guide to transformer operation and specifications.

Basics

Transformers are usually classed as step-up or step-down. This refers to the *output voltage* compared to the *input voltage*. This applies both to power transformers, and in a more roundabout way, to impedance-matching transformers as well. How the transformer changes the input voltage isn't too complicated, although like anything else, you can make it as complex as you want (we'll stick to finding basic parameters for replacement or simple design).

Imagine a coil of wire suspended in the air. Or you can imagine Brooke Shields or Robert Redford holding it up. Your choice. Now we apply a direct current through it; this creates a magnetic field around the wire. Nonbelievers may hold a compass near it and see the deflection. Unfortunately for those in need of lots of magnetism, you can't get a whole lot out of an air-core. To increase the available magnetic energy, the coil is wound on a *ferromagnetic core. My italics key is stuck!* Sorry. As I was saying. You can demonstrate this by winding some wire around a screwdriver shaft and applying an amp or so; the shaft will become magnetized enough to pick up paper clips. Borrow your neighbour's screwdriver if you try this, because it stays magnetized and will drive you crazy later picking up nails and things when you don't want it to.

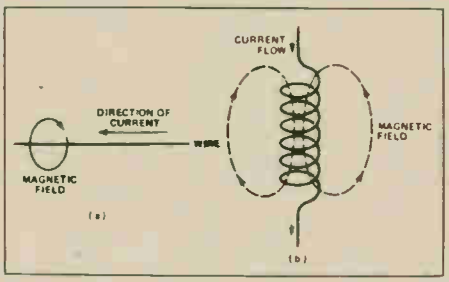

Fig. 1. If an electric current is passed through a coil of wire, a magnetic field is generated; in effect, an electromagnet.

Like all good things, though, there's a catch. First, there's a limit to how much magnetism the metal will store; this depends largely upon the material selected. As the applied current increases, so does the magnetic field until it reaches the limit called *saturation*; after this point is reached, increasing the current causes no further increase in magnetism. This effect is very important when it comes to selecting an audio transformer for low-distortion power applications. A further disadvantage to the metal core is *hysteresis* (pronounced hister-eesis). This effect happens because the field in the ferromagnetic core lags slightly behind the energizing current it it's AC; if the delay is significant, energy is wasted heating up the core. Unless you plan to design your own windings, you won't be bothered much by this; hysteresis effects are minimized by the cleverness of transformer manufacturers.

The energy stored in a coil can be substantial. For instance, you'll often see a reverse-biased diode across the winding of a relay coil. The purpose of this diode is to absorb the energy stored in the coil

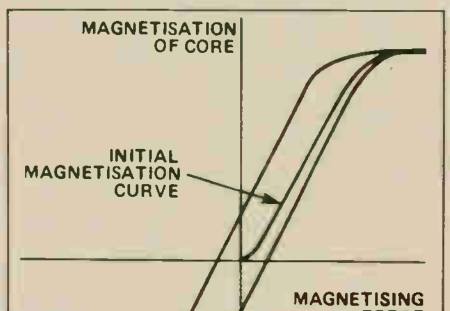

Fig. 2. The hysteresis effect caused by the lag between the magnetising force and the actual magnetism in the core.

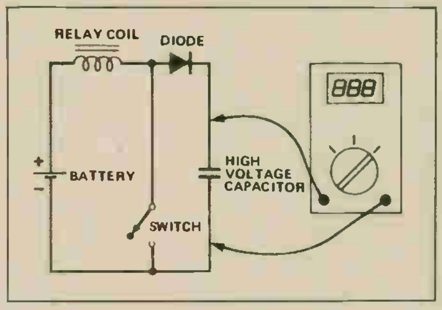

Fig. 3. An experiment to observe the storage of inductive energy in the coil of a relay; the induced voltage can be higher than the battery voltage.

when the driving circuit is switched off. Otherwise, a good-sized reverse voltage is produced, causing an unwanted spike which can feed into signal lines or even damage any transistors driving the relay.

This can be shown by the circuit in **Fig. 3.** If the switch is turned on and then off, the induced current in the coil will flow through the diode into the capacitor and charge it up above the battery voltage. With a suitable choice of relay (or other coil) and capacitor, much higher voltage can be induced into the capacitor than was originally applied to the coil.

Two Coils

If two coils are wound on the same core, the surge of voltage and current generated as in Fig. 3 will be generated in both coils, because the magnetic field is around both coils. You could connect the power switch and relay to one coil and the diode/capacitor to the other and meter the energy being transferred from one coil to another. This effect is called mutual inductance and is the principle of the transformer.

The transfer of energy between coils isn't perfect; there's always some loss, some of it due to the fact that the magnetic field generated doesn't overlap the coils perfectly. This effect is often minimized by designers by specifying *bifilar* winding. In this type of transformer, the wires for both coils are applied together rather than winding one coil, then the other. This increases the coupling between coils.

Power Transformers

They come in two basic types: the E-core and the toroidal. **Fig. 4** shows the more common E-core, so-called because its magnetic core is put together from stampings in the shape of Es and Is; this allows the windings to be done easily on rotary machinery. You've noticed that these cores are made up of thin sheets or

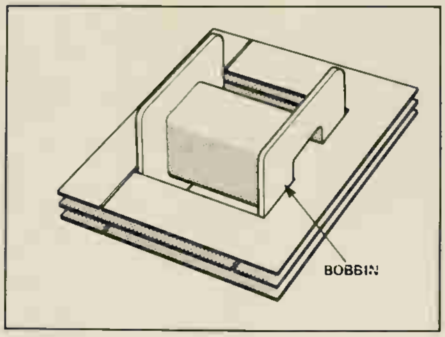

Fig. 4. E and I shaped core leaves on a plastic bobbin.

laminations; the reason is to reduce losses from eddy currents. Just as a coil can induce currents in another coil, current may be induced in the core itself, creating heat and wasting energy. The laminations break up these eddies and reduce them to a fraction of what they would be in solid cores.

The second type of transformer is the toroid; the coils are wound on a donut-shaped core which is itself wound from a strip of magnetic material (**Fig. 5**). The lack of corners reduces stray fields, and the aligned grain of the rolled iron strip makes it easier to magnetize. This makes them smaller and lighter for a given

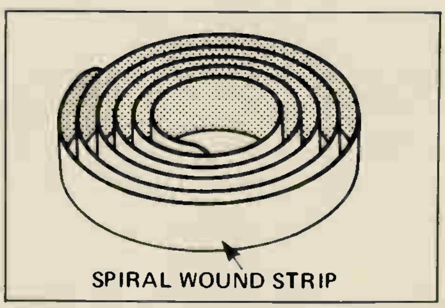

Fig. 5 The core of toroidal transformer is made from a wound strip of magnetic material.

power than the E-cores; in addition, the symmetrical shape reduces the external hum field, important in audio or test equipment.

Power Parameters

Now we come (finally) to the actual characteristics that concern you if you're looking for a new or replacement power transformer. The first one is the voltage step-up or step-down, directly determined by the *turns ratio*. If you have 500 turns on the input (primary) side, and 100 turns on the output (secondary) side, then the turns ratio is 5:1 and the output voltage will be equal to the input divided by five. As we've mentioned often in these pages, transformer voltage ratings are specified, for example, as either 12VCT (Volts Centre Tapped) or 6-0-6; both mean the same thing and both are RMS voltage ratings.

The next problem is to determine the current rating. This is a bit more complex, because it depends entirely on the sort of load the transformer will be driving. If the load is a resistor, which is possible but used less often, you can take the ratings at face value: if you need 1 amp at 25VAC across your resistor, you specify a 1 amp, 25V transformer. However, the majority of applications call for conversion of the output to DC using one of the many methods available. The method of rectification determines the ratings of the transformer. Onward:

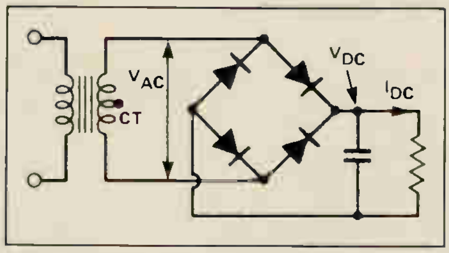

Fig. 6. The conventional full wave rectifier discussed in the text; 0.68 ohm resistor was added between the diodes and the capacitor for monitoring the charging current.

Figure 6 shows the typical full wave bridge with a capacitor input, used for the majority of rectifier circuits because it uses the available secondary energy in the most efficient way. First, we work backwards from the desired DC voltage. Let's say that you want a 35VDC supply. The secondary AC voltage for a no-load condition is:

VAC = VDC x .707

The capacitor is charged to the peak value of the AC sine wave, which happens to be 1.414, or root 2, times the RMS value; working backwards to find the secondary AC produces the .707 factor. This neglects the voltage drop across the diodes, and gives us a no- load secondary voltage of about 25VDC.

The problem here is that the transformer output voltage will sag somewhat under load, and the diode voltage drop increases a bit with current; the diode drop is especially important in lower voltage supplies. Here's another rule-of-thumb which takes these factors (and others) into account, and is taken from a nifty chart in a catalogue available from the L.H. Frost Co. (see the list at the end):

VAC = 0.8(VDC + 2)

Now we find that our secondary voltage under load works out to 29.6VAC. Huh? This seems a bit high compared to the original estimate of 25.

The reason for this is that the current drawn from the transformer is non-sinusoidal. Let's go over the setup so far. I tested a full wave capacitive rectifier as shown in Figure 6; the only difference was the insertion of a 0.68 ohm resistor between the rectifier and the capacitor in order to scope the capacitor charging current. The transformer was a 25 volt, 150mA unit, the capacitor was 2200uF, and the load resistor was 460 ohms, giving a load current of 76mA. Note that the transformer voltage rating applies only at the full load current into a resistor; it will rise a bit under lighter loads. Spec sheets usually give you the range of output voltages you can expect under different load conditions.

At 76mA, the secondary voltage metered as 29.5VAC and the capacitor

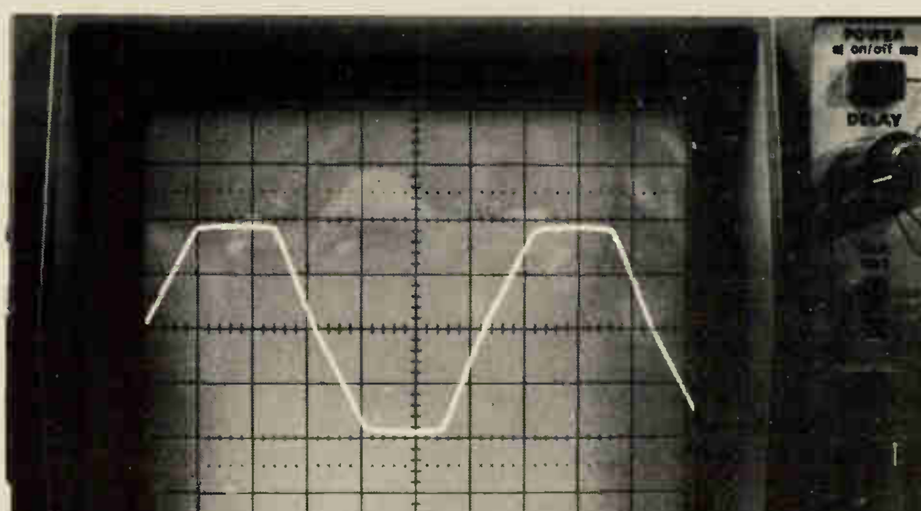

Fig. 7. The secondary AC voltage of the transformer under load; the rush of charging current into the capacitor flattens the peaks.

voltage was 35VDC. If you multiply the 29.5 by 1.414 to find the expected peak, you get about 42 volts instead of the measured 35. The reason for the discrepancy here can be seen from the photograph in **Fig. 7.** The peaks of the sine wave are clearly flattened; this is the point where the rising voltage from the secondary exceeds the stored capacitor voltage, the diodes turn on, and the capacitor draws a large current as it charges up again.

In the photo in **Figure 8**, the scope has been placed across the 0.68 ohm resistor to monitor the charging current. Since the scope was set at 100mV/div, the peak voltage is about 280mV, and therefore the peak charging current is about 410mA, considerably higher than the transformer's rated continuous value of 150mA. Note that each positive-going peak corresponds to one of the peaks of the AC waveform from the secondary.

It's this non-sinusoidal waveform out of the secondary that throws things into a cocked hat. Voltmeters, either digital or analog, respond to the *average* value of the applied waveform. This value is then increased artificially, either by the digital circuitry or the analog meter face, to show you what the RMS value would be if the input were a pure sine wave. Unless your meter says "True RMS" on it, this will be the case, and the reason that the volts don't seem to match up where they should.

Check out the peak value of the waveform in Figure 7; at 20V/div, the peak value is about 38 volts. After hazarding the journey through the rectifier diodes and the 0.68, our rectified and smoothed peak voltage is now 35V, agreeing with the rule of thumb from the good folks at L.H. Frost.

Here are two more handy equations for the circuit in Figure 6:

IAC = 1.8 x IDC
VA = 1.4 x (watts + 2IDC)

The Mysterious VA

The "watts" mentioned above is just the DC volts times the DC load amperes, but you may have noticed that transformers are rated using the VA (volt-ampere). The essential difference is that the VA implies the possibility of phase shift between the current and the voltage. In a purely resistive circuit with an AC signal, the current changes are exactly in step with the voltage changes, as you'd expect. In a circuit containing inductance, such as a transformer/rectifier, the current can happen at a different part of the cycle than the voltage; in other words, you can't multiply volts times amps to get watts because the volts and amps don't occur together. VA is not true power, but an indication of the volts and amps needed under reactive conditions.

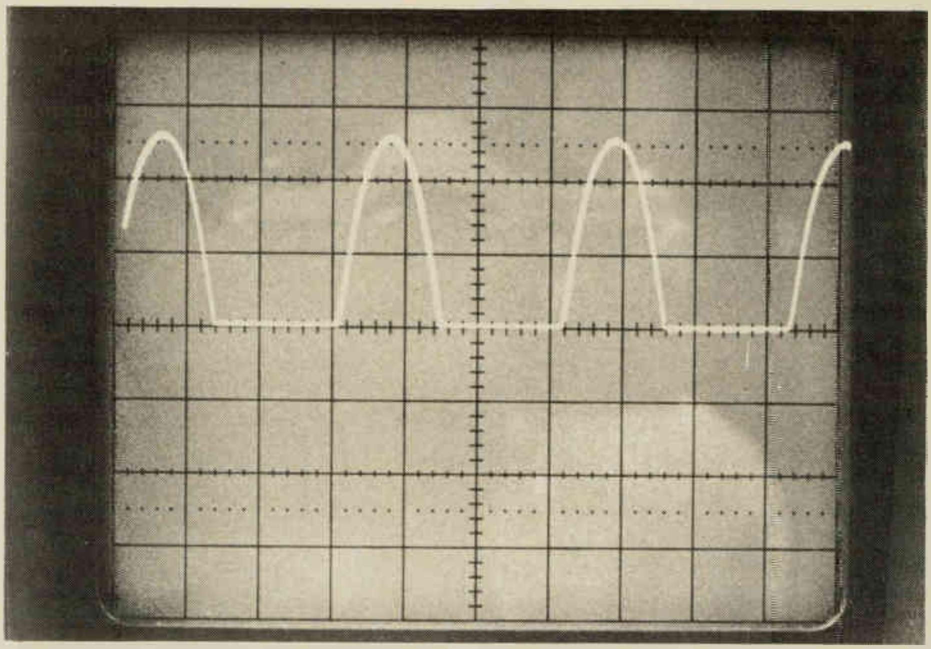

Fig. 8. The bursts of charging current as the diodes switch on can be seen by putting the scope leads across a resistor in series with the capacitor.

The VA rating has to be considerably higher than you'd expect in order to allow for peculiarities such as the sudden bursts of current as the diodes switch in and out of conduction. In our test circuit, the resistor dissipates 2.66 watts, and the VA rating works out to about 4VA.

Taps

Most commercially available transformers have a centre tap. If you're concocting a power supply from scratch, you probably wondered about the choice between a full-wave (Figure 6) and a centre-tapped (**Figure 9**). Simple: if you're building a low voltage supply, perhaps less than five volts, the voltage drop across the diodes becomes a significant part of things. By specifying the CT type, you only need two diodes and the transformer VA rating can be reduced a bit. However, it isn't quite as efficient as the full wave because the secondary isn't fully utilized; only half of it works at a time. Because of this, the VA rating will have to be fractionally higher than the full wave version. Remember that the voltage rating must be twice as high as the full wave type; our 25V transformer in the example would have to be a 50VCT, or 25-0-25.

