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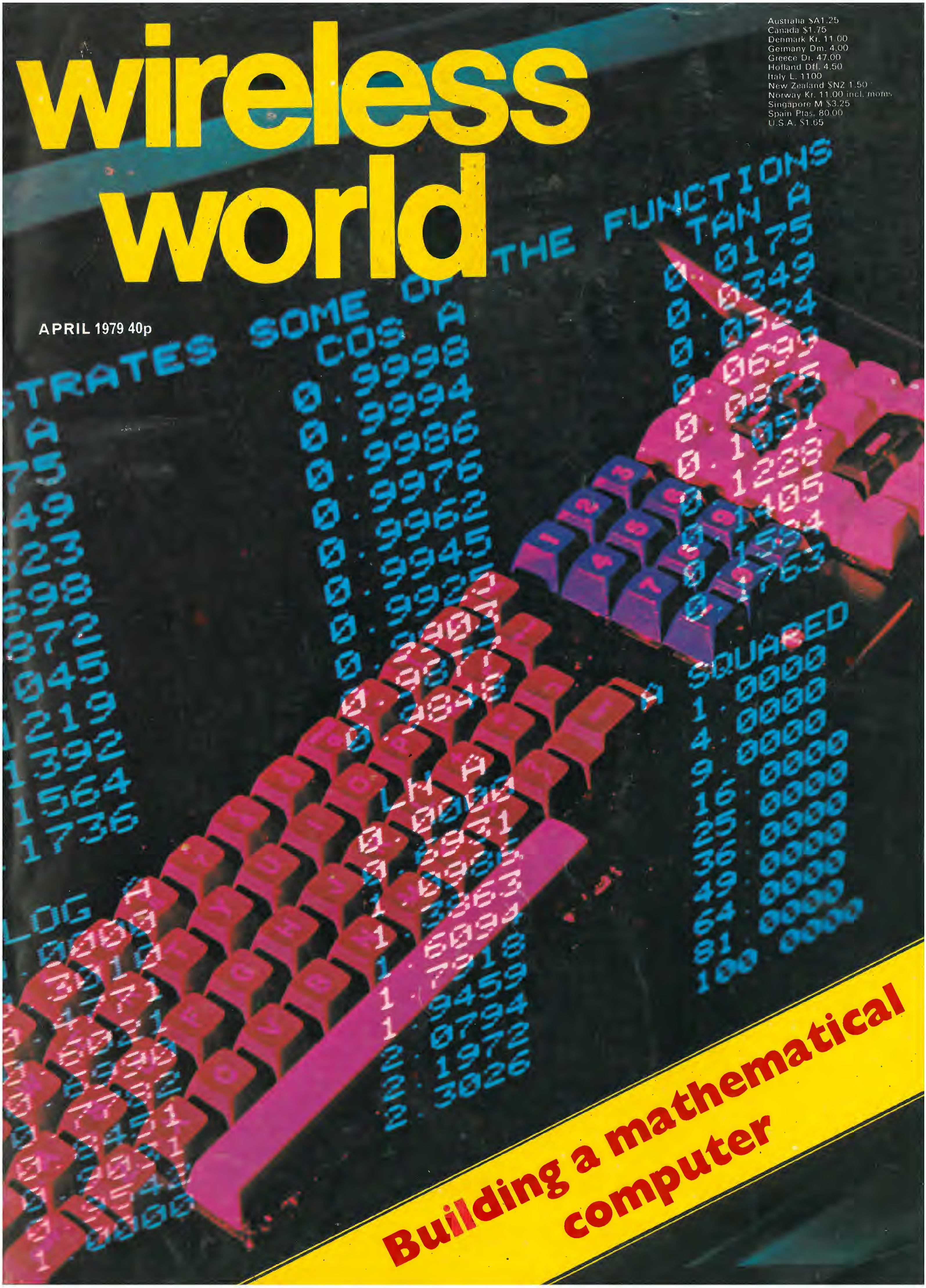

Building a mathematical computer

WIRELESS WORLD APRIL 1979 VOL 85 NO 1520

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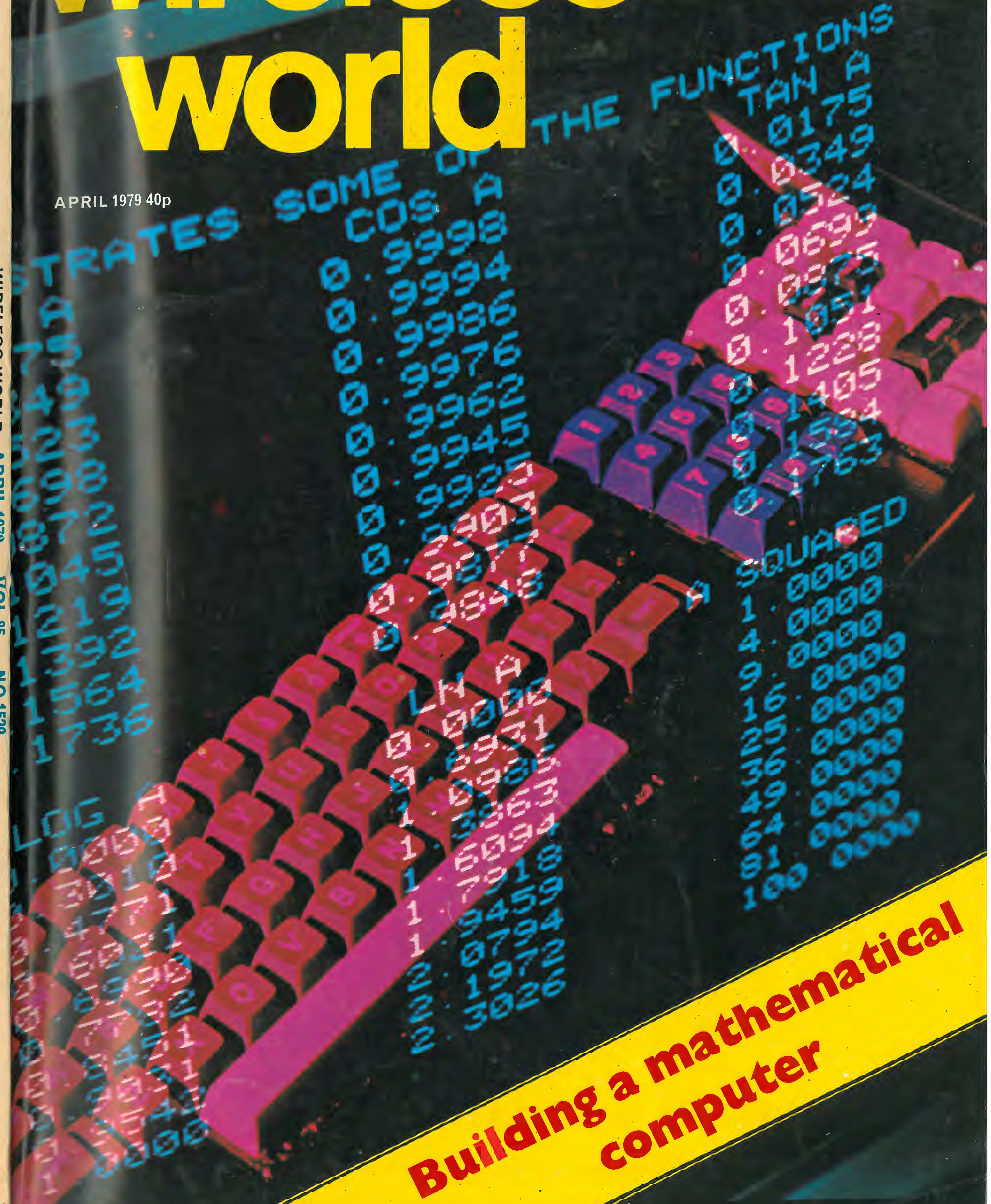
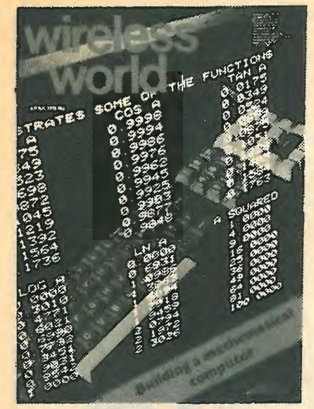


Building a mathematical computer



Front cover shows the prototype keyboard of the scientific computer together with a display of trigonometric values. Part 1 of the constructional design starts in this issue.