The main use for the centre tap is in producing the familiar supply with lots of names: symmetrical, bipolar, or split. These put out both positive and negative voltages for use with op amps, power amps, etc. They're really just a variation on the full wave of Figure 6; the output is simply split in the middle by calling the centre tap zero-volts or ground. The beginner may be confused into thinking that there are two different kinds of electricity, positive and negative, but it's not so; it's all in how you designate it. If we used two series capacitors in Figure 6 and connected the centre tap to their midpoint, we'd have plus-and-minus 17.5V instead of 35V. If we move the ground connection to the bottom capacitor's negative, and call that "ground", then we now have a supply with 17.5 and 35 volts. It's all in the labels. Our rules of thumb from Figure 6 still apply to the split version.

Audios, amigo

I won't go into immense detail on the audio transformer because they're largely out of favour these days. At one time they were used all over the place, especially in microphone inputs because they furnished voltage gain, and in those days gain stages cost a lot of money (no gain without pain). Now that we have all kinds of complex circuits integrated onto chips for next to nothing, the transformer has been relegated to providing balanced lines in professional audio, and even then they're being replaced with differential amplifiers.

The idea of the balanced line is simple: because the transformer will transmit only those voltages which appear across its primary, it rejects signals which appear

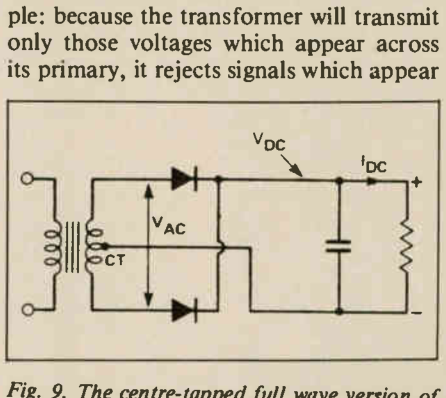

Fig. 9. The centre-tapped full wave version of the supply shown in Fig. 6.

equally on both primary terminals ("common mode signals"). Microphone and output lines are usually twisted pairs running into a transformer, and since the lead is symmetrical, noise and hum are induced on both wires with equal phase and voltages, and they get cancelled out by the transformer. The pair also has a grounded shield or braid, which is why some audio cables have three wires instead of the expected two. Good audio transformers may reject low-frequency common-mode signals by as much as 75 dB or more. High-frequency interference tends to jump from the primary into the secondary via the inevitable stray capacitance; this can be reduced by looking for a transformer with an electrostatic shield between primary and secondary. This shield is connected to ground via the chassis.

In selecting a microphone transformer, the turns ratio and impedance ratio are important; the turns ratio squared gives the impedance ratio. For example, a transformer with a 1:10 turns ratio will step up the voltage by 10 and the impedance by 100. If you drive the transformer primary with a 250 ohm microphone, the impedance looking into the secondary is 25,000 ohms.

Impedance matching is important with an audio transformer, particularly on professional equipment. If serious mismatches occur, the most likely result will be either poor low-frequency response (source too large or load too low) or a boost in the high end (source too low or load too large). However, there's some elbow room if you can't find the exact model that you need. The general rule for fudging trannies is: select a model that has the turns ratio that you need (mike trans almost always have 10 to 20dB in gain, a turns ratio spread of 3.2 to 10). Check the impedance specs; the primary should be *more* than the driving load, and the secondary should be *less* than the secondary load.

An example: a PA amp requires a replacement transformer. Microphones are mostly 150 ohm low impedance types, and the secondary feeds a transistor amp with about 40k input impedance.

Thumbing through a Hammond catalogue turns up the 809, a broadcast-quality transformer with a 200 ohm primary and 10,000 ohm secondary. A nice bit of luck; if the impedances don't turn out to match this closely, you can always mismatch by 100 percent, or even more (who said that?). The 809 has an impedance ratio of 1:50. Taking the square root gives the turns ratio, or 7.07. The voltage gain in dB is:

$20 \log 7.07 = 17\text{dB}$

This should be fine as is, but check the frequency response anyway. If you find a boost in the treble, it may be necessary to load the secondary with a resistor sub box until you find a value that smooths it out. Will the 17dB of voltage gain overload the input amp during use? Maybe. It all depends on the circuit; if you know the original equipment transformer gain, you should try to stay within 3 or 4dB of the original.

I'm out of room already, and I didn't even get to audio output transformers or autotransformers or tuned types. There's an excuse for another article in an upcoming issue. ■

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continued from page 34

plied through the component via banana jacks on the front panel, and goes to the scope's vertical and horizontal circuits. A good diode, for instance, will display a straight line (no conduction) up to about 600mV, where the trace will angle sharply to show increasing current under the forward bias conditions.

Other features include TV sync and sync separator circuits for optimum triggering of the sweep during TV testing. It comes with dual probes that can be set to 1:1 or 10:1. Price is $654.50 from Duncan Instruments, 121 Milvan Drive, Toronto, Ontario M9L 1Z8, (416) 742-4448.

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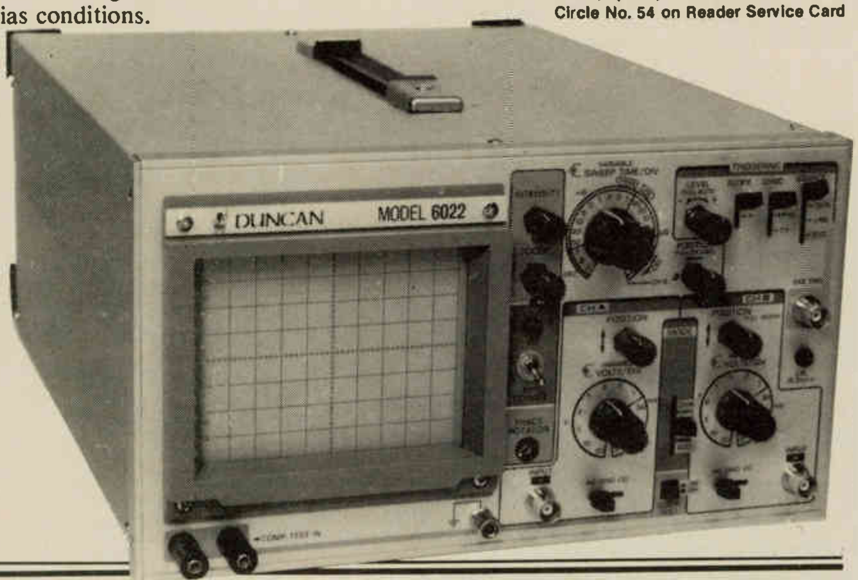
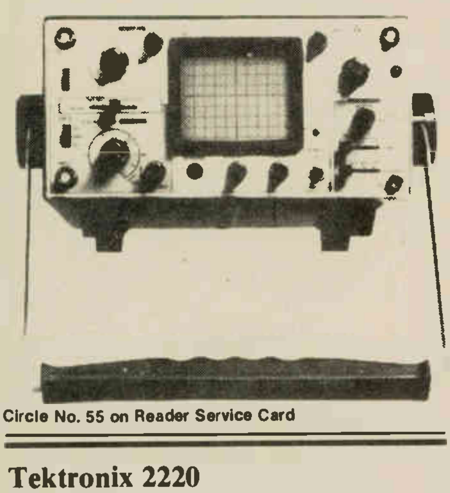


Duncan 3015

Also from Duncan Instruments (see model 6022 above) is the model 3015 Dual Trace Portable. Easy portability is the dream function for field servicing, and the 3015 fills the bill by running from 90 to 260 VAC power lines from 48 to 440Hz, NiCads with internal recharger, and DC from 11 to 30V. It has 15MHz bandwidth, a 3.8 inch CRT, 2mV/div vertical sensitivity and a comprehensive trigger amp, making it just about ideal for taking your show on the road. The price is $951.50.



Circle No. 55 on Reader Service Card

Tektronix 2220

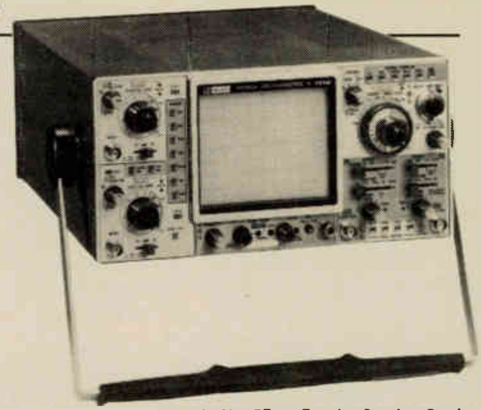
The Tek 2220 is one of a new family of scopes combining both storage functions and portability. It has 60MHz bandwidth, which should be adequate for checking your Silvertone guitar amp, TV-pre-post triggering, glitch capture to 100nS, an analog output, and optional communica-

tions links such as GPIB and RS232. Signal averaging can be used to salvage the signal from noisy environments. Others in the family include the 2230 and 2240, with various extra features such as increased bandwidth, glitch capture to 2nS, and a controllable cursor for on-screen measurements. Contact the Marketing Communications Department, Tektronix Canada Inc., PO Box 6500, Barrie, Ontario L4M 4V3, (705) 737-2700.

Circle No. 56 on Reader Service Card

B&K 1596

The B&K Model 1596 is a quad input scope. Remember quad sound? Edsels? Nothing to do with it. The 1596 can parade four waveforms, just the ticket for analyzing data circuits. The vertical sensitivity is 500uV/div up to 70MHz, and 5mV/div at 150MHz. There's also a Dual function in which the A sweep and B sweep operate independently; two signals can be viewed with different sweep times, a fairly unusual feature. At 7.4kg the



Circle No. 57 on Reader Service Card

Model 1596 is suitable for either bench or field use. List price is $4555.85. Contact Atlas Electronics, with sales offices in Montreal, Ottawa, Winnipeg, Calgary and Vancouver, or the head office at 50 Wingold Avenue, Toronto, Ontario M6B 1P7, (416) 789-7761.

Hitachi V-1100A

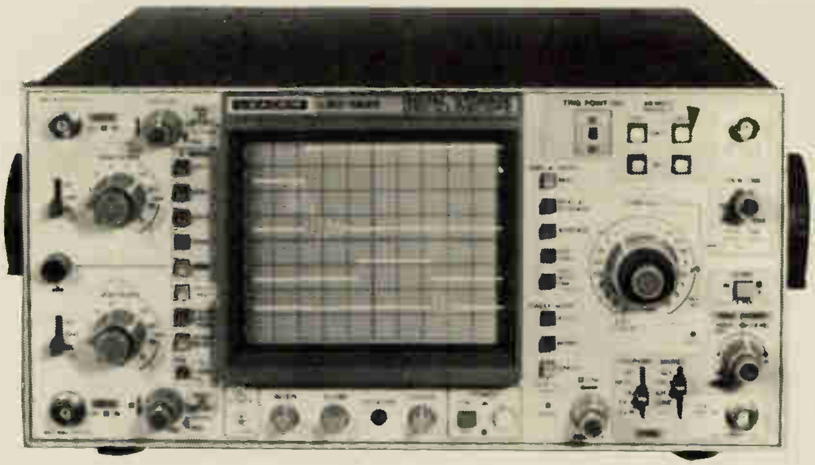
The Hitachi V-1100A's primary feature is cursoring capability and a digital multimeter display on the CRT. Moving the cursor dots between two points on the display is not only a super-convenient way to measure waveforms, but it eliminates guesswork and errors. The 1100A's CRT displays scope setting information, cursor locations and values, DVM values, and programmable text (8 lines of 30 characters each).

Vertical sensitivity is 5mV/div (1mV/div with x5 control) and the bandwidth is 100MHz; the CRT is a 6-inch. The cursor measurement facility has a resolution of .01V/div; list price is $3978 including FST. Contact their offices in Nepean (Ont.), St Laurent (Que.), Calgary, or the head office: Hitachi Denshi, Ltd., (Canada), 65 Melford Drive, Scarborough, Ontario M1B 2G6, (416) 299-5900.

Circle No. 58 on Reader Service Card

Leader 5825

The Leader LBO 5825 is yet another digital storage scope. If you haven't used a storage scope yet, and wonder why there are so many around these days, upgrading to a storage is like going from a slide rule to a computer. The 5825 is a 35MHz real time scope, or 500kHz in dual channel storage mode. There are memories for each channel; the memory permits four waveforms on two channels to be stored



and displayed simultaneously, and if a waveform in the Real Mode is included, six waveforms may be displayed. A battery backup holds the memories for up to two weeks with the power off. List price is $4995 from Omnitronix, 2410 Dunwin Drive, Unit 4, Mississauga, Ontario L5L 1J9, (416) 828-6221, or 8100F Trans-Canada Highway, St. Laurent, Quebec H4S 1M5, (514) 337-9500.

Circle No. 60 on Reader Service Card

Gould 1425

Another advantage from the proliferation of microchips is the ability to have your scope converse with a computer for the analysis or control of whatever's under test. Several of the scopes listed above have outputs for interfacing, and the Gould 1425 is no exception. It's a dual trace, 20MHz storage scope that offers on-screen measurement of time and voltage via cursors and an alphanumeric readout; data can be read to and from an external computer via an RS232/RS423 serial interface. The interface can also drive a plotter for copying of the trace. The optional Type 125 waveform processor keypad allows waveforms to be stored, magnified, attenuated, transferred, averaged, filtered, etc. The 1425 lists at $4204, taxes extra. From Allan Crawford Associates, Electronic Instruments and Systems Division, 5835 Coopers Ave., Mississauga, Ontario L4Z 1Y2, (416) 890-2010. ■

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The Electronics Today Electrivia Contest Results

AND THE the grand winnah of our July/August contest is... Bill Markwick, editor of Electronics Today!!! Well, thank you, thank you, I know I'll enjoy this computer for many years to come... what? I can't? Why not? What contest rules?

Okay, okay, I'll draw again. This time, the winner is:

Terry Wong
118th Avenue Edmonton, Alberta

Our congratulations on your new computer.

Here are the correct answers. Since the contest was finally decided by a draw, we marked as liberally as we possibly could without being unfair to those who had gone to a lot of effort researching the questions. There were over 200 entries with correct answers.

1. The relationship between sound intensity and distance is governed by the Inverse Square Law, or the reciprocal of D squared. It doesn't matter what unit you select for measuring the sound; it falls off inversely with the square of the distance. A lot of readers got sidetracked onto the measurement units for intensity, using decibels and the Weber-Fechner law and so forth.
Inverse-square was the magic word.

2. The common-base equivalent of Beta (current gain) is Alpha, or HFB, or Ic/Ie. We also accepted other mathematical equivalents or the Greek character for Alpha.

3. False. The Wheatstone bridge, named after Charles Wheatstone, was developed by Samuel Christie in 1833. Some readers wrote False because we forgot the "Sir" in Charles' name. We gave it to you anyway.

4. The oscilloscope figures resulting from similar signals applied to horizontal and vertical inputs are called Lissajous patterns. Some readers put only special cases, such as the circle or the ellipse. We were generous.

5. True. The turns ratio of a transformer is indeed equal to the root of the impedance ratio.

6. The Bel, the log of a power ratio, was named after Alexander Graham Bell. We also accepted the decibel or dB.

7. The voltage gain of an analog buffer is one, or unity, or zero dB. A lot of entrants put "close to one", which we accepted because it's generally true, but we didn't accept "zero" unless you mentioned decibels.

8. An asynchronous counter is also known as a ripple, or serial, counter. We were liberal on this one, accepting such entries as "ring counter", even though it's a special case of the ripple counter.

9. The algebra used in logic was named after George Boole, 1815-1864. We had to turn down the several "Boolean algebra" entries on the grounds that the question wasn't read closely.

10. True. Maximum power is transferred when the source and load resistances are equal.

Many thanks to the nearly 1,000 readers who entered the contest. We'll have another one coming up in a future issue.

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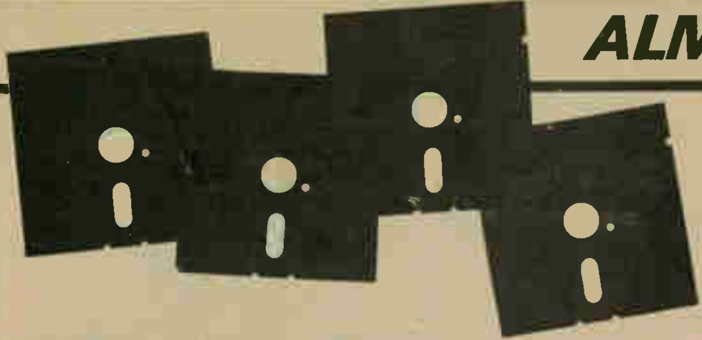

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Almost Free Software

Almost Free Software (CP/M) .... #1

Almost Free Software #1, #2 and #3 are for CP/M and are available in a variety of formats: Apple // + CP/M, 8 inch SSSD*, Access Matrix, Morrow Micro Decision, Superbrain, Xerox/Cromemco*, Epson QX-10VD, Sanyo MBC 1000, Nelma Persona, Kaypro II, Osborne and double densities, Televideo, DEC VT-180, Casio FP-1000, Zorba.