IN OUR NEXT ISSUE

***Converting between analogue and digital quantities — 1* is the first part of a series of articles on this topical subject, starting with a discussion of digital codes.**

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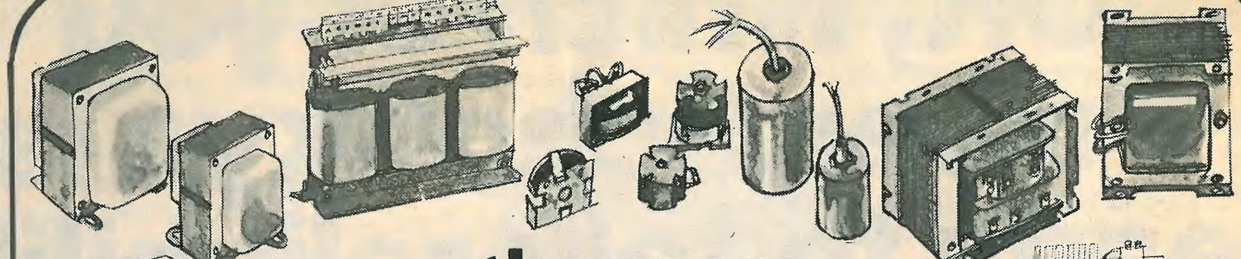
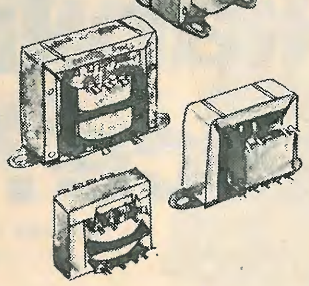
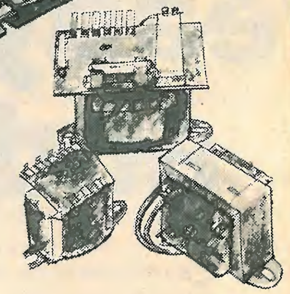
ELECTRONICS/TELEVISION/RADIO/AUDIO

APRIL 1979 Vol 85 No 1520

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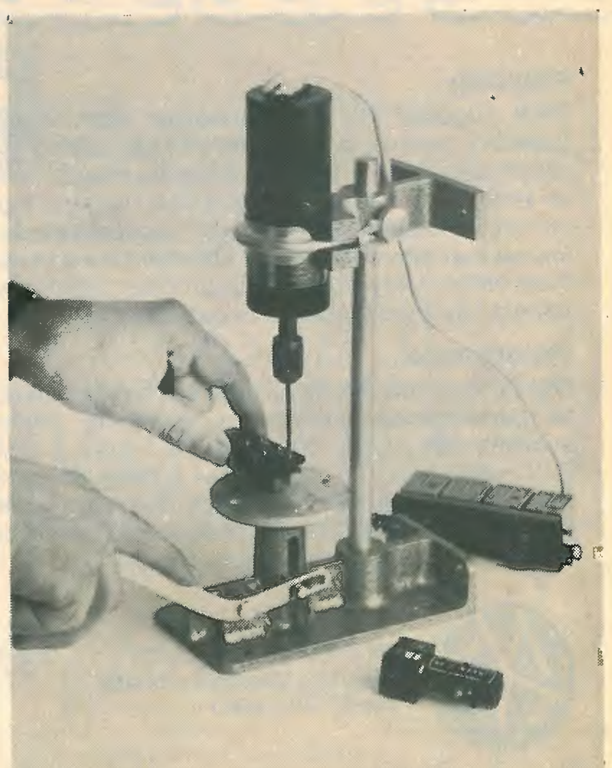

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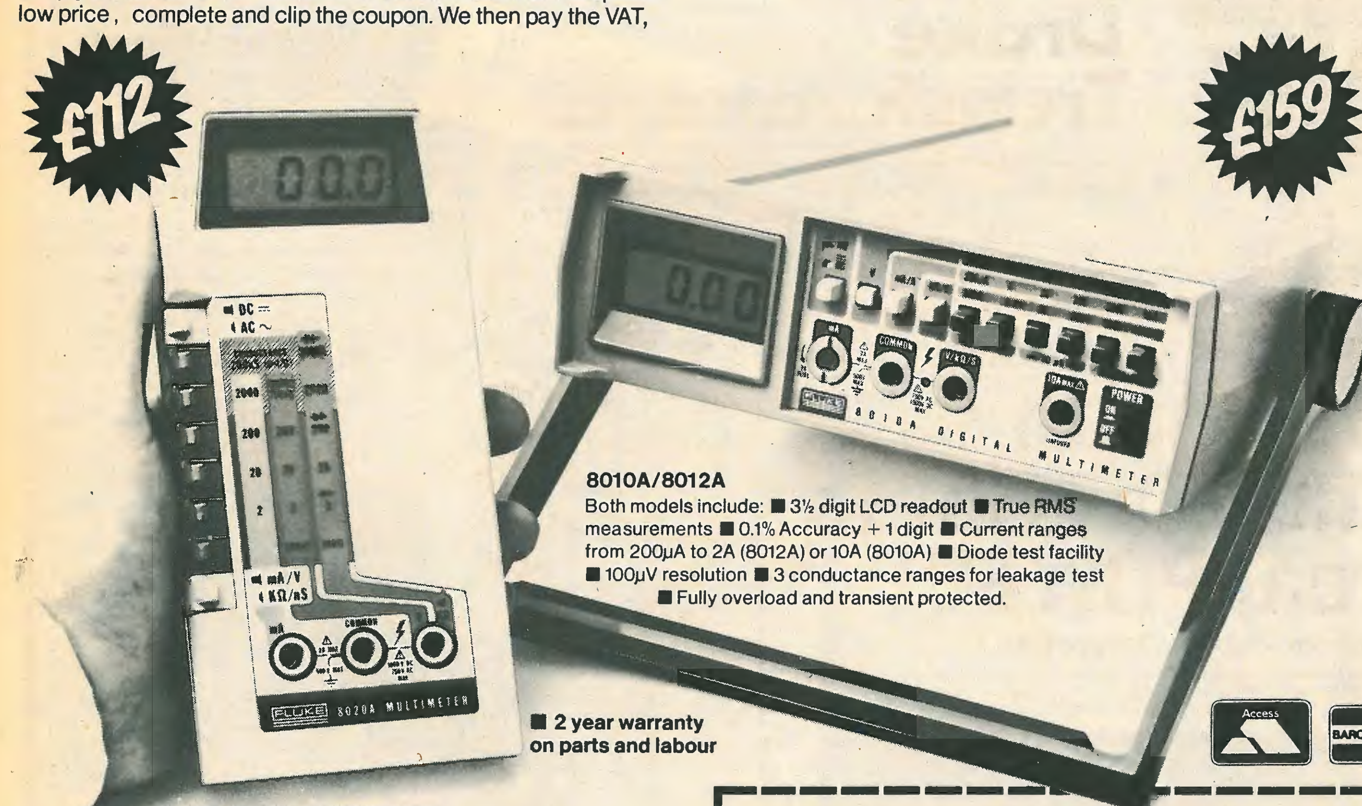

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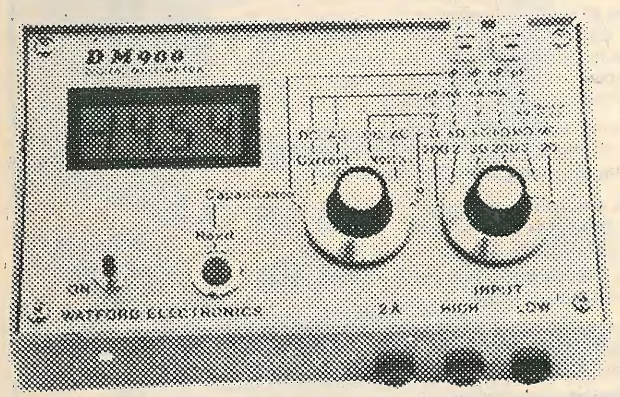
DM 900



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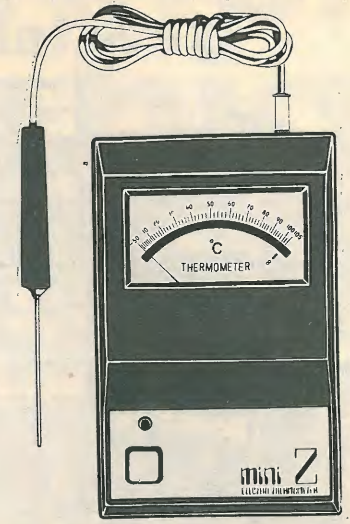

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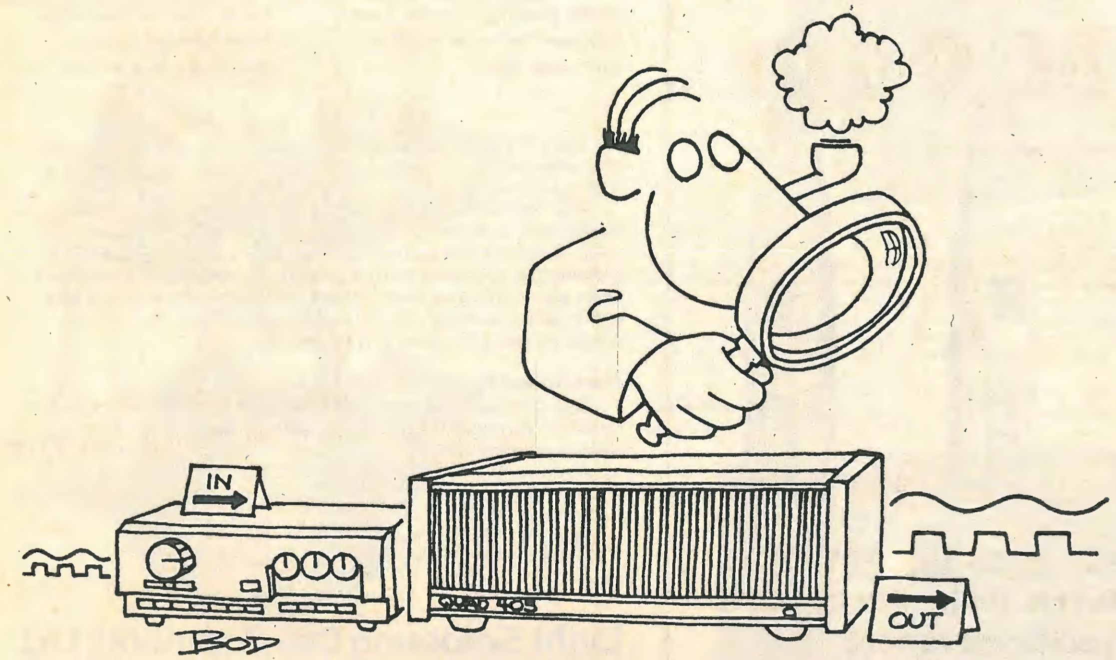

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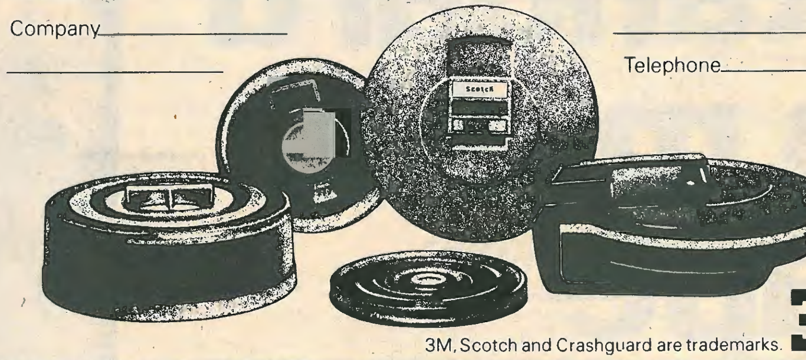

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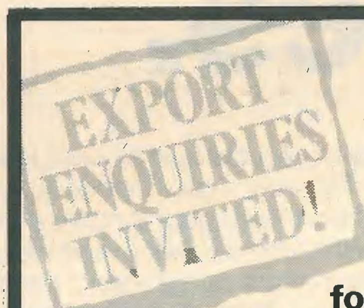

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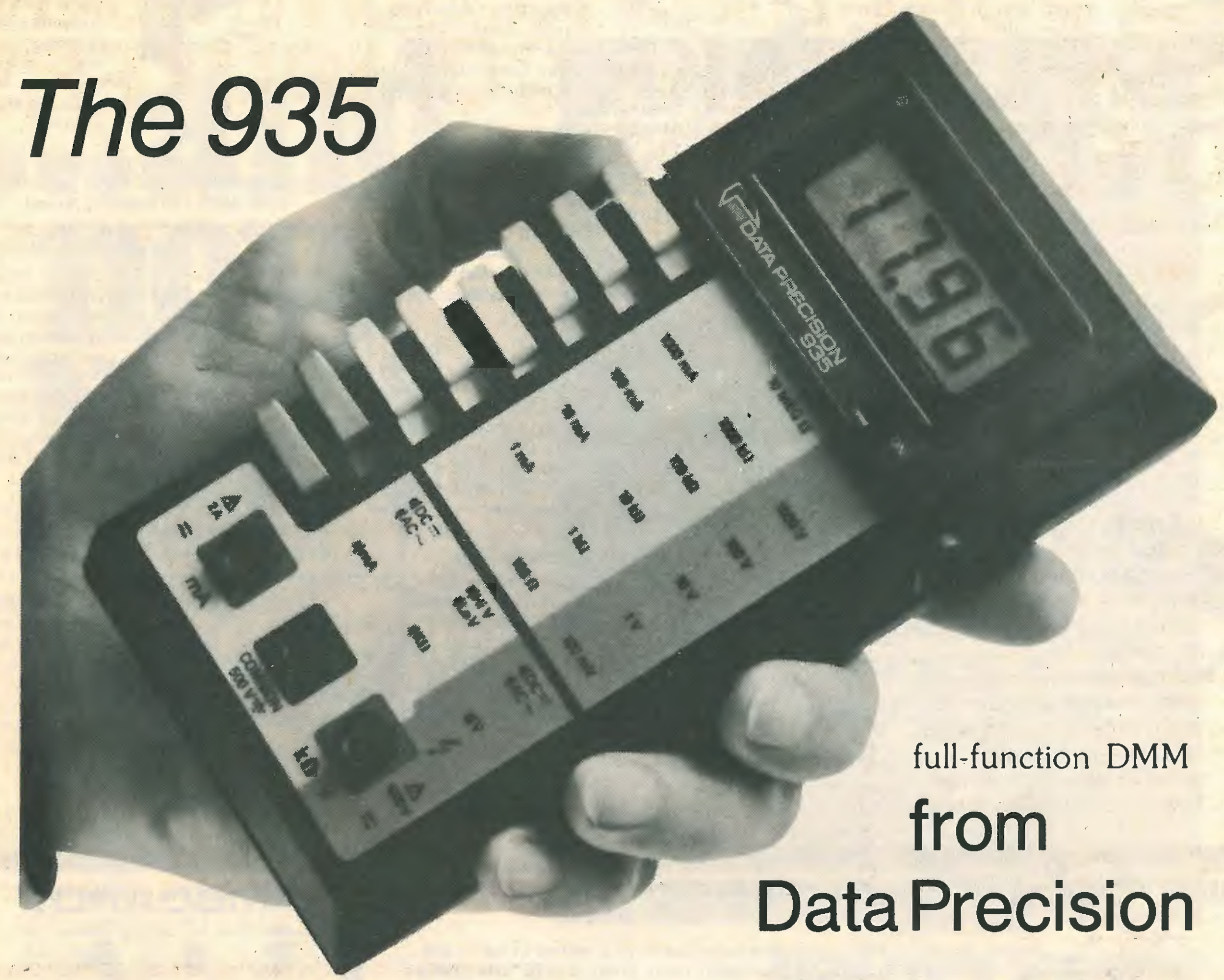

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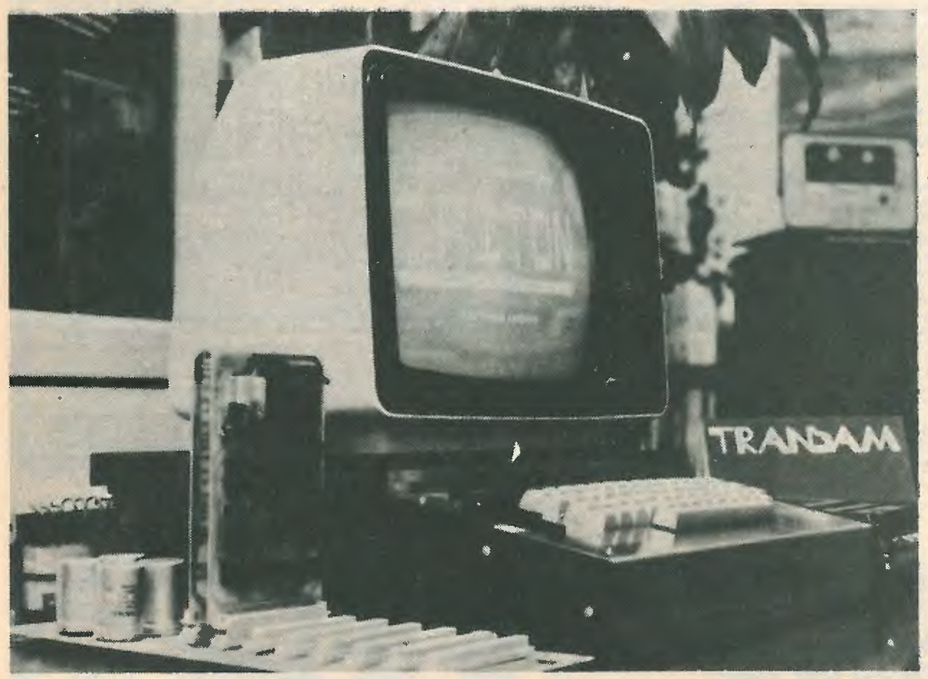