Modem 7. Allows you to communicate with any CP/M based system and download files. Complete details were in Computing Now! November 1983.

PACMAN. You can actually play PACMAN without graphics, and it works pretty fast.

FORTH. A complete up-to-date version of FIG FORTH, complete with its own internal DOS.

DUU. The ultimate disk utility allowing you to recover accidentally erased disk files, fix gorched files, rebuild and modify your system. A real gem.

D. A sorted directory program that tells you how big your files are and how much space is left on the disk.

USQ/SQ. Lets you compress and uncompress files. You can pack about 40% more stuff on a disk with this system.

Finance. A fairly sophisticated financial package written in easily understandable, modifiable Microsoft BASIC.

BADLIM. Ever had to throw out a disk with a single bad sector? This isolates bad sectors into an invisible file, making the rest of the disk useable.

DISK. Allows you to move whole masses of files from disk to disk without having to do every one by hand, you can also view and erase files with little typing.

QUEST. A "Dungeons and Dragons" type game.

STOCKS. This is a complete stock management program in BASIC.

SEE. Also known as TYPE17, will TYPE any file, squeezed for not allowing you to keep documents in compressed form while still being able to read them.

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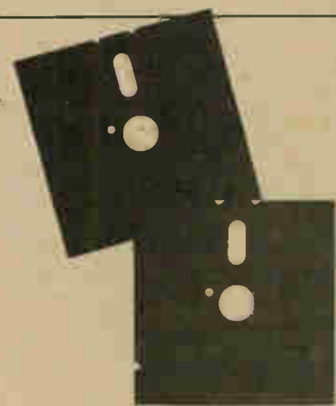

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Almost Free Software (CP/M) .... #2

BISHOW The ultimate file typer, BISHOW version 3.1 will type squeezed or unsqueezed files and allow you to type files which are in libraries (see LU, below). However, it also pages in both directions, so if you miss something, you can back up and see it again.

LU Every CP/M file takes up unneccessary overhead. If you want to store lots of ata in a small space, you'll want LU, the library utility. It permits any number of individual files to be stored in one big file and cracked apart again.

MORTGAGE This is a very fancy mortgage amortization program which will produce a variety of amortization tables.

NSBASIC Large disk BASIC packages, such as MBASIC, are great . . . and very expensive. This one, however, is free . . . and every bit as powerful as many commercial programs. It's compatible with North Star BASIC, so you'll have no problem finding a manual for it.

RACQUEL Everyone should have one printer picture in their disk collection.

Z80ASM This is a complete assembler package which uses true Zilog Z80 mnemonics. It has a rich vocabulary of pseudo-ops and will allow you to use the full power of your Z80 based machine . . . much of which can't be handled by ASM or MAC.

VFILE Easily the ultimate disk utility. VFILE shows you a full screen presentation of what's on your disk and allows you to mass move and delete files using a two dimensional cursor. It has heaps of features, a built-in help file and works extremely fast.

ROMAN This is a silly little program which figures out Roman numerals for you. However, silly programs are so much fun . . .

CATCHUM If you like the fast pace and incredible realism of Pacman, you'll go quietly insane over Catchum . . . which plays basically the same game using ASCII characters. Watch little "C"'s gobble periods while you try to avoid the delay "A's" . . . it's a scream.

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Almost Free Software (CP/M) ....#3

OIL. This is an interesting simulation of the workings of the oil industry. It can be approached as either a game or a fairly sophisticated model.

CHESS. This program really does play a mean game of chess. It has an on-screen display of the board, a choice of colours and selectable levels of look ahead.

DEBUG. The DDT debugger is good but this offers heaps of facilities that DDT can't and does symbolic debugging... it's almost like being able to step, trace and disasemble through your source listing.

DU87. The older DUU program does have some limitations. The version overcomes them all and adds some valuable capacities. It will adapt itself to any system. You can search map and dump disk sectors or files. It's invaluable in recovering damaged files too.

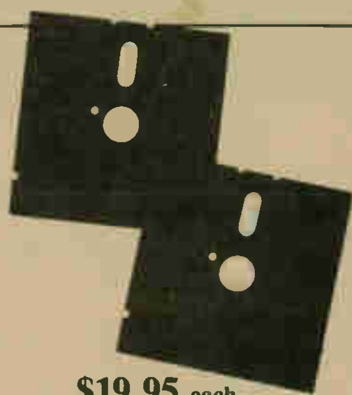
ELIZA. This classic program is a micro computer head shrinker... it runs under MBASIC, and with very little imagination, you will be able to believe that you are conversing with a real psychiatrist.

LADDER. This is... this program is weird. It's Donkey Kong in ASCII. It's fast, bizarre and good for hours of eye strain.

QUIKKEY. Programmable function keys allow you to hit one key to issue a multicharacter command. This tiny utility allows you to define as many functions as you want using infrequently used control codes and to change them at any time... even from within another program.

RESOURCE. While a debugger will allow you to disassemble small bits of code easily enough, only a true text based disassembler can take a COM file and make source out of it again. This is one of the best ones available.

**Order as AFS #3
and specify system**



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Almost Free Apple DOS Software

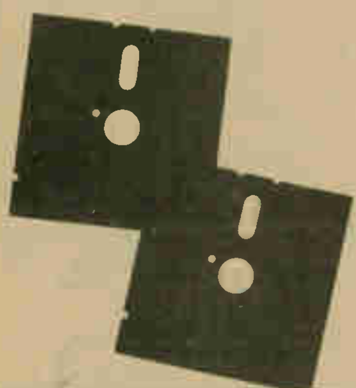
Almost Free Apple DOS Software ....#1

While CP/M is a wonderful thing in its own right, the Apple computer can also, and usually does, operate under DOS. For this reason, there's a multitude of programs available for it. Below, we offer a mini-multitude of our own.

The following programs will operate on any Apple //+, //e, //c, or true compatible operating under DOS 3.3. Apple users operating only under ProDOS may have to make alterations to some programs.

Picture Coder: All Apple HiRes pictures take up 36 sectors in their binary form. This program creates a textfile of a program in memory, squeezing out the zero bytes, that can later be EXECd into memory. The textfile often takes up less room on the disk.

DNA Tutorial: Operating under Integer BASIC, this program might appeal to 'clone' owners. In actuality, though, it's an interactive low-res graphics tutorial of DNA in its inherent forms. And you thought your Apple was only good for games...



Toad: Speaking of games, this program is an Applesoft BASIC implementation of 'Frogger' that can be controlled with either a joystick or the keyboard. The user's high scores are saved to disk.

Function Plotter: A fairly extensive Applesoft BASIC program that takes any inputted function and plots it on the HiRes Screen.

Data Disk Formatter: Apple DOS disks need not be bootable to be useful. This binary program formats a disk without setting DOS on the tracks, conserving useful disk space.

BASIC Trace: A program for the advanced Applesoft programmer, this file, when EXECd, displays the hexadecimal locations of each Applesoft line number of a program in memory.

Gemini Utility: A word processor pre-boot for Gemini printer users, this BASIC program initialises the printer's font or pitch before you boot your word processer.

Payments: This BASIC program allows you to keep track of payments and credits to and from up to 100 accounts on a single disk. A sample account is included.

Databox: A small but useful database program in Applesoft BASIC. Sample files are included to get you started.

Nullspace Invaders: A quick BASIC HiRes game testing coordination and judgement as you manipulate a monolith through mysterious gates.

Fine Print: The majority of this software has been obtained from on-line public access sources, and is therefore believed to be in the public domain. Any remaining programs were written in-house. The prices of the disks defer the cost of collecting the programs, debugging them, reproducing and mailing them, plus the cost of the media they're supplied on. The software itself is offered without charge.

Moorshead Publications warrants that the software is readable, and if there are any defects in the medium, we will replace it free of charge. While considerable efforts has been made to ensure that the programs have been thoroughly debugged, we are unable to assist you in adapting them for your own applications.

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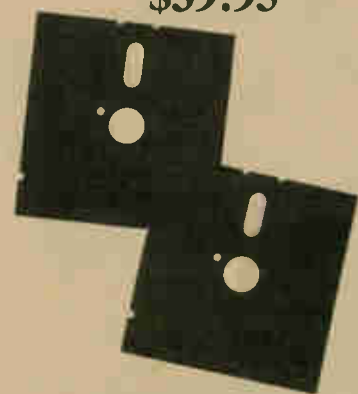

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Almost Free Apple DOS Software . . . . #2

Amort: A monthly amortization program that calculates monthly payments to an inputted figure, calculates principle, interest on every balance, and prints out the resulting chart.

Voiceprint: An unusual program that uses the HiRes screen to sample sounds inputted through the cassette jacks at the back of your Apple. Sampling rate and other variables can be controlled, and two sounds may be compared side-by-side.

Calc NOW!: Written in BASIC, this spreadsheet program is somewhat slower than VisiCalc, but still offers the power you expect from a spreadsheet. With sample files.

Cavern Crusader: A mix of BASIC and binary programming, winning this HiRes game is difficult, to say the least. For every wave of aliens shot in the cavern, there's always a meaner bunch in the wings.

Newcout: With source file. This binary program replaces the I/O hooks in the Apple with its own so you can operate your Apple through the HiRes screen. Comes with a character set.

Charset Editor: A utility to help you create your own character sets to use with Newcout.

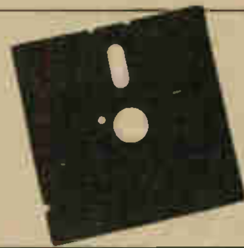
Calendar: A BASIC utility useful for finding a particular day of any inputted month and year, or for printing out any given year.

LCLODR: With source. This binary utility BLOADs any given file into the 16K language card space at $D000. The source is useful in showing how to use DOS commands through assembly language.

Cristo Rey: An animated HiRes BASIC program showing Cristo Rey by moonlight. For apartment—bound romantics.

ATOT: That's an acronym for 'Applesoft to Text'. EXEC this textfile to produce a textfile of your program.

Applesoft Deflator: This program takes a textfile made by ATOT and squeezes it, replacing PRINT statements with '?' and removing unnecessary spaces from the listing.



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Almost Free PC Software

Almost Free PC Software . . . . #1

Our Almost Free Software disks, volumes one through three, for systems running CP/M have been so thunderingly popular that we have assembled a volume for IBM PC users. The considerably greater power of a sixteen bit system, coupled with its larger capacity disk drives, have enabled us to offer a collection of programs that will knock the socks off virtually any sentient life form booting the disk. Be warned... wear sandals when you unwrap this thing.

This software will run superbly on genuine IBM PC's and compatible systems.

PC-WRITE While not quite Wordstar for nothing, this package comes extremely close to equalling the power of commercial word processors costing five or six bills. It has full screen editing, cursor movement with the cursor mover keypad, help screens and all the features of the expensive trolls.

SOLFE This is a small BASIC program that plays baroque music. While it has little practical use, it's just a kick to toodle with. It's also a fabulous tutorial on how to use BASICA's sound statements.

PC-TALK Telecommunications packages for the IBM PC are typically intricate, powerful and huge. This one is no exception. It has menus for everything and allows full control of all its parameters, even the really silly ones. It does file transfers in both ASCII dump and MODEM7/XMODEM protocols and comes with... get this... 119424 bytes of documentation.

SD This sorted directory program produces displays which are a lot more readable than those spewed out by typing DIR. It's essential to the continued maintenance of civilization as we know it.

FORTH This is a small FORTH in Microsoft BASIC. It's good if you want to get used to the ideas and concepts of FORTH... you can build on the primitives integral with the language.

LIFE This is an implementation of the classic ecology game written in 8088 assembler. While you may grow tired of watching the cells chewing on each other, in time the source will provide you with a powerful example of how to write code.

MAGDALEN This is another BASIC music program. We couldn't decide which of the two we've included here was the best trip, so we wound up putting them both on the disk. Ah... the joys of double sided drives.

CASHACC This is a fairly sophisticated cash acquisition and limited accounting package written in BASIC. It isn't exactly BPI, but it's a lot less expensive and suitable for use in most small business applications.

DATAFILE This is a simple data base manager written in... yes, trusty Microsoft BASIC.

UNWS Wordstar has this unusual propensity for setting the high order bits on some of the characters in the files it creates. Looks pretty weird when you try to do something other than Wordstar the file, doesn't it... Here's a utility to strip the bits and "unWordstar" the text. The assembler source for this one is provided.

HOST2 This is a package including the BASIC source and a DOC file to allow users with SmartModems to access their PC's remotely. It's a hacker's delight.

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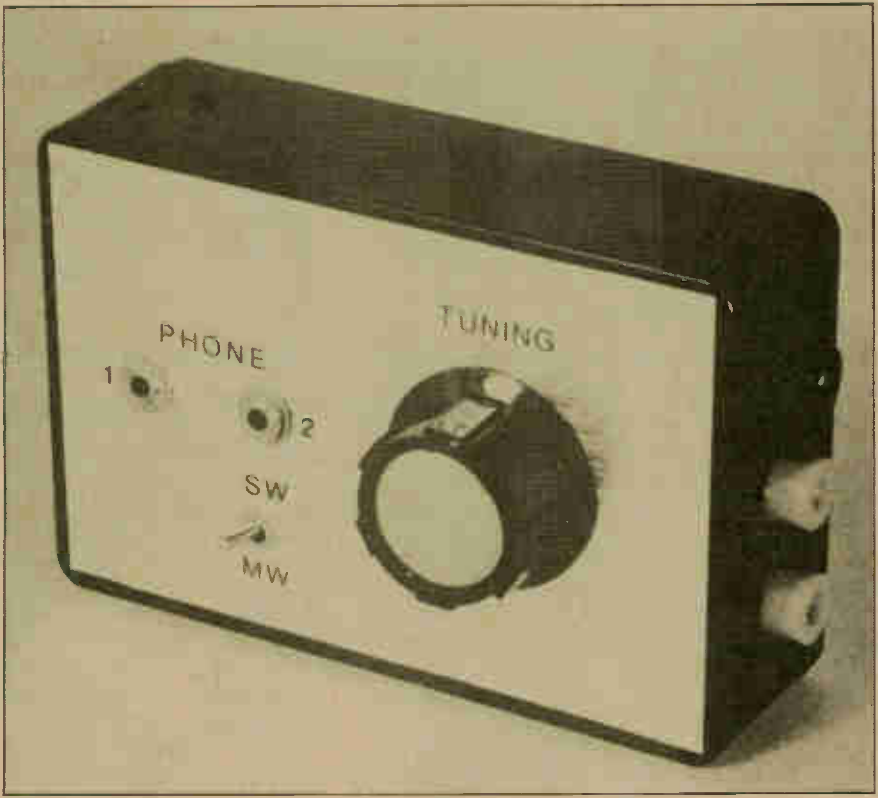
Natural Crystal Radio

A crystal radio is the simplest form of radio, and an interesting experiment for both beginners and experts.

By R.A. Penfold



WHEN WRITING an article about a radio receiver it is normal to start by extolling the virtues of the new miracle design, but such an approach is really not appropriate for a crystal set. By any standards the level of performance provided by a crystal set is pretty mediocre, and one could reasonably ask why bother to build one? Even in these days of high technology, crystal receivers remain quite popular among electronics enthusiasts and there are a number of reasons for this:

1) Very inexpensive to build.

2) The most simple type of radio that will work.

3) Zero running costs as no power is required.

4) No setting up or any form of adjustment required once completed.

5) Easy enough for even a complete beginner to construct.

There are a couple of disadvantages apart from the general lack of performance. One is merely that there is only sufficient output to drive a sensitive earphone or headphones, and loudspeaker operation is out of the question. The second is that ordinary ferrite or telescopic aerials provide an inadequate signal level, and a so called *longwire* aerial is needed. This is not such a major drawback as one might think, since the aerial can just be a few meters of ordinary hook-up wire strung between two supports outdoors. A sophisticated installation with insulators and masts is not required.

This crystal set is a fairly conventional design which covers two wavebands. These are the normal medium wave broadcast band, and short wave bands from about 4.5 to 12MHz.

Circuit Operation

The simplicity of a crystal set is readily apparent from the circuit diagram of Fig. 1. There are only seven components plus the input and output sockets. SK2 is the normal aerial socket, and a reasonably efficient aerial wire will give output levels of a few hundred millivolts peak to peak or more on strong signals. Although the signal levels are quite respectable, the output impedance is quite high and the available current is therefore quite low. It is for this reason that a low impedance load such as a loudspeaker can't be driven from a crystal set, and it is not even possible to use low impedance headphones successfully.

The signals provided by the aerial are at high frequencies, and the audio signal is amplitude modulated on to each signal. Fig. 2 helps to explain the amplitude modulation and demodulation process. The waveform of Fig. 2a represents an unmodulated *carrier wave*, and here there is no variation in the strength of the signal with each half cycle having the same peak voltage. In Fig. 2b the carrier wave has been modulated by a lower frequency squarewave, and the signal switches between two levels in sympathy with the modulation signal. In practice the modulation signal is the audio signal that is to be transmitted, and it would normally be a complex speech or music waveform. However, whatever the waveform the system works precisely the same way, with the amplitude of the carrier wave being varied in sympathy with that of the audio modulation signal.