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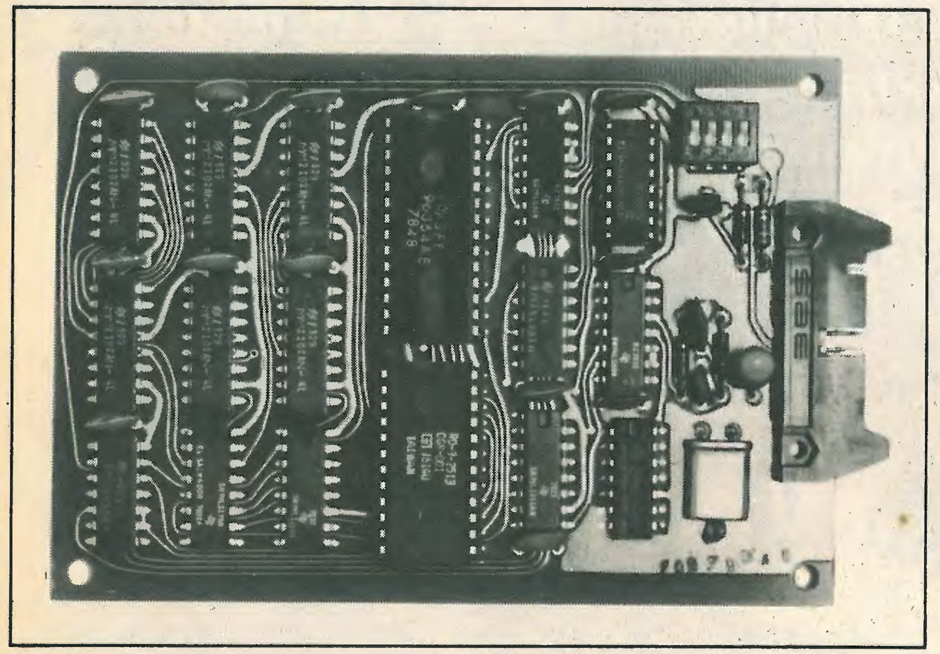

Complete board available ex-stock only £69 (+VAT)

In many applications a computer or a microprocessor transmits parallel data for display. The SF.KEX 68364 1-1 allows interface of a computer or a microprocessor with ASCII coded parallel output to a standard TV set (625 lines 50 Hz CCIR standard or 525 lines 60 Hz US standard).

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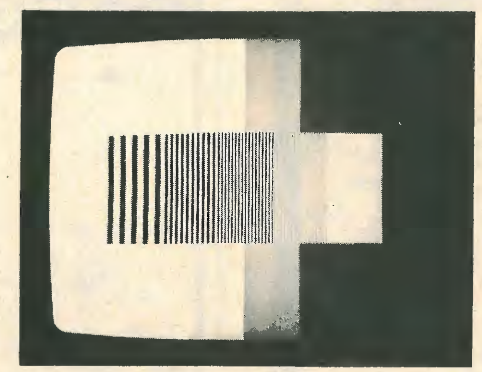

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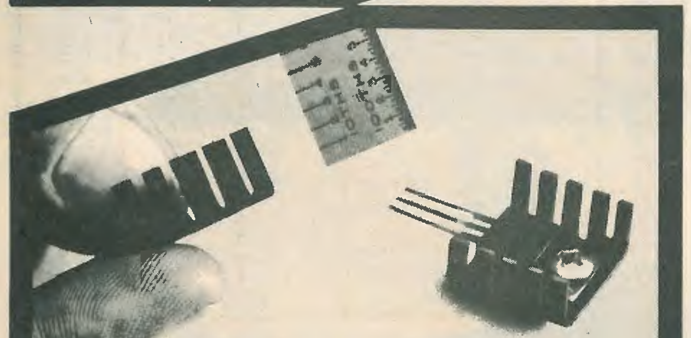

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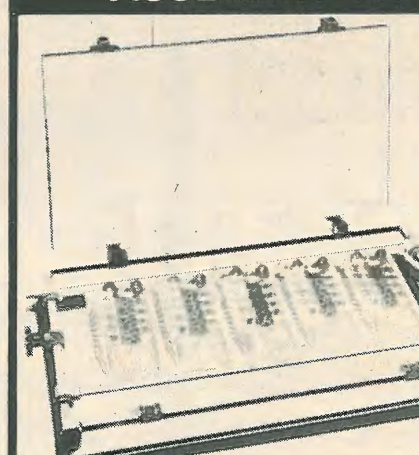

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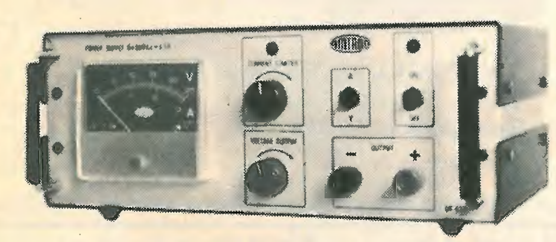

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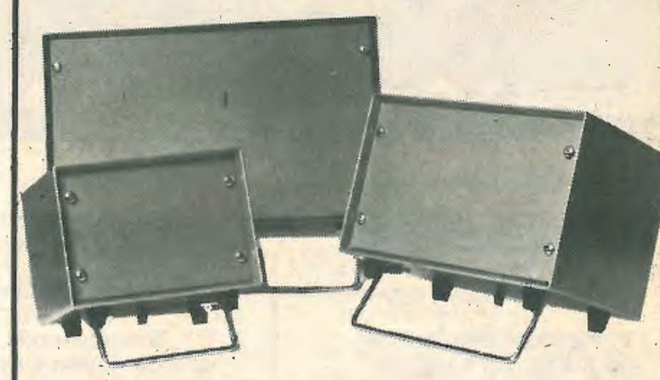

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22	8½"	5½"	5½"	—	6.50	1.15
23	10½"	6½"	6½"	—	7.70	1.30
24	12½"	7½"	7½"	—	8.45	1.30
25A	6½"	4½"	4½"	5.60	6.20	1.30
25B	6½"	4½"	6¼"	6.00	6.60	1.30
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26B	8¾"	5¾"	8¼"	8.25	8.85	1.30
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28A	14"	10½"	6½"	10.20	10.90	—
28B	14"	10½"	8½"	11.15	11.85	—
29A	10"	4"	6"	7.15	7.75	1.30
29B	10"	4"	8"	7.53	8.13	1.30
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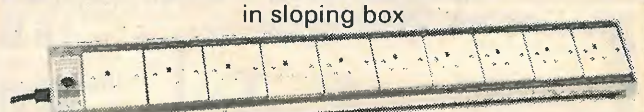

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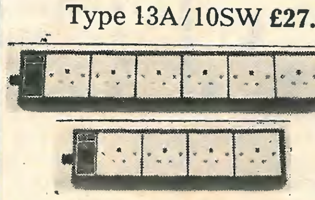

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Micro mania

The government's plans to encourage microelectronics, announced last year, are most welcome. Not only are they helping the development and manufacture of integrated semiconductor devices within the UK electronics industry to the tune of £70 million spread over five years; they are also encouraging the whole of British industry to apply microprocessors to plants in the UK to make them more efficient and to the design of new products to make them more competitive than earlier ones on world markets (initial support £15 million). In all this they are backed up enthusiastically by the semiconductor chip manufacturers and the organizers of private courses and conferences on microelectronics.

On the face of it this is all good news. The campaign does, however, carry with it all the dangers of over-selling that we saw in industrial electronics in the 1950s and in computers in the early 1960s. When some people discovered the limitations of what they had bought — maybe in performance, reliability or suitability to their needs — their disappointment led to an over-reaction against the new technology and the net effect was a setback for electronics and computers. A more considered approach by the campaigners would have had better results.

At the moment microelectronics is being presented as a brand-new technology which has suddenly arrived out of nowhere, when of course it is simply electronics in modern dress and qualitatively can do no more than the old-fashioned electronics with valves and discrete transistors could do, namely the transmission and processing of information. The microprocessor is being presented as a miraculous invention which by itself can transform British industry overnight if only people will use it. That it needs software which is becoming increasingly complicated and expensive to provide, that it will probably need storage, interfaces and other supporting electronics, and that the design problems and cost of the electrical or mechanical system within which it must function will probably exceed those of the electronics hardware many, many times, all these facts and other difficulties such as labour relations are not being given proper weight in the propaganda. From what he has gathered so far, a typical factory manager might well think he only has to send the works electrician on a fortnight's course to get boned up on these microelectronics gadgets for the firm to leap dramatically into the technological age in one bound and astonish its rivals with its efficiency.

As we know, higher productivity is brought about by technical changes in methods of manufacture, but these are taking place on a broad front and include a variety of things such as better organization of work and the use of new materials. Productivity is improved not only through the reduction of labour input for a given product output but also by increasing the utilisation of capital equipment and reducing the wastage of raw materials. A recent American study on the prospects for "intelligent electronics" in industry has shown that since about 95% of the time that material spends in a factory it is idle either in stores or in transit, much more can be gained by properly organizing the overall manufacturing process than by applying electronic automation systems to individual machines on which the material remains for only 5% of the time.

This is not to denigrate the benefits that electronics — sorry, microelectronics — can bring to industry. But it will be better served when it is clearly defined to the layman as essentially an information processing technique and firmly put in perspective along with developments in other engineering fields — electrical, mechanical, chemical, hydraulic and so on — which it complements but does not displace. In this way expectations will not be raised too high nor dashed to the ground too soon.

A scientific computer — 1

Powerful design uses two microprocessors and BURP, a new high level language

by J. H. Adams, M.Sc.

This series of articles describe a complete scientific computer which is based on two microprocessors. Unlike conventional mini and microcomputers which rely on large and expensive memories for complex subroutines, the present design uses a Z80 to handle the general processing and leaves the "number crunching" to a MM57109 microprocessor. This second device contains all of the algorithms necessary to execute standard mathematical functions. The basic design uses 8K of memory although this can be easily expanded to 32K.

The series will also describe tests and diagnoses, together with the computer's operation, both in machine code and the high level language BURP. Games, mathematical and financial programmes will also be given, and the series will conclude with several options including graphics and symbolic displays, graph plotting and an e.p.r.o.m. programmer.

A COMPUTER, to quote the dictionary, is an "apparatus for making calculations or controlling operations that are expressible in numerical or logical terms". With the advent of the microprocessor it has become possible to build low cost computers but, as industry has demanded, the majority of these devices are designed with the controlling-operations aspect of computing as their particular forte. Therefore, as numerical calculators, they are rather limited, and this has led to many disappointed owners of development kits who find their idea of microcomputers and that of the kit manufacturers are poles apart.

To meet the needs of such buyers, i.e. a system that can do sums and communicate in a language based upon English, various versions of the language BASIC (Beginner's All-purpose Symbolic Instruction Code, a programming language devised in 1964 by the Americans Kemeny and Kurtz) have been produced, ranging from Integer Basic, the mathematical applications of which are limited to computer games and the like, to quite complex versions which are able to handle floating point numbers and to perform several mathematical and trigonometrical operations on those numbers. These operating systems need computers with large memories, not for running large pro-

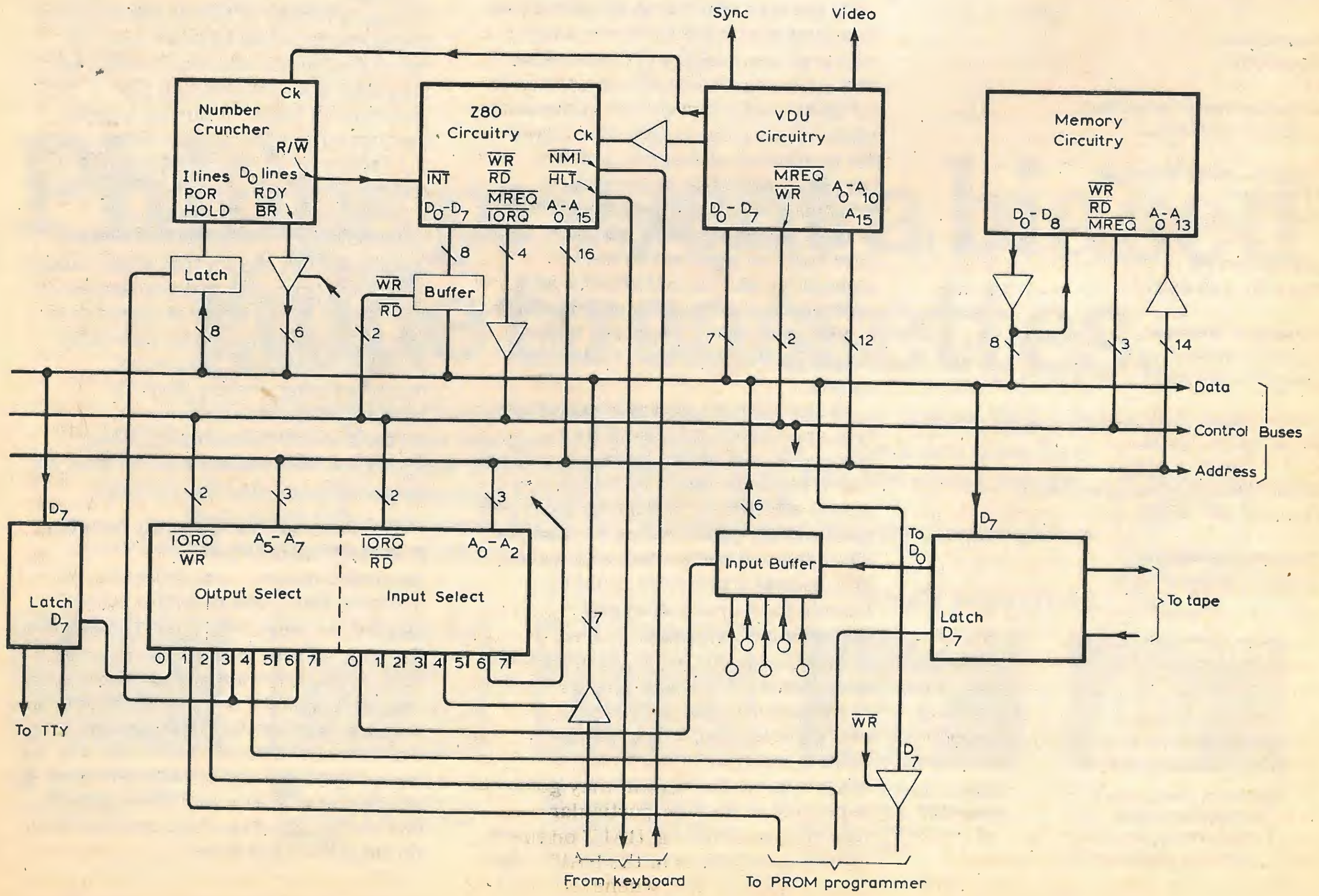

Fig. 1. Block diagram of computer. Control and data buses are buffered as they leave the Z80, while buffering for the address bus is in the memory circuitry. Five buffered serial inputs and one buffered output are available for external add-on circuitry, together with three output and five input select signals which may be used to latch data off or buffer it on to the data bus.

Specification

Commands available

LOAD	Loads program lines into memory.
ADD	Adds program lines to those already in memory.
DEL n	Deletes program line n.
RUN n	Runs from program line n.
MOD*	Converts Print statements to Write and vice-versa. (For use with second output device.)
LIST n	Lists from program line n.
DUMP n	Lists on second output device.

Statements available
Input, Print, Write, For, Next, Goto or Go, If, Then, Gosub, Return, Top Erase, Halt, Let.
Write is the print command for a second output device, such as a teleprinter.
Top clears the top line of the v.d.u. and sets this as the next printing position.
Erase is similar to Top, except that the whole screen is cleared.
Halt stops execution until any key, except FS or RS is depressed.

Mathematical capability
Calculates to 8 figures plus 2 exponent digits.