A crystal set has to perform two basic functions in order to recover the audio signal modulated onto the required transmission. First it must select the required signal from the multitude of signals provided by the aerial, which picks up transmissions on all bands from long waves through to VHF bands. Then it must demodulate that signal to recover the audio signal it contains.

The filtering is provided by C1 and L2 which form a parallel tuned circuit. This type of circuit has an infinite impedance at its resonant frequency, with the impedance falling as the signal frequency is varied either side of resonance. In practice the impedance does not reach infinity at resonance due to imperfections in the components (leakage in C1 and resistance through L2), but a very high impedance is still achieved. The impedance falls rapidly on either side of resonance. This gives the desired bandpass filtering with transmissions at the resonant frequency being unaffected by the tuned circuits while transmissions at other frequencies are virtually short circuited to ground.

The value of L2 and C1 enable the tuned circuit to be tuned over the medium waveband by varying the value of C1. For short wave reception L1 is switched into circuit by closing S1, and the inductance in the circuit is then the parallel inductance of L1 and L2 (approx. 4.6uH). This boosts the resonant frequency so that it covers the desired short wave broadcast bands.

Demodulation

Having selected the signal we want, the next step is to demodulate it. If you look at Fig. 2b you will see that the average signal level does not vary in sympathy with the strength of the audio signal, but

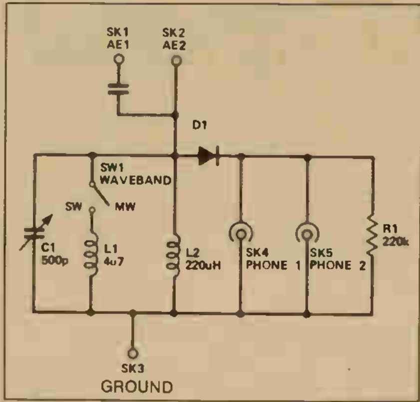


Fig. 1 The circuit: only seven components.

is always zero as the negative half cycles cancel out the positive ones. If one set of half cycles is removed as in Fig. 2c, the situation is then different, and the average signal level is proportional to the modulating signal. All that is required to recover the original signal is a simple lowpass filter to remove the radio frequency signal and leave a DC output voltage equal to the average input potential. This gives the waveform in Fig. 2d. Although the demodulated signal is a varying DC type rather than a true AC signal, this is of no real consequence, and the sound from the earphone is the same either way. A capacitor could be placed in series with output to convert the signal to an AC type, but this would not give any practical advantage and is not done here.

The filter is a C–R smoothing circuit. Although the capacitor may seem to be absent, the unit is designed to feed into a crystal earphone, and this provides a capacitance of a few nF which gives the smoothing. R1 prevents the charge on the smoothing capacitance from simply charging to the peak input voltage and remaining there, by providing a discharge path. Two output sockets are provided, and the unit can drive two earphones if required. The unit will also operate with high impedance (about 4000 ohms) headphones. However, with these R1 should be replaced with a capacitor of about 4n7 in value as magnetic headphones provide a DC path but no significant capacitance.

Removing one set of half cycles is easy enough, and can be achieved by processing the signal with a diode (D1 in this circuit). A diode passes current in one direction, but blocks any significant current flow in the opposite direction, and gives exactly the action we need here. Unfortunately, practical diodes are less than perfect, and silicon types do not conduct in the forward direction unless a voltage of about 0V5 or more is applied to them. This level would not be achieved on many stations, resulting in many signals giving no output at all, and severe distortion plus loss of volume on the strongest signals. This is overcome by using the older type of germanium diode. These are inferior to silicon types in most respects, but have a much better forward conduction characteristic which makes them vastly superior for this application.

PARTS LIST

Resistors	
R1	220k 0.25W 5%
Capacitors	
C1	500pF Variable
C2	27pF ceramic plate
L1	4.7uH RF choke
L2	220uH RF choke
Semiconductors	
D1	1N34 or 1N60 germanium diode
Miscellaneous	
SK1,2,3	4mm sockets
SK4,5	3.5mm jack sockets
SW1	SPST sub-miniature toggle switch

Case about 120 x 80 x 35mm; control knob; crystal earphone with 3.5mm plug; connecting wire, solder, aerial wire, etc.

Selectivity

An obvious problem with a crystal set is that of obtaining a strong enough signal to give good volume. A less obvious one is that of sorting out one transmission from the rest once on adequate aerial signal has been obtained. The problem is partly due to the broad response of the filtering provided by the tuned circuit. In fact, in isolation the tuned circuit would give adequate selectivity for a simple receiver in most cases. The tuned circuit is not in isolation though, and it is damped by the signal extracted to drive the demodulator and earphone. The output impedance of the aerial often has an even greater damping effect, and making the aerial longer tends to reduce its output impedance and give reduced selectivity from the receiver. This is unfortunate as it means that using a good aerial to obtain decent volume can result in poor selectivity with two or more stations being received simultaneously.

Where possible it is best to connect the aerial to SK2 and obtain maximum volume, but if lack of selectivity is a problem it is better to use SK1 instead. C2 then gives a loose coupling into the tuned circuit which gives improved selectivity at the expense of slightly reduced volume. A ground can be connected to SK3 and this will give improved signal strengths.

Construction

With so few components there is no need for a printed circuit board and the components can be connected directly to the sockets and controls. Try to stick as close as possible to the layout shown in Fig. 3 and the photograph.

The major concern during soldering of the components is making sure not to damage D1, the germanium diode. Use heat shunts on each of the leadout wires when completing this step and be quick with the iron.

Aerial and Ground

Without a reasonable aerial the unit will not function at all. The minimum requirement for good results is about 10 meters of wire strung indoors, around a picture or window frame. If possible, 20 or 30 meters of wire strung up outdoors should be used. In any case the wire should be high enough from the ground so as not to interfere with anyone's neck! Proper aerial wire can be obtained but ordinary PVC covered multistrand connecting wire will work just fine.

A ground connection is not essential, but can give a substantial improvement in results. All that is needed is a rod or pipe about one half to one meter in length pushed into the ground, and connected to SK3 via a lead which should be no longer than is absolutely necessary. It would not be a good idea to make a connection to the AC ground as this could be dangerous.

In Use

It is probably best to try the medium waveband first (SW1 open) as in most areas there is normally a good selection of strong medium wave stations. With even a modest aerial and no ground connection there should be several stations received at good volume, and using a good aerial plus a ground there should be a dozen or so receivable after dark. When using either tuning range, if a lack of selectivity proves to be a problem, try connecting the aerial to SK1 instead of SK2.

Results on the short wave bands are less predictable, and stations can come through loud and clear one minute, only to disappear the next. A lot of patience is required when listening on these bands, but some interesting stations can be picked up. ■

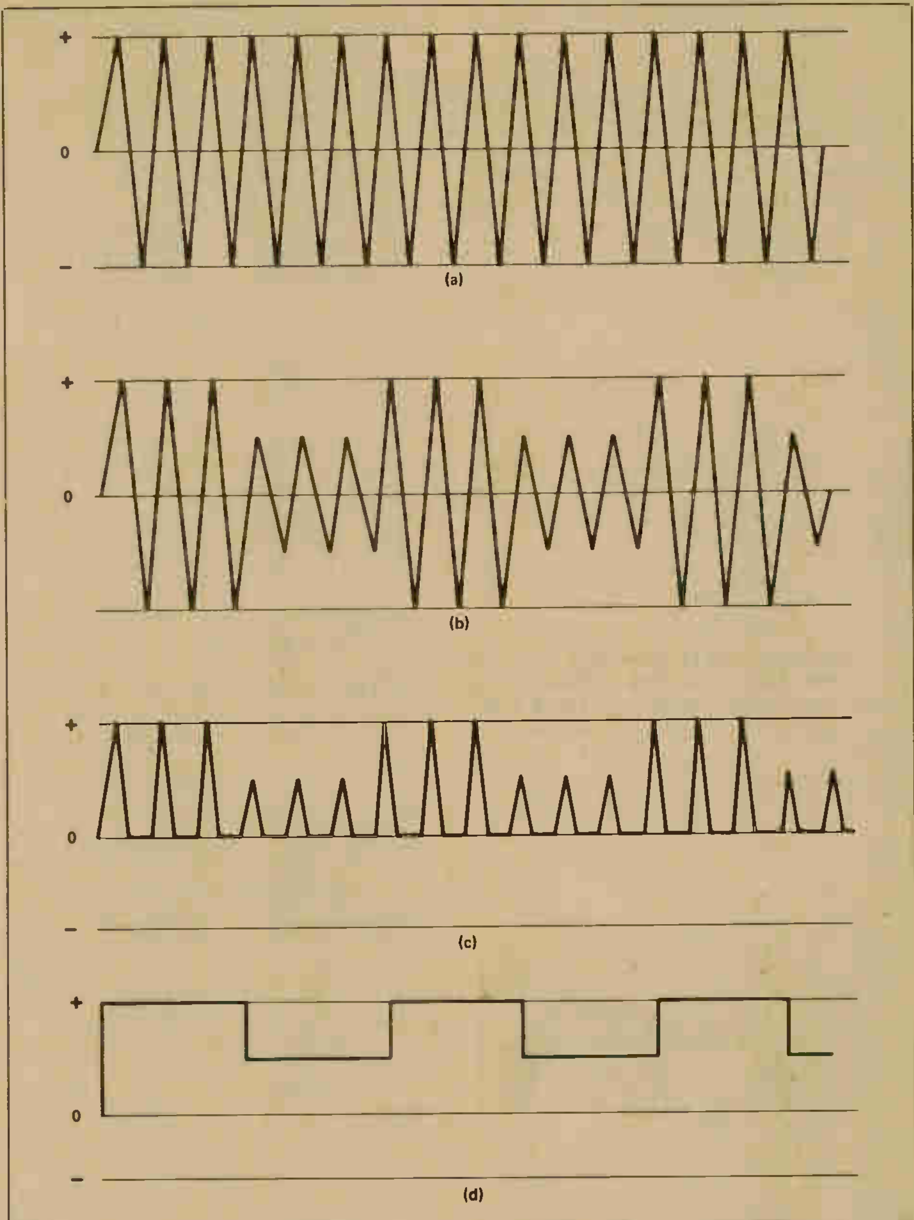


Fig. 2 A series of waveforms illustrating the processes through which the aerial signals go through: a) an unmodulated carrier b) a carrier modulated by a square wave c) the negative set of half cycles removed d) a low pass filter removes the carrier wave and leaves the square wave.

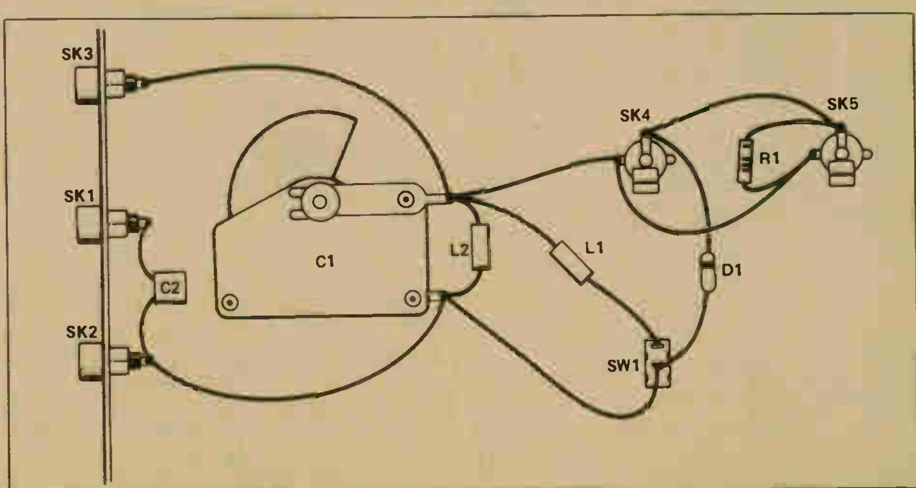


Fig. 3 No PCB! All the components are soldered to each other. Tin the joints to ensure good connections, but beware of damaging the heat-sensitive germanium diode.

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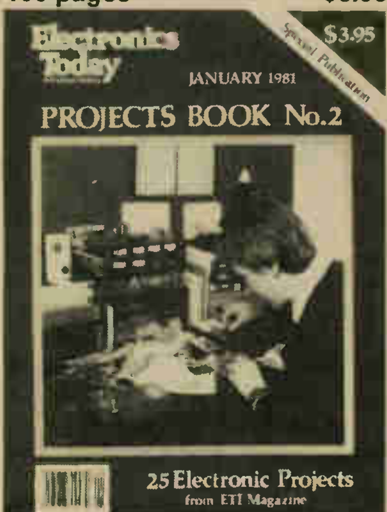

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Low Cost Audio Mixer

This modular mixer is not super-fi, but it is inexpensive, portable, and so versatile you can use any source.

By John Linsley Hood

THE UNIT described here was designed and built as a control console containing the necessary electronics, and fader pots, so that an operator could mix in various voices with programme material from other sources such as: disc, radio, or tape, to produce a final stereo cassette tape.

The general layout is versatile enough for the actual inputs to be modified for other types. I will show some of the other input circuits which may be slotted in, in place of, or in addition to, the existing layouts.

One general requirement for mixer consoles such as these is the provision of a reasonable quality stereo headphone monitor facility, allowing the control engineer to hear just what is being put on to tape. The unit has been designed to be operable from a battery DC supply. It could be used as a fully portable 'studio' in conjunction with a suitable battery operated cassette recorder.

No VU metering system has been provided since it is assumed that the recorder used will have this facility.

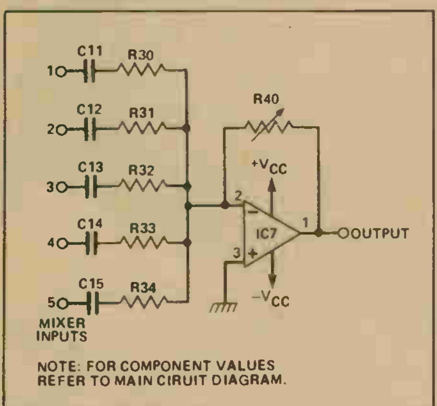


Fig. 1 The central circuit of a virtual ground mixer.

Basic Layout

The circuitry is organized around the virtual ground mixer layout shown in Fig. 1, which can be hooked up easily around an IC op-amp and allows as many inputs as one wishes to be combined together into a common signal (only five are shown).

This is a very powerful technique for mixing inputs, and has the great benefit that there is no leakage back from one input into another, since the inverting input of IC1 in this layout really does look like a ground point to the incoming signals. This also implies that the input impedance of the circuit is determined by the values chosen for each input resistor, R30, R31, etc.

The overall gain of the stage is determined, for any one input channel, by the ratio of R40:Rin (Rin = input resistor). If R40 is variable (As in Fig. 1, but not in the main circuit diagram), the gain of all the input channels may be reduced or increased simultaneously.

The various inputs to this mixer stage are obtained from input stages of the types described below.

Line Input Stage

In the simplest case, where a signal is obtained from a radio or tape recorder having a line output socket (300-700mV @ low impedance), all that is required is a simple slider pot connected as shown in Fig. 2. On the other hand, if it is known that the unit may be used with signal sources having outputs conforming to the DIN standard, in which the output is arranged to provide 1mV for each 1K of load impedancy, the alternative arrangement of Fig. 3 is possible.

This is quite a versatile system, and can be used with any input source where a flat frequency response is all that is needed, and where the input signal level will not exceed more than about 0.5V RMS.

Microphone Input Stage

This uses an identical circuit layout to that of Fig. 3, but with the values of R55 and R56 changed to R11 and R16 in Fig. 4 to give a higher gain. The reason for this being that the expected output signal level from the mic may be only 2-3mV. The input impedance is also made switchable between 100k and 4k7 (R1 and SW1 in Fig. 4) to suit either crystal or dynamic (moving coil) microphones. Electret mics with a built-in FET buffer output could be used equally well with either.

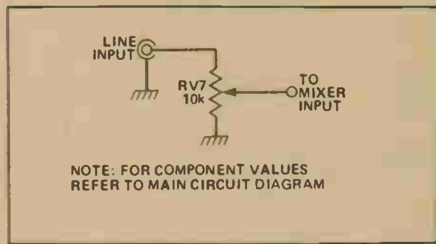


Fig. 2 A mono line input arrangement.

Turntable PU Inputs

This facility was not required on the prototype, but there is no difficulty in modifying the op-amp input stage to provide the required gain and frequency response characteristics. The circuit for this is shown in Fig. 5. Since we're not aiming at the 'ultimate-fi' in this unit, a conventional series feedback layout, as used in 99.9% of domestic hi-fi amplifiers, will be adequate.