Functions
+, —, ÷, square, square root, log, 10^x. In (nat log), e^x, sin, cos, tan, $\sin^{-1}$, $\cos^{-1}$ $\tan^{-1}$, y^x, $1/x$, π, degree to radian conversion and vice-versa.

Variables	26, denoted by A to Z.
Range	10^{-99} to 9×10^{99}.
Program lines	Up to 254, or the limit of the read/write memory.

Print capability
Automatic switching to scientific mode on results greater than 10^9 or less than 10^{-4}.
Printed figures may be tabulated or close-packed, to any number of decimal places from 0 to 7.
Automatic rounding occurs on results abbreviated in this way.
Alphanumeric data may be interposed with printed variables.

Input/output
Input via ASCII encoded keyboard.
Output via v.d.u. of 32 lines, 64 char/line. Separate video and sync signals to 625 standard.
Optional output to teleprinter.
300 baud f.s.k. input/output, using tones of about 1200Hz and 2400Hz, for the storage and retrieval of data via a tape recorder.

grams, but for storing the mass of information required to instruct the logic oriented microprocessor on how to behave as a number oriented device.

The aim of this project was to produce a computer with extended mathematical capabilities and avoid the need for such heavy investments in memory i.cs. This has been achieved by using two processors, the Z80 standard microprocessor which takes the dominant role as the processor of data moving around the system, and the MM57109, a number-oriented processor which handles the calculations. The Z80 has been well covered in this and other journals, but the MM57109 may be less familiar. This device appears to be a not entirely successful transplant of a scientific calculator chip into the world of data buses and memories. It can perform most of the standard scientific calculator functions and, in common with many such devices, it uses a sequence for instructions known as Reverse Polish Notation. This system differs considerably from the standard algebraic notation, and is based upon the logical idea that the instructions to be performed or, in the case of a calculator, keys to be pressed, should be listed in the order which they are to be performed. For example, consider the calculation $c = \sqrt{(3^2+4^2)}$. The first operator following the equals sign is the last operation to be carried out and yet the last, brackets, is not the first. The actual order of execution is in fact quite complex, and the more complex the expression to be solved, the worse things become. The algebraic sequence would actually be 3, sq, move to memory, 4, sq, +, memory recall, =, root. In algebraic BASIC, the computer line would be, LET C = (3↑2 + 4↑2) 0.5 where ↑ means raised to the power of.

However, a simple RP calculator would execute the operations in the sequence which the operator would follow, ie, 3, sq, store, 4, sq, recall, +, root. In practice this is even simpler because calculators and the MM57109 have a stack of registers, each capable of holding a number. In the MM57109, this stack consists of four registers called X, Y, Z and T for top. Data enters and leaves via the X register, but may be pushed up into the stack either for temporary storage, or to take part in a two number operation involving the contents of the X and Y registers (e.g. YX which calculates the Y number to the Xth power). There are specific instructions which move or exchange the contents of the stack registers to facilitate calculations; however, the system ensures that in normal use of the language, numbers are pushed or entered into the stack as and when necessary. As RP is a step-by-step system, no brackets are required, and in the expression originally considered the RP BASIC version of the computer line would be

LET C = 3 SQ 4 SQ = ROOT

Some other examples of calculations and the stack operations are given in table 1. In my view, having used both types of notation, the Reverse Polish wins every time. For this reason a new language was formed for the computer Basic Using Reverse Polish or BURP.

Hardware

The block diagram of the computer in Fig. 1 follows standard microcomputer techniques, with an eight wire data bus, a sixteen wire address bus and a four wire control bus which interconnect the various elements of the computer. The majority of lines in this design are active low, ie, for an i.c. output, they go to the low state when the particular output label is occurring, e.g. HALT on the Z80 goes low when it is in the HALT condition, WR goes low whenever the Z80 wants to write some information into the memory. With an input, that input must go low for the input label to occur, e.g. $\overline{INT}$ needs to go low for the Z80 to be interrupted. An active low label is identified by a bar over it.

To describe the operation of the c.p.u. shown in Fig. 2, it will be helpful if some aspects of microprocessor operation are discussed. The Z80 can execute a repertoire of 158 groups of instructions, of which there are about 600 in total, and these instructions are read in through the data bus of the system as 8-bit words or bytes. The reading in, or writing out of bytes from or to memory locations or input/output devices is controlled by the four processor output lines RD, WR, MREQ, IORQ. For example, a low RD and a low MREQ output from the Z80 indicates that it wants to read in a byte from a memory location, whereas a low WR and IORQ means that it is writing a byte out along the data bus to an output device, such as a teleprinter. The address of the memory location, which is stored in a 16-bit register within the Z80, known as the program counter, or code number of the input/output device, is simultaneously sent out onto a second 16-line bus by the Z80. External circuitry selects which memory location or device is coupled to the data bus for that particular Z80 operation. When pin 26 RESET, of the Z80 is taken to 0V, the program counter is cleared, and when pin 26 returns to 5V, the Z80 begins by reading in the data byte in memory location 0, executing it as an instruction, increasing the program counter by one, and reading in the next byte from memory and so on. Thus, the memory will contain lists of instructions to be executed sequentially, interspersed with bytes of data which are required by some of them. The Z80 will then work its way through these lists or programs.

The instructions cover such operations as LOADS, which move bytes between registers within the Z80 or the memory. Logical and arithmetic functions, usually on the contents of the A register of the Z80. JUMPS, which, by feeding two new 8-bit bytes into the program counter register, cause the sequence of instruction execution to jump to a different point in the program. And CALLS, which are similar to jumps except that the old program counter contents are kept in a last-in first-out store in the read/write memory of the system, to be restored to the program counter on execution of the Z80 instruction RETURN. Calls are particularly useful whenever a certain block of instructions need to be used at several points in a program. If the instructions are written once in a program with a return instruction at the end, the block may be called at any point during the rest of the program. Such blocks are known as subroutines.

One feature of most microprocessors, including the Z80, is that CALL instructions may also be forced into the instruction sequence by activating either of the pins $\overline{\text{NMI}}$ or INT. The subroutines called by these interrupts are executed immediately after the instruction in progress, and, as with most CALLS, once the subroutine has been completed, instruction execution recommences at the point where the sequence was originally interrupted. These interrupts are generally used by other devices that want to communicate with the Z80 and, in this case, the $\overline{\text{NMI}}$ interrupt is initiated by the strobe pulse from the keyboard and hence by the depression of any key. The keyboard subroutine reads in and acts upon the keyboard data before returning control to the main program as shown in Fig. 3. This is just one method of using the keyboard and another common approach is the polling system where, as part of the main program, the Z80 reads in the strobe pulse as part of a byte, then tests to see if the strobe is active and jumps back to the read operation if it is not. When it is active, the Z80 reads in the keyboard data byte. This method requires six bytes of instructions and memory locations, or at least a three byte CALL instruction to a read-the-keyboard subroutine whenever a byte of keyboard data is required.

In contrast, an interrupt driven system only requires the one-byte HALT instruction to be executed whenever a byte of keyboard data is needed. The only method for the processor to get out of the HALT state, once the instruction has been executed, is by operation of the reset button or by an interrupt, the Z80 waits for the interrupt which directs it into the subroutine for the keyboard. The interrupt system which was chosen, saves on memory space and the subroutine contains an extra section which will reset the entire system if the processor is not in the HALT state. If it is necessary to interrupt, for example, a program under development which has a fault, this can be achieved by pressing any key. The HALT command is also available in the high level language where it will also stop program execution until a key is pressed.