The op-amp output resistors in the DIN, mic, and RIAA stages (R57, R21, and R62 respectively), are included to prevent changes in the loading of the op-amp, due to the setting of the output gain controls which would alter the frequency response characteristically of the gain stage.

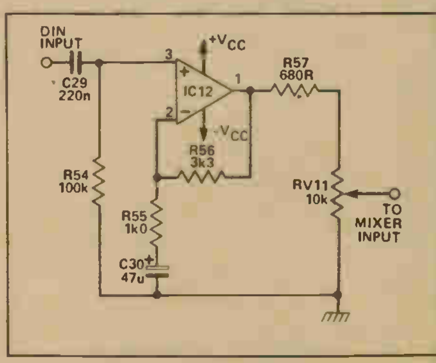


Fig. 3 A DIN input stage.

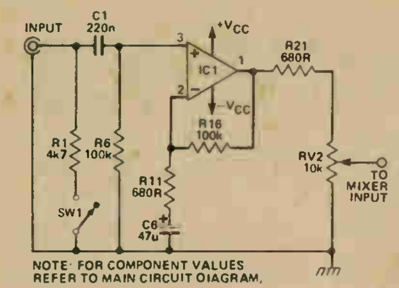


Fig. 4 Mic input stage.

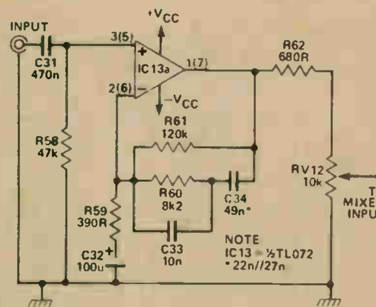


Fig. 5 Optional RIAA input stage.

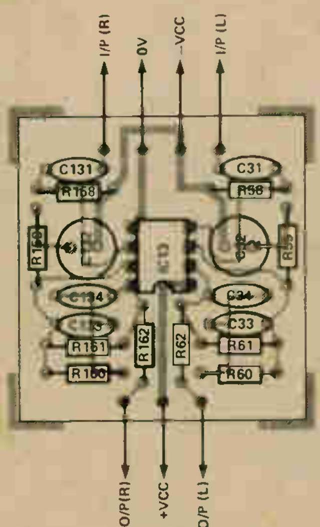


Fig. 6 PCB overlay for the RIAA stage.

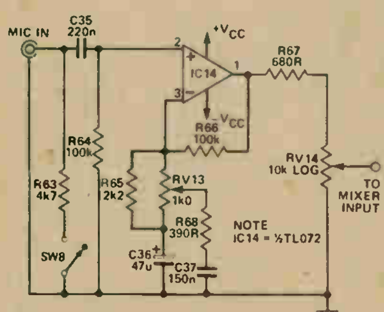


Fig. 7 Optional treble-lift mic input.

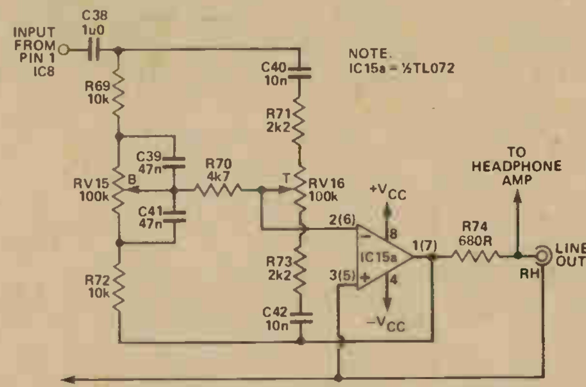


Fig. 8 Optional bass and treble lift#cut tone control stage.

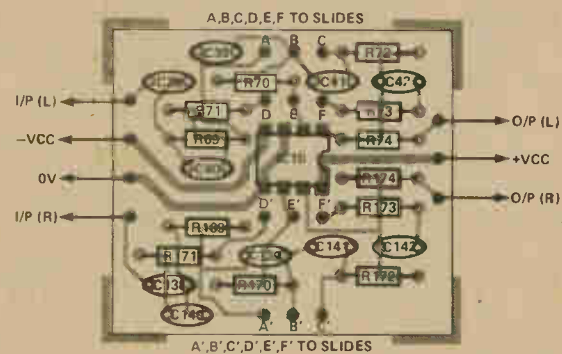
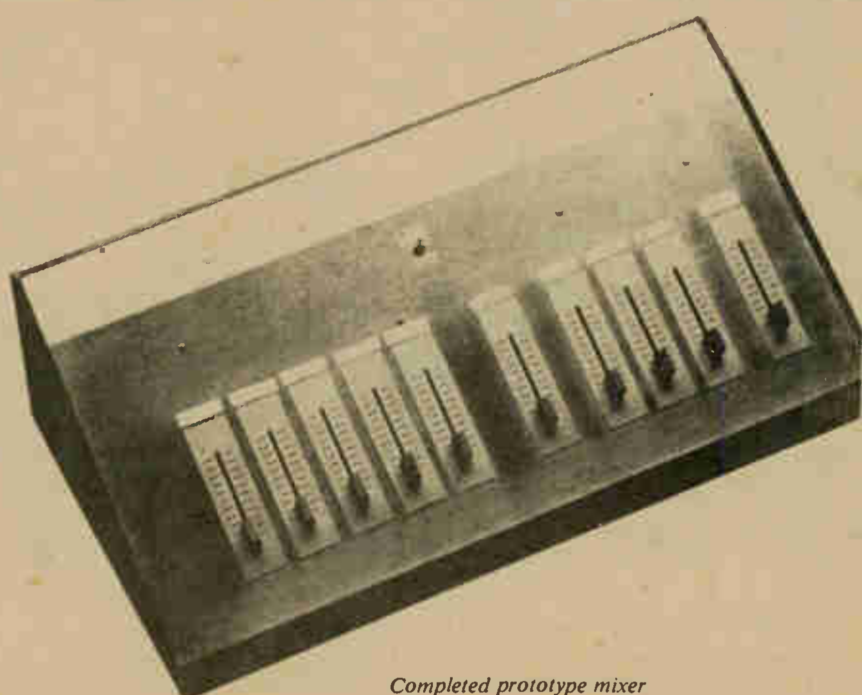


Fig. 9 PCB overlay for optional tone control stage (stereo).



Completed prototype mixer

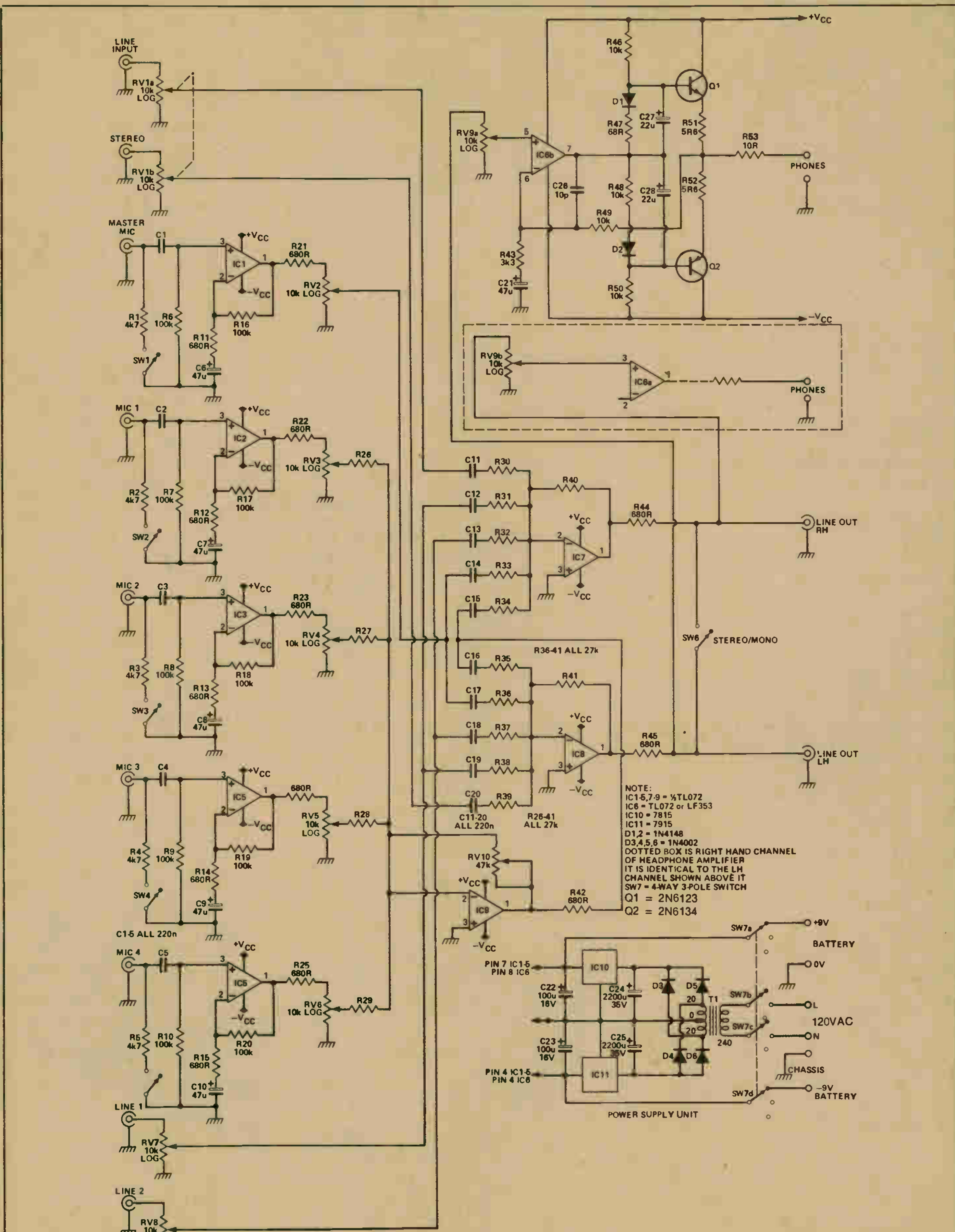


Fig. 10 Circuit diagram of the complete mixer.

Headphone Output Stage

This is fairly conventional, and again uses an op-amp as the gain block, to which some muscle power is added by the transistors Q1 and Q2. These are biased into class A by the diode/resistor network R46–R50, D1 and D2. A small capacitor, C26, is connected across the op-amp to ensure HF stability. Several pairs of headphones can be connected in parallel across the output, provided that the isolating resistors (R53) are taken separately to each output jack. This will ensure that there are no problems if phones of dissimilar type of impedance are used. (Fig. 10)

AC Power Supply

Although the mixer unit can be used quite satisfactorily on a pair of 9V batteries, batteries are expensive and it is probable that it will be powered from 120V on most occasions. A very simple dual power supply, with a couple of voltage regulator ICs, was used on the prototype, as shown in Fig. 10.

Complete System

The circuit for the whole unit is shown in Fig 10 and fitted into a shallow sloping fronted box, approximately 19 inches long, as shown in the photograph.

Since the specification to which this unit was built called for a stereo line input, as well as a pair of mono line inputs, a ganged 10k slider pot was used for RV1, while single slider units were employed for RV7 and RV8. The four main mic inputs are controlled individually by slider pots RV3 to RV6, with a master fader, RV10, controlling their overall level so that it can faded down if, for example, a voice-over commentary is to be superimposed from the master mic.

A dual-gang slider pot, RV9, is used to control the volume level of the headphone outputs. Finally, an overriding stereo/mono control is provided by SW6, which simply parallels the two L and R outputs. In general, however, the unit is used in the stereo mode, with a stereo signal from the line input, over which the (mono) mic input voices appear on 'centre stage'.

No tone control facilities were required for the unit as it appears here, but subsequently a microphone input treble lift facility was added, to give greater clarity to voices. This was done as shown in Fig. 7. The unit can completely replace the mic input shown in Fig. 4.

A more formal bass/treble-lift/cut tone control stage could be added, at pin 1 of ICs 7 and 8 in Fig. 10. The tone control circuit is shown in Fig. 8.

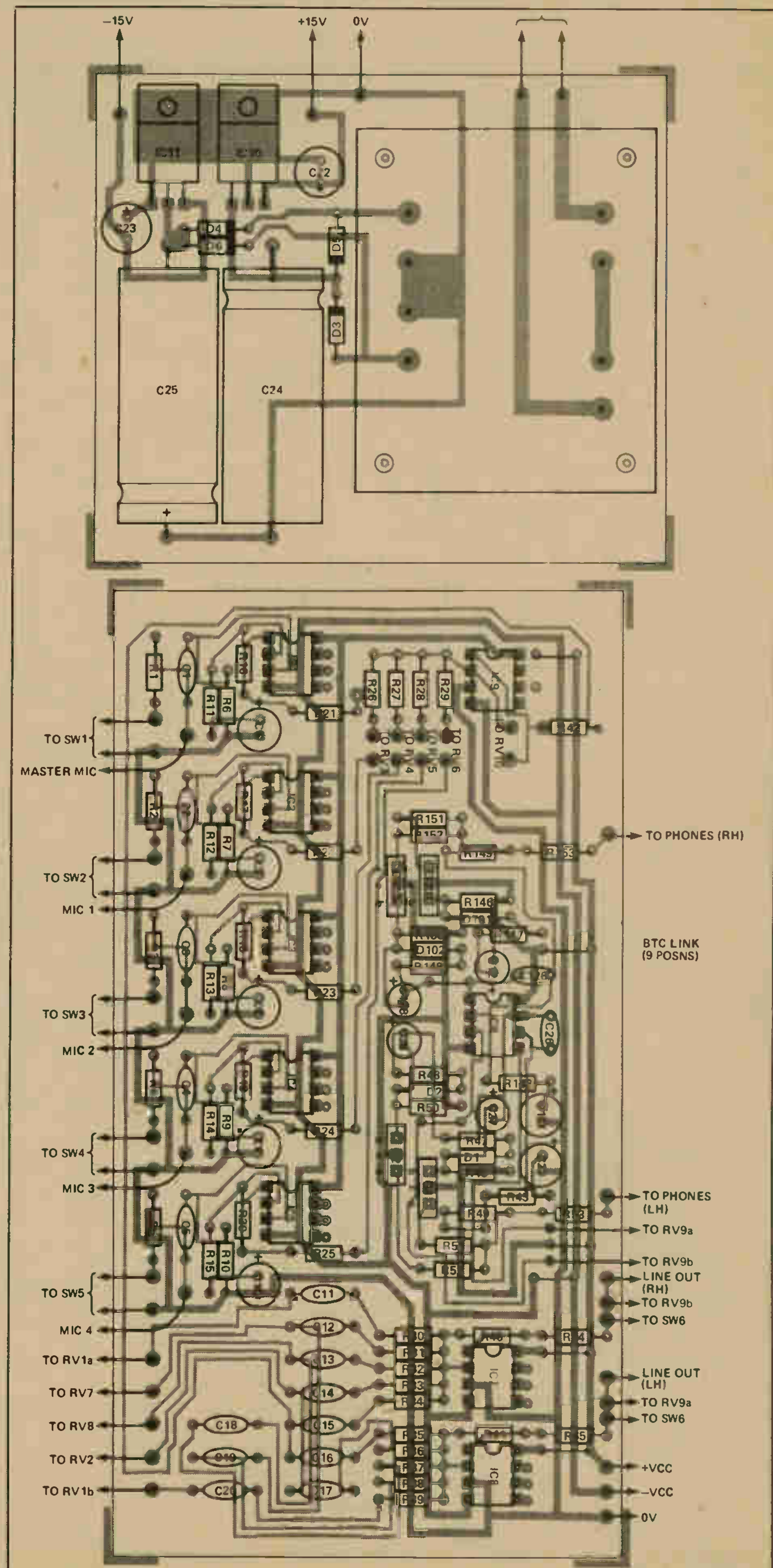


Fig. 11 Overlays for the mixer and PSU boards.

PARTS LIST

MAIN BOARD

Resistors
(all ⅓ watt unless stated)

R1,2,3,4 .... 4k7
R6,7,8,9,10,16,17 18,29,20 .... 100k
R11,12,13,14,15, 21,22,23,24,25,42,44,45 .... 680R
R26,27,28,29,30 31,32,33,34,35,36 37,38,39,40,41 .... 27k
R43 .... 3k3
R46,49,50 .... 10k
R47,28 .... 68R
R51,52 .... 5R6 W/W
R53 .... 10R/W/W
RV1,9 .... 10k log ganged sliders
RV2,3,4,5,6,7,8 .... 10k log single sliders
RV10 .... 47k single slider

Capacitors

C1,2,3,4,5,11,12,13,14 15,16,17,18,19,20 .... 47u 16V
C6,7,8,9,10,21 .... electrolytic 100u 16V
C22,23 .... electrolytic
C24,25 .... 2200u 40V electrolytic
C26 .... 10p
C27,28 .... 22u 16V electrolytic

Semiconductors

IC1-6,8,9 .... TL072/LF353
IC10 7815
IC11 7915
Q1 .... 2N6123/2N5296
Q2 .... 2N6134/2N6109
D1,2 .... 1N4148
D3,4,5,6 .... 1N4002

Miscellaneous

SW1,2,3,4,5,6 .... SPST switches
SW7 .... 3 pole, 4 way switch

Standard jack sockets (13 for main board configuration); 9V battery clips (x2); 20-0-20 20VA transformer, TR1; 19" shielded cabinet.