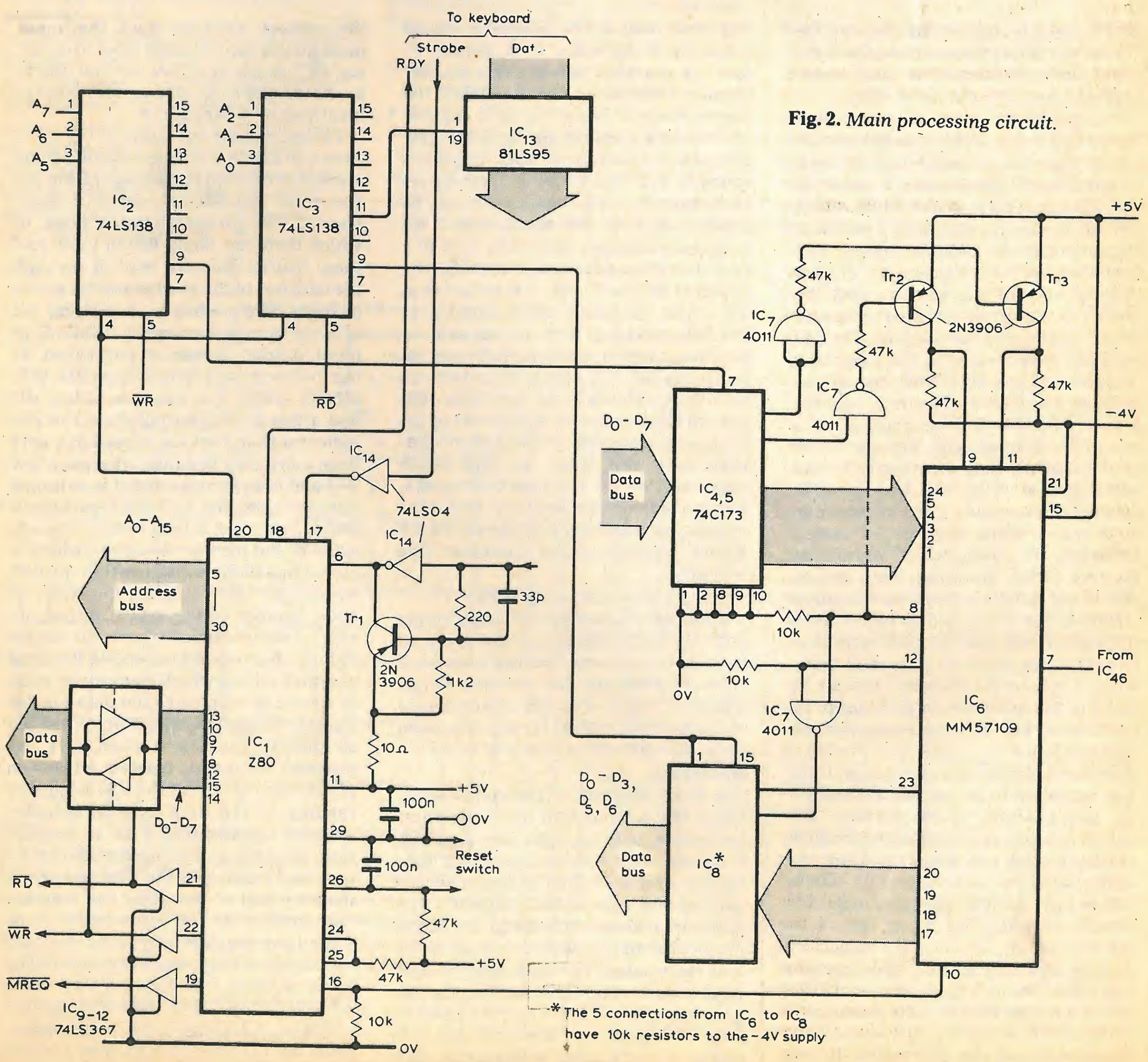

Fig. 2. *Main processing circuit.*

The NMI input (non-maskable interrupt) operates under all conditions and just calls to a fixed address in the memory. The other interrupt input, INT, can be enabled or disabled by instructions within the program being executed. This particular interrupt line comes from the MM57109 R/$\overline{\text{W}}$ output and indicates that the 57109 wants to send b.c.d. data to the Z80. This output can do some peculiar things during the initial reset of the processor; therefore, during this period, it is essential that the INT input is disabled. This is automatically done by the Z80 whenever it receives the reset signal. The interrupt can be programmed to respond in one of three ways, but in this system its response is similar to that of the NMI input, i.e., a CALL to a particular memory address.

Operation of the MM57109 is most easily understood by reference to the simplified diagram in Fig. 4. The device has open drain outputs which require external pull-down resistors, and some non-t.t.l. compatible inputs, but these have been left out of the diagram. The 57109 has a 6-bit input word into which 70 instructions, mostly of single bytes, have been encoded. The two relevant control lines are the RDY output and the HOLD input. RDY indicates that the device is ready to receive an instruction. If the HOLD input is low, RDY will go low after 16 μs, and the current instruction on the input lines will be executed. If the HOLD is high, RDY remains high and the operation of the 57109 is suspended until HOLD goes low. In this system, RDY is sensed, and HOLD is controlled by the Z80. The HOLD input is normally high, and the typical sequence used by the Z80 when it wants the 57109 to execute an instruction is shown in Fig. 5.

Although this sequence is adequate for the execution of most instructions, the 57109 has been designed to operate as a separate microprocessor and will therefore sometimes produce RDY pulses during the execution of certain instructions. These pulses are intended to cue memory counters etc. As the HOLD is on during the execution of instructions, these RDY pulses must be supressed otherwise the Z80 may think that it's time for another instruction to be sent to the 57109 latch. Fortunately, in such cases the output ISEL at pin 12 goes low, and this is used to gate the RDY signal to, and the HOLD signals from, the Z80 via IC_7.

The data read in by the Z80 via the tri-state buffer, IC_8, consists of the modified RDY signal together with the four DO (digit output) lines which carry the b.c.d. data from the 57109 X register, and the BR line on pin 23. This line pulses low whenever one of the seven tests that the 57109 can perform proves to be true. Pin 10, R/$\overline{\text{W}}$, goes low whenever b.c.d. data bytes are waiting to be read in by the Z80. During the execution of an OUT instruction, twelve such pulses occur which signal the two

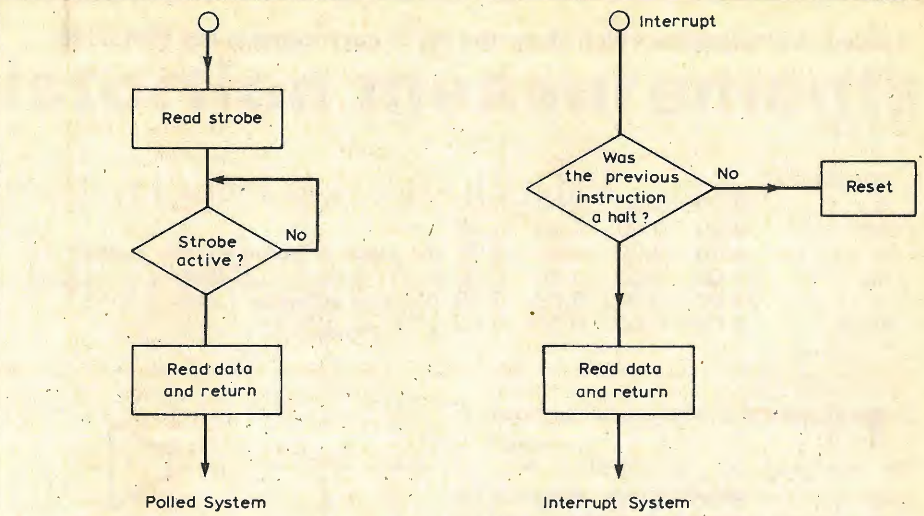

Fig. 3. *Polled and interrupt keyboard systems.*

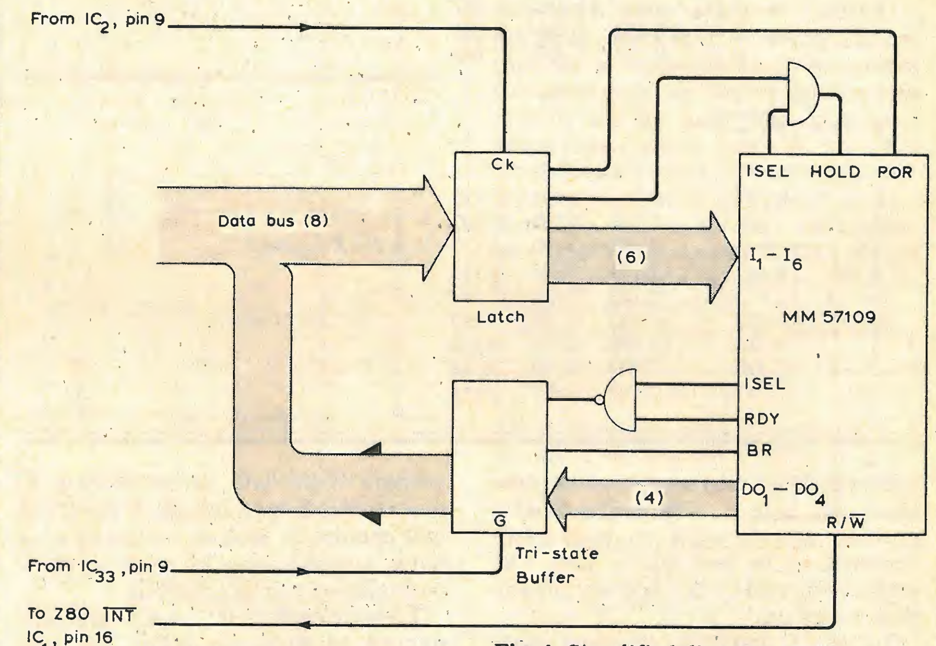

Fig. 4. *Simplified diagram of the MM57109 logic. The microprocessor also has open drain outputs which require external pull-down resistors.*