(Note: R43-53, C21, 26-28, Q1-2,D1-2 have corresponding components for the right-hand headphone amplifier. They are marked R143-153, C121, 126-128, Q101-102, D101-102 on the overlay diagram).

OPTIONAL BOARD

Resistors
(all ⅓ watt)

R54,64,66 .... 100k
R55 .... 1k0
R56 .... 3k3
R57,62,67,74,75 76,79,80 .... 680R
R58 .... 47k
R59,68 .... 390R
R61 .... 120k
R63,70 .... 4k7
R65,71,73 .... 2k2
R69,72 .... 10k
R77,78,81,82 .... 27k
RV11,12,13 .... 10k log sliders
RV13 .... 1k0 slider
RV15,16 .... 100k sliders
RV18 .... 47k ganged slider

Capacitors

C29,35,45,46 .... 220n
C30,36 .... 47u 16V
C31,43,44 .... electrolytic 470n
C32 .... 100u 16V
C33,40,42 .... electrolytic 10n
C34 .... 49n (22/27n)
C37 .... 150n
C38 .... 1u0 ceramic
C39,41 .... 47n

Semiconductors

IC12-16 .... TL072/LF353

Miscellaneous

Standard jack sockets are required.

(Note: R58-62, RV12 and C31-34 have corresponding components on the second channel of the RIAA equaliser board. They are numbered R158-162. RV112 and C131-134 on the component overlay. Likewise for components R69-74, RV15-16 and C38-42 whose second channel equivalents on the tone control board are marked R169-174, RV115-116 and C138-142).

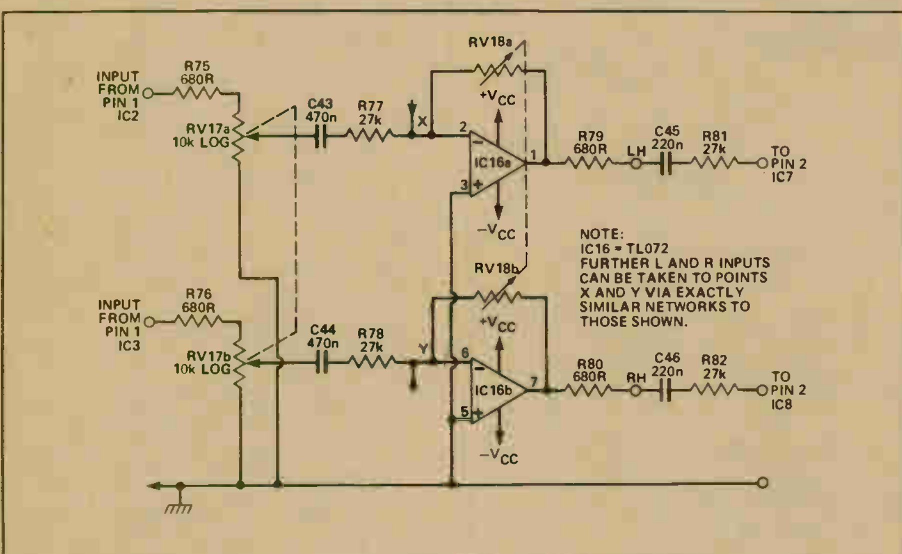


Fig. 12 Single stereo mic input arrangement using two mono input stages.

Full Stereo System

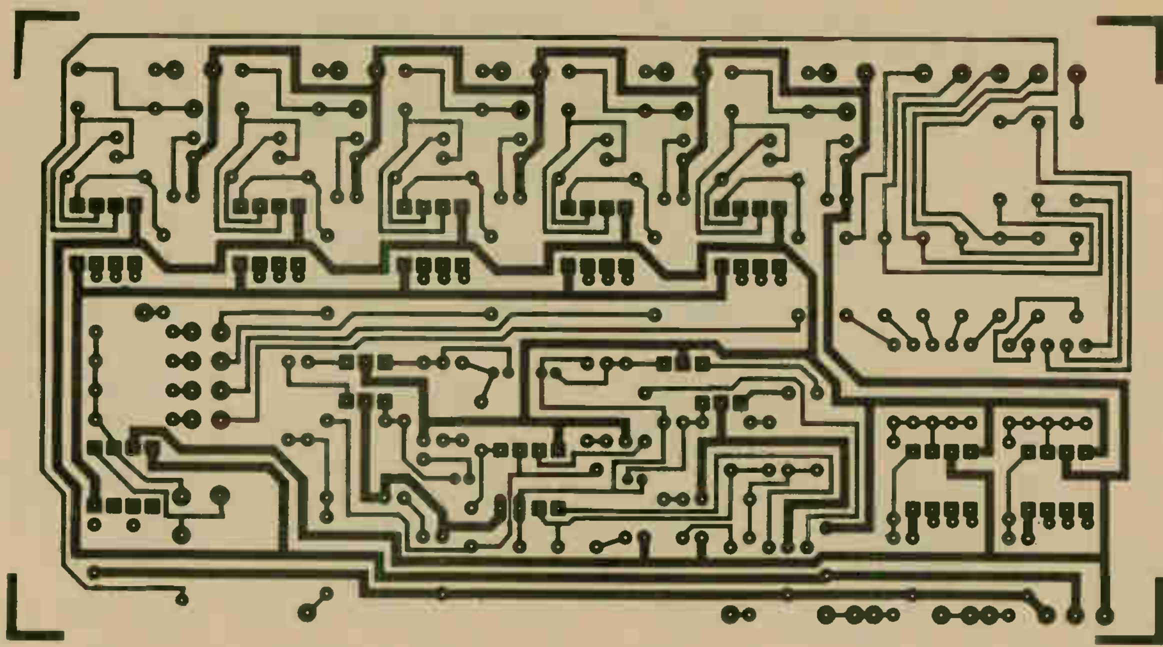
It is very easy to organize this layout to provide more stereo input channels than the one stereo line input on the prototype.

This is done by taking each pair of inputs, say those from IC2 and IC3 (Fig. 10) and routing them to a pair of master fader stages, IC16a and IC16b, as shown in Fig. 12, and from there to ICs 7 and 8, as before.

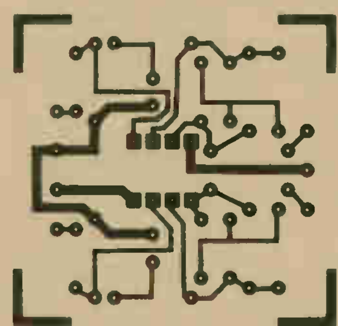
The prototype unit was designed around TL071s or their higher specification equivalents, LF351. To enable the addition of extra facilities with relative ease, we have designed the board using TL072s (LF353s) exclusively. Pads for the unused halves of the op-amps can be found on the main PCB.

And As We Go To Press...

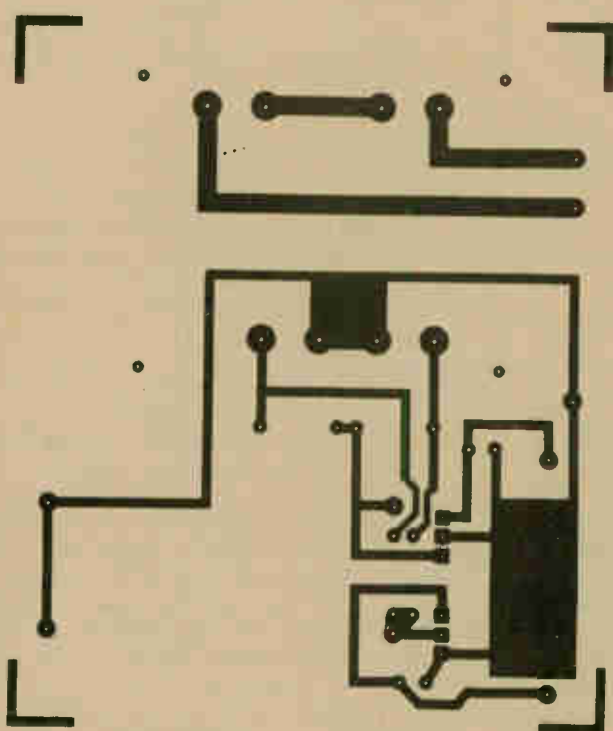
In Fig. 6, overlay for the RIAA stage, the board is incorrectly shown from the foil side. The PCB artwork itself is shown correctly.



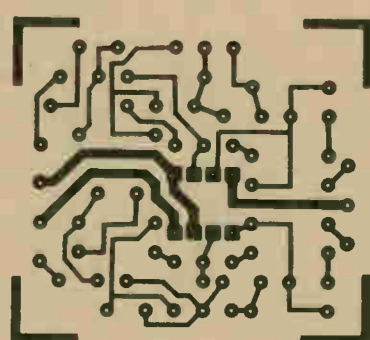
The pattern for the main board of the audio mixer.



The audio mixer RIAA input stage board



The power supply board for the audio mixer.



The optional tone control board for the audio mixer.

Designer's Notebook: Transistor Summary

A look at the several types of transistors available and the applications to which they are best suited.

By John Linsley Hood

AS A WORKING electronics engineer I tend to look unsympathetically at the propaganda of the *back to tubes* brigade. The enormous scope for circuit design now available to the electronics set is due entirely to the wealth of devices at our disposal. Of course, you have to know what devices are available and how to use them properly so that they perform up to specs, and it is also necessary to know their individual strengths and weaknesses so that you always use the most appropriate device for the job at hand. There are several types to choose from, so let's take a look.

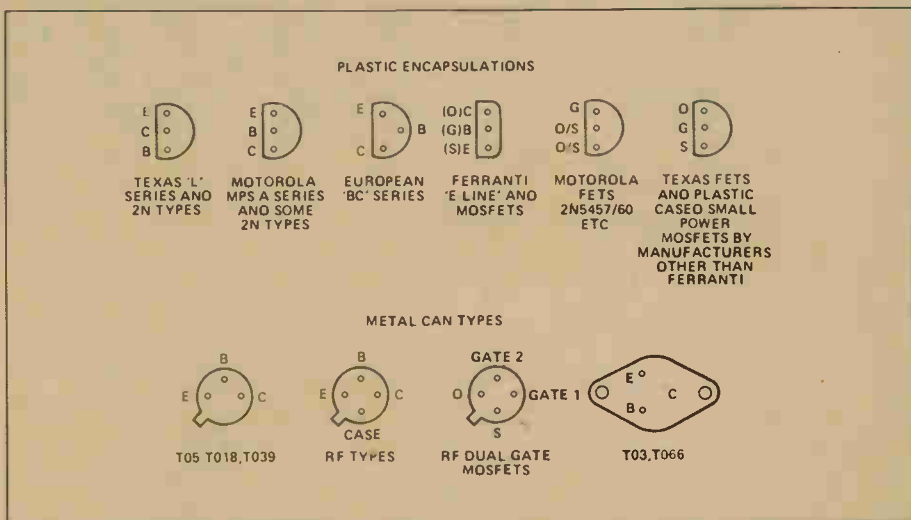


Fig. 1 Common transistor connection arrangements.

Small Signal Junction Transistors

These exist as small metal cans or blobs of moulded plastic with three (or sometimes four) leads, as shown in Fig. 1. There isn't much difference these days between the longevity and reliability of plastic and metal can encapsulations, especially since the can is often just a receptacle into which epoxy resin has been poured to hold the silicon chip in place. Metal can types, especially those which are hermetically sealed, are usually far more expensive than plastic moulded types.

The chip inside the encapsulation will normally be of either the planar or the epitaxial planar type, both of which are shown in Fig. 2. Epitaxial (or epitaxial base) types have an additional thin layer of a different type of silicon grown on the chip by vapour phase techniques before the other diffusions have been made. They are cheaper and generally work better than other types and are therefore the most commonly used.

Typical power dissipations for small signal plastic transistors range from about 250 to 650 milliwatts. Metal can types will typically handle from 300–1000mW dissipation. It's a good practice to keep dissipations down to about half of the rated maximum.

Small signal NPN and PNP transistors can generally be regarded as the *workhorses* in the small circuit field. They are easy to use, inexpensive, reasonably difficult to damage, and will work well when used within their limits. Certain types are particularly suited for use in very low-noise, low impedance applications. Because they can be used in complementary symmetry arrangements, some very crafty circuit layouts are possible. The circuit symbols for these devices are shown in Fig. 3a.

Darlington Transistors

These consist of a pair of small signal transistors coupled together in one case. They are available in NPN and PNP types and the circuit symbol for the NPN type is shown in Fig. 3b, with my own preferred symbol shown in Fig. 3c. They are similar to other junction transistors except that they have current gains of between 20000 and 50000 and relatively high input impedance. Typical input impedances would be from 100k to 250k for output currents of between 2 and 10mA, which is the range over which they work best. The Motorola MPSA-12/14 (NPN) and the MPSA-62/64 (PNP) are good examples. Inevitably they are more expensive than standard single transistors.

Junction Field Effect Devices

These were the original high impedance transistor types and are represented in circuit diagrams by the symbols shown in Fig. 3d. Their physical construction is shown in Fig. 4

They differ from junction bipolar transistors in that their input terminal, the gate, is normally non-conducting. In fact, it is a reverse biased junction diode, and the only current which will flow is the normal reverse leakage current of such a diode. Typical input impedances for good quality devices of this type range from ten thousand to a million megohms.

Contrary to popular belief, these devices will not normally be damaged by static charges any more than any other small signal diode would be, so they don't need special care in use. They're used in instances where high input impedances are needed, and where the cost of using a junction FET is justified – they are about five times the cost of an equivalent bipolar device. The better types are also less noisy in high impedance circuitry than bipolar devices but you need to choose carefully because some of the cheaper junction FETs are not very good in this respect.

continued on page 63

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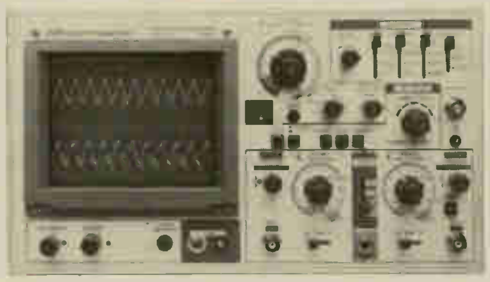

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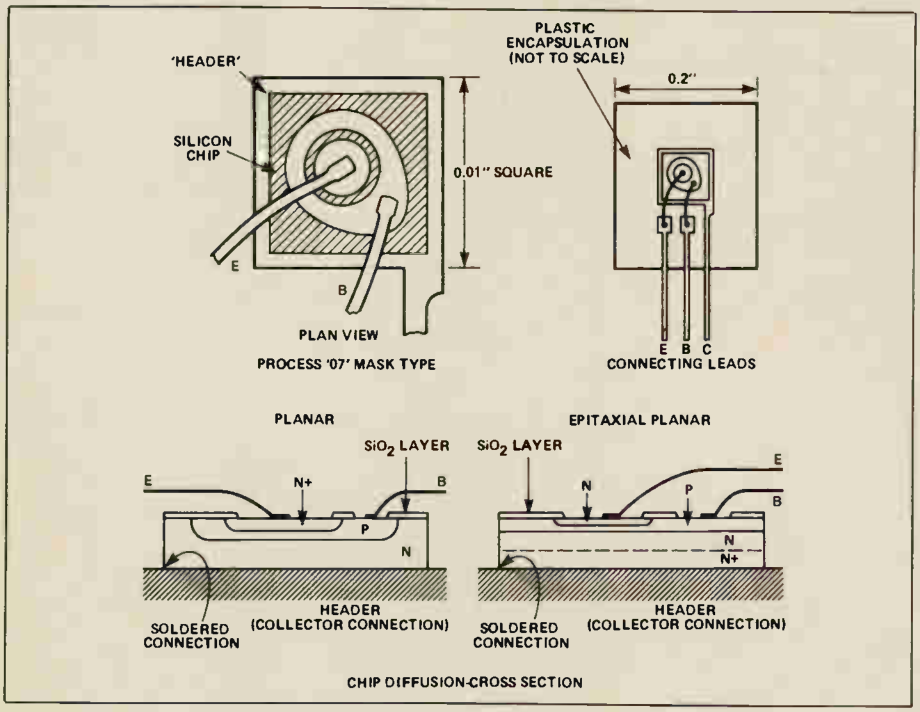

Fig. 2 The construction of a typical small-signal, plastic encapsulated transistor.

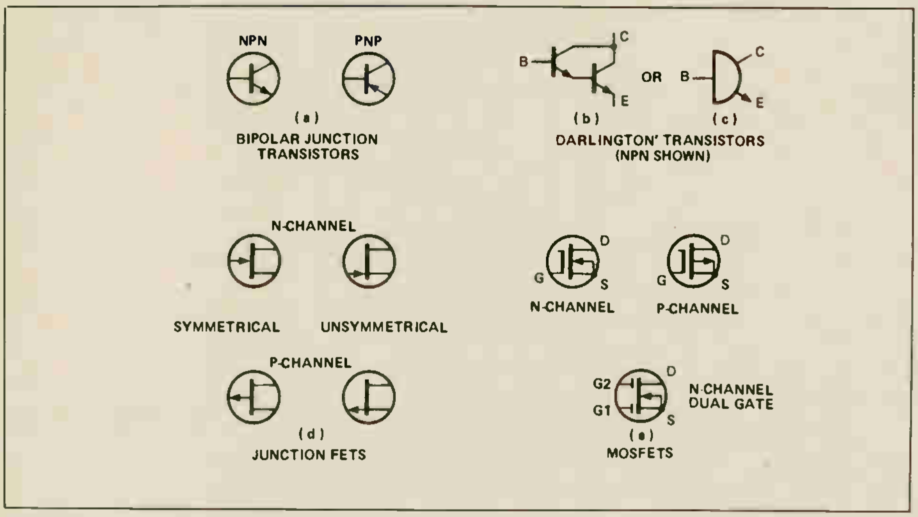

Fig. 3. Transistor circuit symbols.

Junction FETs also make good RF amplifier devices at frequencies up to about 300MHz, and can offer very low noise in this application. In circuitry, they will tend to have a lower stage gain than bipolar device, unless a very high impedance output load is employed which usually means an active load of some kind. They have a very flat drain current/drain voltage characteristic which makes them good at rejecting HT line ripple effects, and also allows them to be used as nearly ideal constant current sources.

The chip construction of a junction FET is shown in Fig. 5. The chip acts as a thin conducting layer of P-type or N-type silicon (germanium is almost never used except in special cases), into which a depletion layer will expand, narrowing and finally cutting off the undepleted layer through which current may flow as the reverse bias potential applied to the gate is increased. Junction FETs are usually, though not always, symmetrical, so source and drain may be interchanged.

Small Signal MOSFETs

These devices, sometimes also known as insulated gate field effect transistors or IGFETs (MOSFET stands for Metal Oxide Silicon FET), have the general construction shown, for the wafer, in Fig. 6a. They work on the principle that if a charge (i.e., a voltage) is applied to an insulating layer, a charge of the opposite type will be attracted to the other face, as shown in Fig. 6b.

If that other face happens to lie in the body of a slice of high impedance (low impurity, or intrinsic) silicon, then current will flow in that charge layer. If the insulating layer is very thin, only a few volts need be applied to the gate in order to make current flow through the charge layer. The layer, which can be less than a micron thick, is usually made by oxidizing the outer face of the silicon slice, so that a metal layer can be deposited on it without making contact. It is normally capable of withstanding an applied voltage of some 20 or 30 volts only, and can be damaged by static charges or careless handling.

In order to make these devices a little less fragile in normal day to day use, it is customary to incorporate on the chip a couple of back-to-back zener diodes across the gate-source connections. this reduces the input impedance to perhaps a million megohms. It is possible to get unprotected MOSFETs which have a higher input impedance, but these need careful handling.

The most common variety of small signal MOSFET is the dual gate type shown in Fig. 7. This was specifically designed as a device for RF amplification and mixing in radio and TV tuners, and is

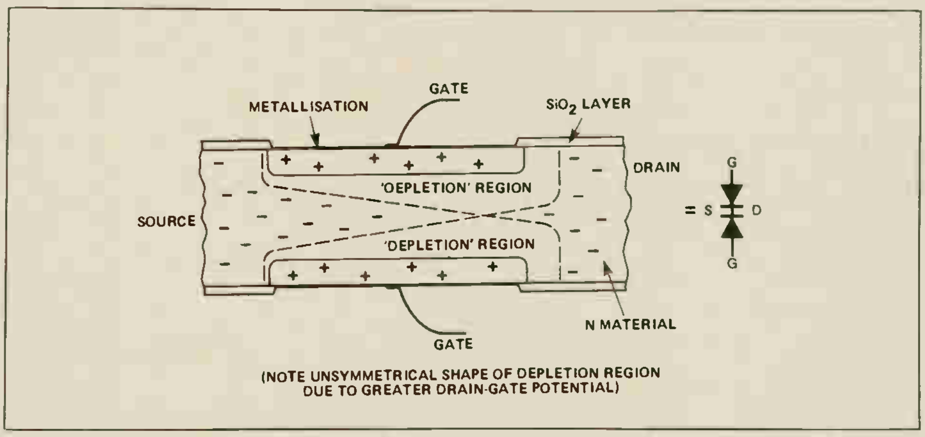

Fig. 4 Cross-sectional view of an N-channel FET, showing the depletion regions which result when the device is just biased to cut-off.

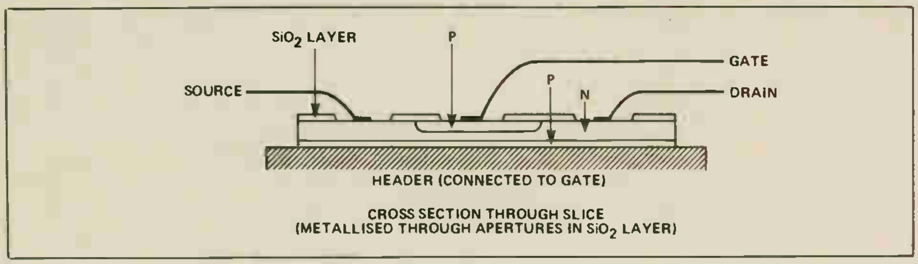

Fig. 5 Cross-sectional view of an N-channel small signal junction FET.

useable up to a few hundred megahertz. The second gate can be used to screen the input signal from the output signal on the drain, permitting stable RF amplification. In this application, it acts in a similar way to the screened-grid or RF pentode type tube. The circuit symbol for these transistors appear in Fig. 3c.

All of these MOSFETs require a forward voltage applied to the gate electrode to cause them to conduct. This will be positive in the case of N-channel MOSFET (operating on a positive DC supply line) and negative in the case of the less common P-channel types. Small signal devices of this type will typically have a mutual conductance or Gm of a few milliamps per volt. This allows a simple calculation of stage gain from:

Gain = Gm x RL

where RL is the effective load impedance.

Recently, small signal versions of the T-MOS type of power MOSFET have been introduced. These have a slightly different type of chip construction to the

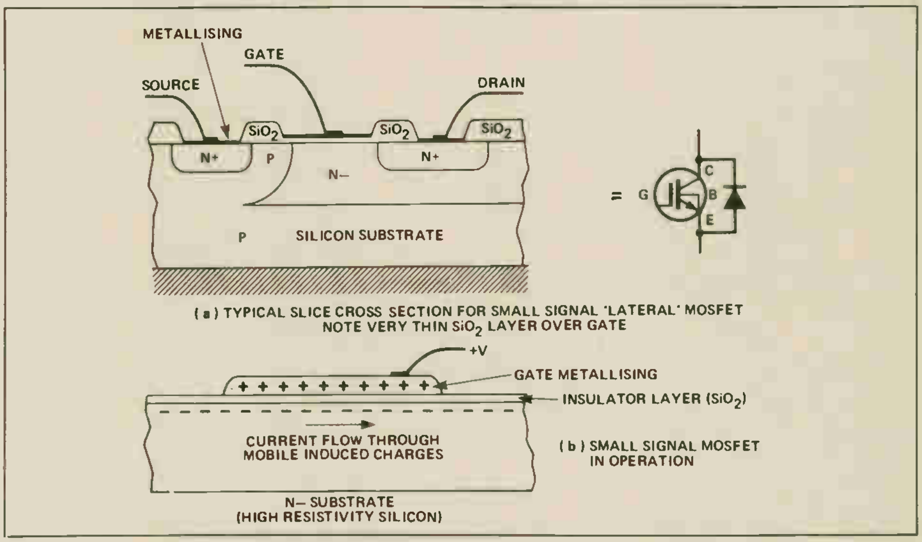

Fig. 6 Cross-sectional views showing the construction and operation of a MOSFET.

	TYPICAL INPUT IMPEDANCE	TYPICAL STAGE GAIN	OUTPUT IMPEDANCE (COMMON EMITTER)	TYPICAL MAXIMUM WORKING FREQUENCY	NOISE FIGURE (dB) (MINIMUM)	TYPICAL (MAX) WORKING VOLTAGE	TYPICAL (MAX) WORKING CURRENT	COMMENTS
SMALL SIGNAL JUNCTION TRANSISTORS	0.5-20k	40-200	200k +	300MHz	1dB	150V	500mA	NOT VERY LINEAR WITHOUT NFB
SMALL SIGNAL DARLINGTON TRANSISTORS	250k	100-500	200k	100MHz	6dB	40V	1A	TEMPERATURE SENSITIVE
JUNCTION FETS	10^{11}R	10-30	10M	400MHz	2.5dB	30V	15mA	LINEAR
DUAL-GATE MOSFETS	10^{12}R	50-100	500k	500MHz	2dB	20V	20mA	CAN BE DAMAGED BY STATIC CHARGES
SMALL POWER MOSFETS	10^{12}R	50-200	250k	500MHz	6dB	100V	1A	CAN BE DAMAGED BY STATIC CHARGES- VERY LINEAR
POWER TRANSISTORS (NPN)	10-200R	10-30	5k	40MHz	N/A	400V	25A	CAN SUFFER FROM 'HOLE' STORAGE EFFECTS
POWER TRANSISTORS (PNP)	10-200R	10-30	5k	10MHz	N/A	100V	15A	SOMEWHAT SLUGGISH & SUFFER FROM 'HOLE' STORAGE
POWER DARLINGTONS	20k	50 +	5k	4MHz	N/A	120V	15A	SLUGGISH AND SUFFER FROM 'HOLE' STORAGE
POWER MOSFETS	100M +	50 +	10k	500MHz	POOR	750V	10A	HIGH INPUT CAPACITANCE-PRONE TO OSCILLATE IF NOT PREVENTED
POWER FETS	10M +	10 +	5k	100MHz	N/A	?	?	HIGH OPERATING CURRENT REQUIRED

Table 1 A comparison of the characteristics of different transistor types.

normal small signal MOSFET, shown in Fig. 8. Their big advantage is that they can withstand drain voltages of up to about 100V, whereas the average dual-gate device or small signal junction FET can only cope with some 20–30V.

By comparison with bipolar transistors, MOSFETs are much more linear in their characteristics and do not suffer from operational problems such as thermal runaway and hole storage. The absence of this latter defect makes small signal TMOS devices considerably better than bipolar junction devices when used in the class A stages of audio amplifiers.

The circuit symbol used for the TMOS device is the same as that used for other MOSFETs except that they are only available in single gate versions.

The normal operating characteristics of the various small signal transistors are shown in Table 1, and a group of curves showing their input voltage/output current characteristics are in Fig. 9.

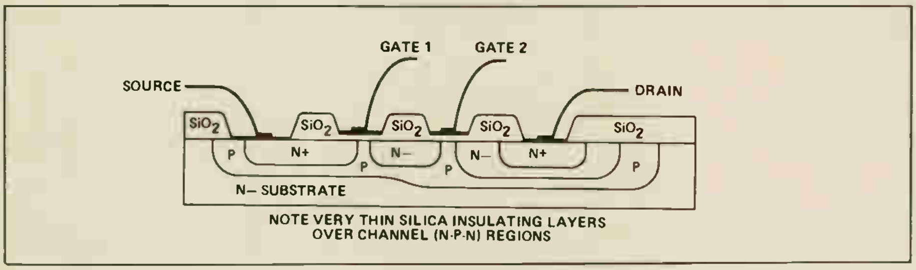

Fig. 7 Cross-sectional view of a dual-gate MOSFET.

Bipolar Junction Power Transistors

These are heavier duty versions of the small signal transistors we have already come across, and range in current handling capacity from an ampere or so for some of the small plastic encapsulated types with a metal cooling tag to 400 amperes in the case of some of the big industrial devices.

Permitted dissipations, with adequate heat-sinking, range from one to many hundreds of watts, and maximum collector voltages can be up to 500–1000 volts in specialized types, with 60–150V being more common in easily found devices such as the 2N3055 or 2N3442.

There isn't a big difference in price between the plastic encapsulated types and the hermetically sealed TO66 or TO3 versions, so for DIY projects where you aren't buying a lot of power transistors, the metal can versions may be preferable. They are certainly easier to cool.

Power junction transistors are available in NPN and PNP types, just like small signal devices, but the PNP versions tend to be a bit slower in action and a bit less burst-proof than the NPN ones. You should beware of assuming that because they are complementary in characteristics they can be treated as identical. A nice comment I once heard was that "NPN and PNP transistors are as similar as a man and a woman of the same height and weight".

The transition frequency of a power transistor, that is, the frequency at which the current gain falls to unity, will usually lie within the range of 4-20MHz, which is considerably lower than the transition frequency of a typical small signal device which would probably be between 100 and 400MHz. In addition to being more sluggish than small signal types, power transistors also have lower current gains. Whereas a small signal junction transistor has a typical current gain of 100–500, a power device might have a current gain of only 15–80, with the lower values usually being found at higher collector currents. ■

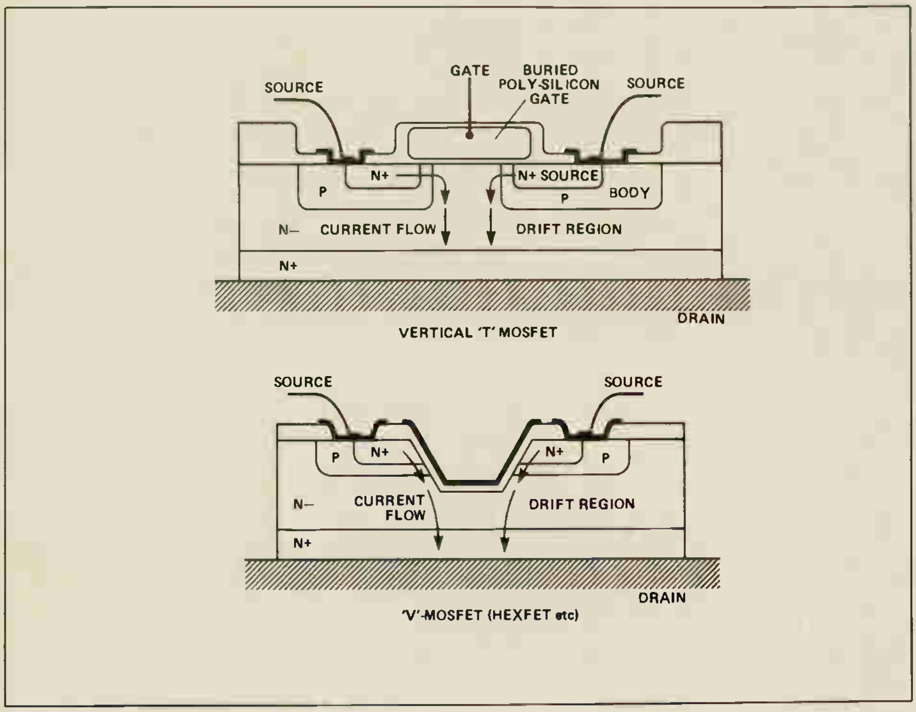

Fig. 8 Cross-sectional views of MOSFETs.

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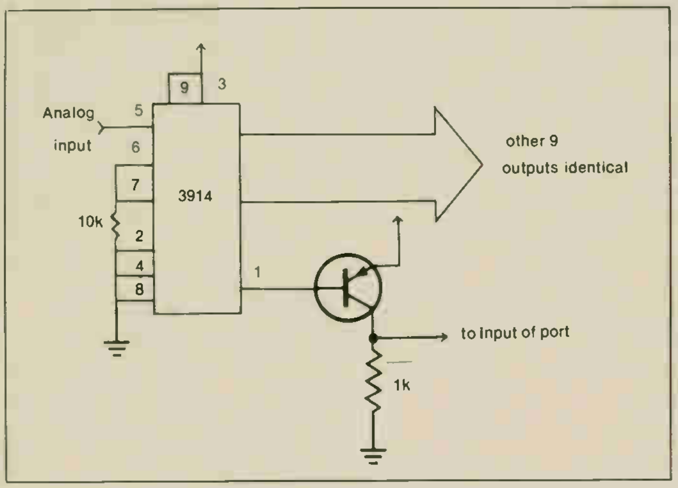

Fig. 5 Converting analog to digital using the LM3914.

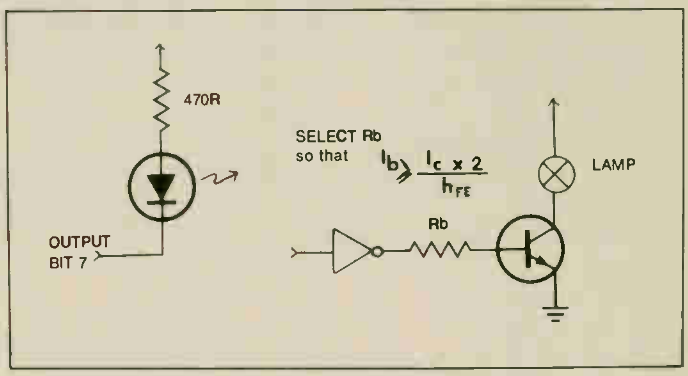

Fig. 7 Connecting LEDs and lamps to the PIO.

Inputs without the PIO

Although the PIO is quite handy with limited I/O ports it can get quite expensive when more input ports are needed. Fig. 6 shows a 74LS245 tristate buffer connected to the CPU as an input port. This circuit uses a 74LS138 3 to 8 line multiplexer to decode the address bus. Only the upper 128 I/O address space is decoded leaving 128 address locations available for other I/O activity. The address of the input port is decoded to be 80H. Seven more input ports can be connected with corresponding addresses from 81H to 87H.

Output Devices and the CPU

Perhaps the simplest output device to be connected to the CPU is an LED or lamp. Fig. 7 shows the schematics for connecting led's and lamps, and in some cases a driver transistor is needed depending on the load. Selecting the proper base resistor to drive the transistor into saturation will eliminate the need for a heat sink in most applications. The software is straight forward, a low at the output turns on the LED and a high turns it off.

Seven segment displays allow us to display numbers and various letters and patterns with only seven outputs. Fig. 8 shows the connection of two seven segment displays to a PIO. While this method might be sufficient for two displays, another method must be employed for 3 or more displays. This method calls for multiplexing the displays.

In this method each display is lit up one at a time over and over again. This is done fast enough so the human eye does not notice. Fig. 9 shows the schematic for connecting 8 seven segment display units; one output port is used to drive the seven segments and another port is used to turn on the individual displays.

```
;[illegible] TO DRIVE A [illegible]EN [illegible]GMENT DI[illegible]PLAY

;[illegible] NUMBER TO BE DISPLAY[illegible]D
[illegible]  LD    B,[illegible]        ;PREPARE REGISTER BC
        LD    H[illegible],TABLE   ;[illegible]OINT [illegible]T SE[illegible]MENT TABLE
        ADD   HL,BC        ;POINT TO CORRECT BYTE
        LD    A,(HL)       ;GET BYTE
        OUT   (PORTA),A    ;DISPLAY IT
TABLE:  DB    01,4F,1[illegible],06,4C,[illegible]4,[illegible]0,0[illegible],00,0[illegible]

;[illegible]WARE FOR MULTIPLEXING 8 SEVEN [illegible]GMENT DI[illegible]

MULTI:  LD    HL,DATA      ;POINT H[illegible] TO DATA AREA
        LD    [illegible],01       ;DIGIT [illegible]ELECT CODE
[illegible]:    LD    A,[illegible]        ;OUTPUT DIGIT SELECT CODE
        OUT   (PORTB),A
        LD    A,(HL)       ;[illegible] DATA FOR DIGIT
        OUT   (PORTA),A    ;DISPLAY DIGIT
        [illegible]   HL           ;INCREMENT DATA POINTER
        R[illegible]   [illegible]            ;ROTATE DIGIT [illegible]
        [illegible]   [illegible]
        RE[illegible]                ;RETURN [illegible] CALLER

[illegible]
```

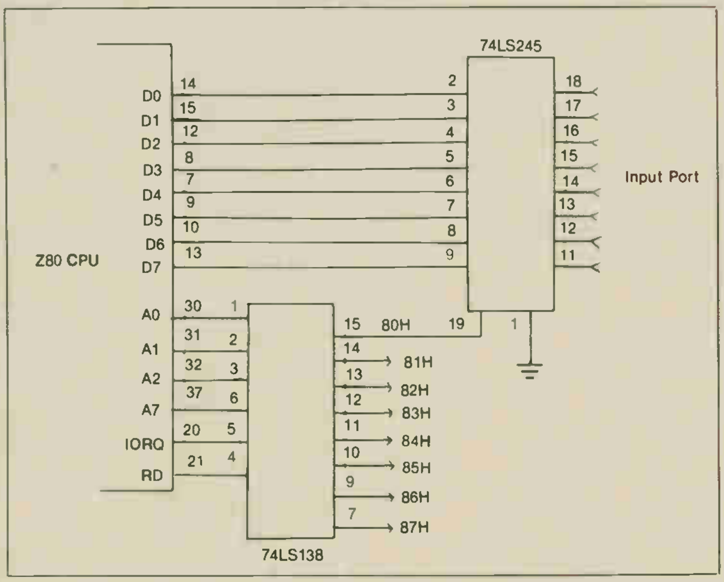

Fig. 6 A 74LS245 used as an input port.

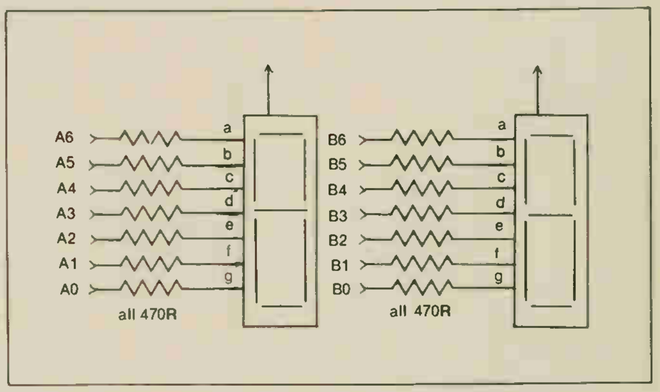

Fig. 8 Connecting two common anode displays to the PIO.

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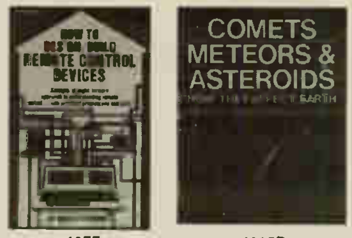

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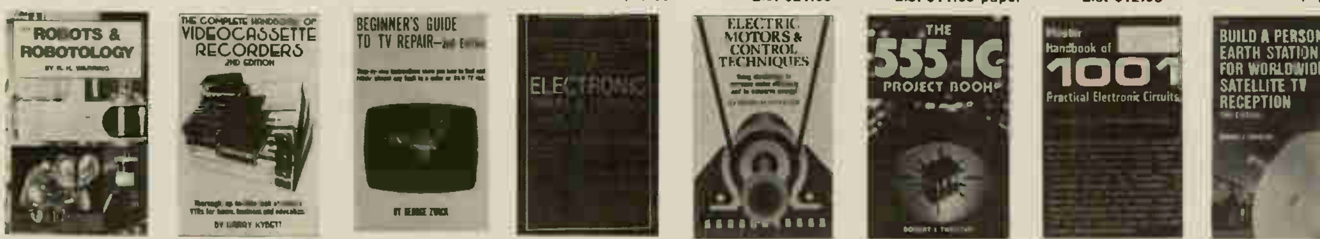

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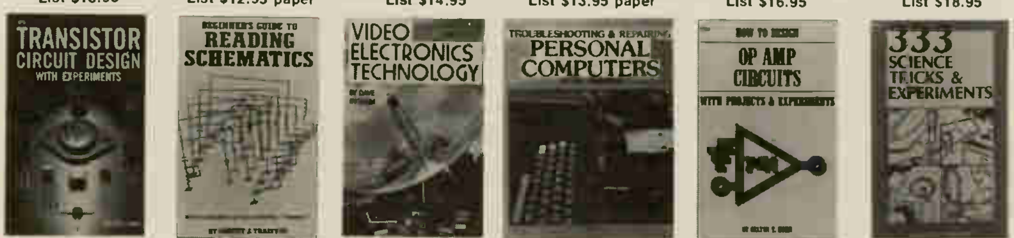

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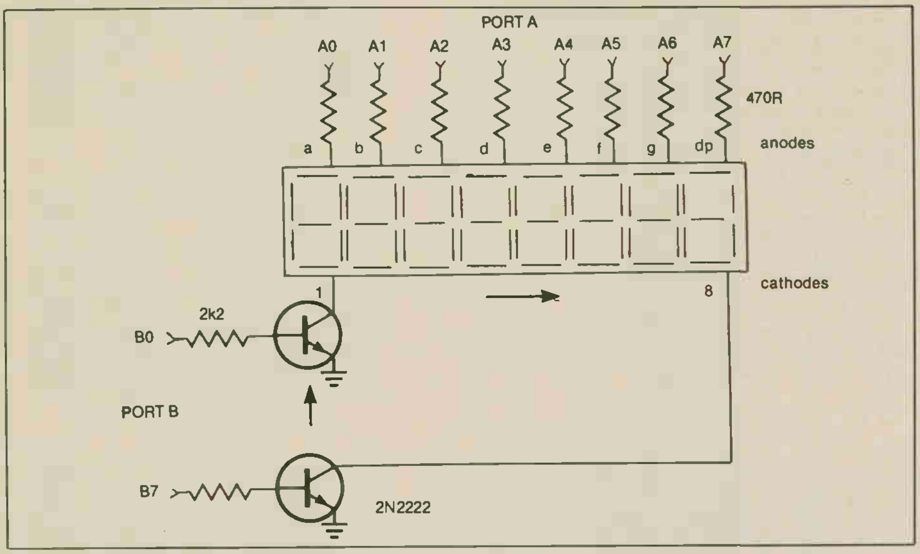

Fig. 9 Multiplexing 8 seven-segment LED displays.

```
;*************************************************************
; I/O SAMPLES-INPUT
;
;  FOR THE FOLLOWING EXAMPLES IT IS ASSUMED
;      INPUT PORT ADDRESS-F8H
;      OUTPUT PORT ADDRESS F9H
;*************************************************************
;  - PUSH BUTTON INPUT
PBIN:   IN      A,(F8H)         ;READ INPUT PORT
        AND     80H             ;MASK OFF BITS 0-6
        JP      Z,PBON          ;JUMP TO PBON IF BUTTON PRESSED
        JP      NZ,PBOFF        ;JUMP TO PBOFF IF BUTTON NOT PRESSED

;  --PUSH BUTTON INPUT WITH DEBOUNCER SOFTWARE
PBIN2:  IN      A,(F8H)         ;READ INPUT PORT
        AND     80H
        PUSH    AF              ;SAVE REGISTER A
        CALL    DELAY           ;WAIT FOR 20MS
        POP     AF              ;RESTORE REGISTER A
        LD      B,A             ;SAVE IN REGISTER B
        IN      A,(F8H)         ;READ INPUT PORT
        AND     80H             ;MASK OFF UNWANTED BITS
        CP      B               ;CHECK TO SEE IF SAME AS BEFORE
        JR      NZ,PBIN2        ;  NO-GO BACK AND READ PORT AGAIN
        CP      A               ;SET FLAGS FOR REGISTER A AGAIN
        JP      Z,PBON          ;JUMP TO PBON IF BUTTON PRESSED
        JP      PBOFF           ;JUMP TO PBOFF IF NOT PRESSED

;  --ROUTINE TO SCAN AN 8 X 8 KEYPAD
;  OUTPUT FROM ROUTINE- REGISTER A FFH NO KEY PRESSED
;                                 OTHERWISE KEY CAP NUMBER
KEYPD:  LD      B,FEH           ;PRESET COLUMN SCAN REGISTER
        LD      C,FFH           ;KEY CAP COUNTER
KSCAN:  LD      A,B             ;OUTPUT COLUMN SCAN REGISTER
        OUT     (F9H),A
        IN      A,(F8)          ;INPUT DATA FROM THAT COLUMN
        CP      0FFH            ;COMPARE FOR KEY PRESSED
        JR      NZ,GETKEY       ;YES- GET KEY CAP NUMBER
        RLC     B               ;ROTATE COLUMN SCAN REGISTER LEFT
        JR      C,KSCAN         ;CARRY RESET IF ALL COLUMNS SCANNED
        RET                     ;RETURN TO CALLER REGISTER A CONTAINS FF

GETKEY: INC     C               ;INCREMENT COLUMN COUNTER
        RLC     B               ;ROTATE COLUMN SCAN REGISTER LEFT
        JR      C,GETKEY        ;LOOP UNTIL COLUMN NUMBER FOUND
        SLA     C               ;MULTIPLY C BY 8
        SLA     C
        SLA     C
GETROW: INC     C               ;INCREMENT KEY CAP COUNTER
        RLCA                    ;ROTATE ROW REGISTER LEFT
        JR      C,GETROW        ;CARRY RESET WHEN ROW NUMBER FOUND
        DEC     C               ;ADJUST KEY CAP COUNT TO 0-63 RANGE
        RET

;  -  ROUTINE TO INPUT FROM A POTENTIOMETER
RPOT:   LD      B,0             ;ZERO TIMER COUNT
        LD      A,00H           ;TRIGGER TIMER
        OUT     (F9H),A
        LD      A,80H
        OUT     (F9H),A
LOOP:   IN      A,(F8H)         ;READ TIMER STATUS
        AND     80H
        JR      Z,TIMOUT        ;TIME OUT IF INPUT ZERO
        INC     B               ;INCREMENT TIMER COUNT
        JR      NZ,LOOP
TIMOUT: RET                     ;RETURN TO CALLER B-CONTAINS DIGITAL
                                ;EQUIVALENT OF POTENTIOMETER POSITION
;  -  SUCCESSIVE APPROAXIMATION METHOD OF A-D CONVERSION
RADC:   LD      B,080H          ;TRIAL BIT REGISTER
        XOR     A               ;CLEAR A REGISTER
RADC1:  OR      B               ;SET TRIAL BIT IN A
        OUT     (F9H),A         ;OUTPUT ON DAC
        LD      C,A             ;SAVE DAC OUTPUT
        IN      A,(F8H)         ;TEST COMPARATOR INPUT
        AND     080H            ;MASK OFF OTHER BITS
        LD      A,C             ;RETURN DAC OUTPUT
        JR      NZ,RADC2        ;KEEP BIT ON IF INPUT G.T. REFERENCE
        XOR     B               ;TURN BIT OFF
RADC2:  RRC     B               ;SHIFT TRIAL BIT RIGHT
        JR      NC,RADC1        ;CARRY SET IF CALCULATION DONE
        RET                     ;RETURN TO CALLER- REG A-DIGITAL EQUIV.
```

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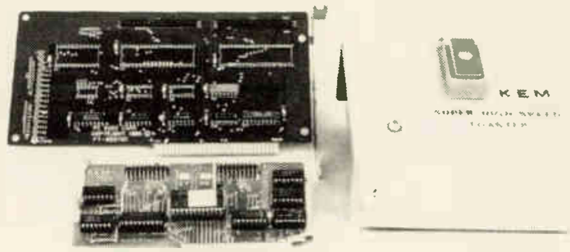

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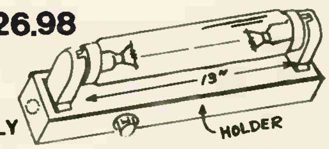

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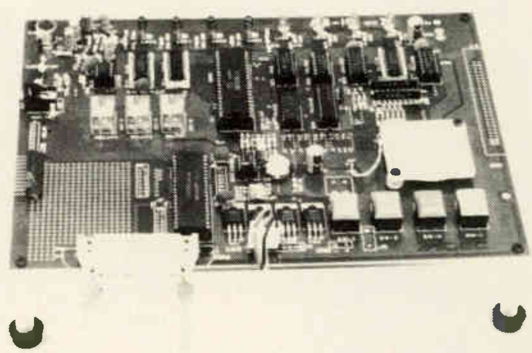

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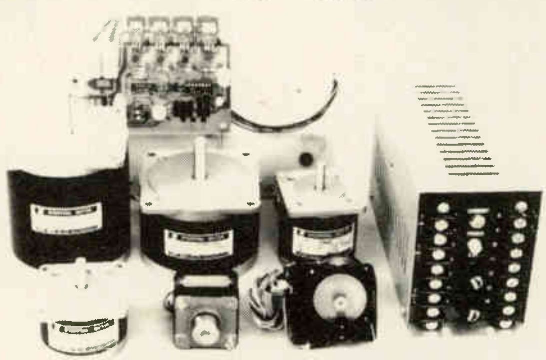

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Record Length	1K/CH	4K/1K Selectable	4K
Peak Detect	Yes (2 ns)	Yes (100 ns)	Yes (100 ns)
Signal Averaging	Yes	Yes	(repetitive sampling)
X-Y Storage Bandwidth	150 MHz	100 MHz	60 MHz
Pre/Post Triggering	Yes/Select	Yes/Select	Yes
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