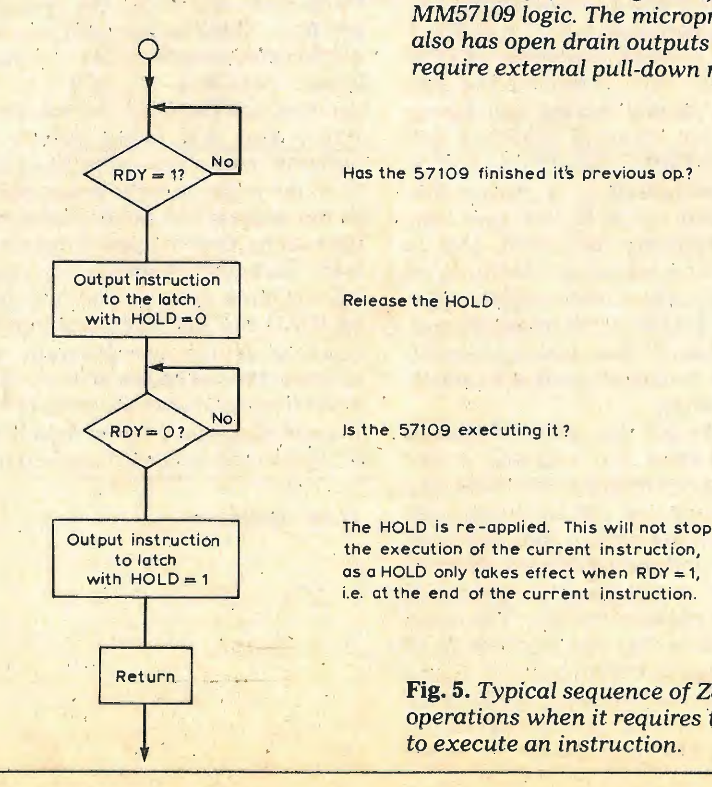

Fig. 5. *Typical sequence of Z80 operations when it requires the 57109 to execute an instruction.*

Table 1. Calculations which show the stack operations in the MM57109.

$\sqrt{3^2+4^2}$

COMMAND	X	Y	Z	T	
3	3.00	0.00	0.00	0.00	
SQ	9.00	0.00	0.00	0.00	
4	4.00	9.00	0.00	0.00	the stack is automatically pushed, i.e.
SQ	16.00	9.00	0.00	0.00	X→Y, Y→Z, Z→T, T lost
+	25.00	0.00	0.00	0.00	the stack collapses, i.e. 0→T, T→Z
ROOT	5.00	0.00	0.00	0.00	Z→Y, result in X.

$\frac{(6+9)}{(4-1)}$

6	6.00	0.00	0.00	0.00
9	9.00	6.00	0.00	0.00
+	15.00	0.00	0.00	0.00
4	4.00	15.00	0.00	0.00
1	1.00	4.00	15.00	0.00
—	3.00	15.00	0.00	0.00
/	5.00	0.00	0.00	0.00

$\sin(1+\sqrt{(5^3-4)})$

5	5.00	0.00	0.00	0.00	
3	3.00	5.00	0.00	0.00	
YX	125.00	0.00	0.00	0.00	Y to the Xth power
4	4.00	125.0	0.00	0.00	
—	121.00	0.00	0.00	0.00	
ROOT	11.00	0.00	0.00	0.00	
1	1.00	11.00	0.00	0.00	
+	12.00	0.00	0.00	0.00	
SIN	0.2079116	0.00	0.00	0.00	

exponent digits, a byte representing the signs, one byte for the decimal point position, and the eight mantissa digits' readiness to be sent to the Z80. The interrupt caused by this line has already been described.

The HOLD and POR (power on reset) lines on pins 9 and 11 respectively, are not t.t.l. compatible and Tr_2, Tr_3 in Fig. 2 act as level shifters. Operation of POR occurs under the control of the Z80 whenever a reset is applied, and during the operation internal registers are cleared and various conditions within the 57109 initialised. It is during this operation that the R/$\overline{W}$ line goes low, but, as previously described, this is prevented from causing interrupts to the Z80. For further information on the MM57109, National Semiconductor produce a data booklet which gives full operational details of each instruction and pin function.

The clocks for the microprocessors are derived from IC_{30} and IC_{46} in the visual display circuitry. To meet the specified swing and rise times required by the Z80, a rise time of 30ns to a level of 4.4V, Tr_1 and the associated circuitry form an active pull-up on the output of the Schottky inverter in IC_{14}. The clock for the 57109 is obtained from pin 12 of IC_{46}. With the link from pin 1 of IC_{46} to pin 12 of IC_{29}, the frequency of this clock is 400kHz, which is the maximum specified in the data sheet. The other position of the link, to pin 14 of IC_{29}, doubles this frequency and, if the 57109 will operate at 800kHz as tested ones have, a worthwhile increase in computing speed can be achieved.

Tri-state buffers IC_9 to IC_{12} are connected to form an eight-line bus transceiver, and buffer the system control lines. These buffers also provide the extra drive required for the heavily loaded data bus. IC_2 is a 3 to 8-line decoder, activated by the control lines IORQ and $\overline{WR}$. This allows eight different output devices to be addressed from the codes that the lower eight bits of the address bus holds during output operations. One of these output devices is the latch $IC_{4,5}$. A similar job is done by IC_3 for input devices, and it is enabled by IORQ and $\overline{RD}$. The three input lines to these devices are different, which spreads the load on the address bus. The input devices shown are tristate buffers IC_8 and IC_{13}, which buffer data from the 57109 and the keyboard respectively. □

To be continued

Literature Received

Digital optical **tachometer** is described by Compact Instruments Ltd in colour leaflet, available from Binary House, Park Road, Barnet, Herts EN5 5SA.
WW 401

Camera tubes. Plumbicon and Newvicon from Mullard are on colourful, but not very informative, wall-chart which can be obtained from Department C1H, Mullard Ltd, Mullard House, Torrington Place, London WC1E 8HD.
WW 402

A range of alphanumeric **printers** is subject of brochure recently sent to us by Syntest, 169 Millham Street, Marlborough, Mass. 01752, U.S.A.
WW 403

General and specific information on **stepping motors** is given by Moore Reed in their 50-page catalogue, which can be had from Moore Reed and Company Ltd, Walworth, Andover, Hants SP10 5AB.
WW 404

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WW 406

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Health and safety recommendations for Bakelite materials in two publications: TIS B212 for impregnated materials; TIS B211 for industrial laminates. Copies from Bakelite UK Ltd, Sales Office, Tuition House, St. George's Road, Wimbledon, London SW19 4DS.
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WW 411

Simplified distortion measurements

Method using audio amplifier under test as a low distortion oscillator

by F. Butler, O.B.E., B.Sc., F.I.E.E., F.I.E.R.E.

The need for an external signal source is avoided by using the amplifier under test as a low distortion oscillator, coupling the output back to the input through a limiter and LC frequency selective network. The author concludes with a review of three common methods of measurement and discusses possible sources of error which become important at distortion levels of about −80dB.

TO MAKE accurate measurements of the distortion products of an audio-frequency power amplifier calls for a test signal source in which the total harmonic distortion is about an order of magnitude lower than that of the equipment under test.

In *Wireless World* for February 1975, Letters, p. 68, T. Magchielse described one way of achieving this performance and gave a condensed account of a highly accurate but rather expensive technique for distortion measurement. His work inspired the present contribution which in essence describes a method of converting the amplifier under test into a low-distortion oscillator by coupling the output back to the input through an amplitude-limiter and a frequency-selective network, thus avoiding the necessity for an external signal source. The rest of the article is taken up with a critical review of three common methods of distortion measurement, together with some discussion of possible sources of error which become important at distortion levels around -80 dB.

This amplifier-feedback technique is of course widely used in the design of many types of audio signal generators of which a common example is the Wien bridge or parallel-T circuit. Frequency-setting is by RC networks and amplitude-limiting by thermistors or filament lamps.

At first glance the Wien network seems ideal for the purpose. It is easily tunable over a wide band; it is of high impedance, causing little loading of the maintaining amplifier and simple range-switching permits coverage from sub-audio to video frequencies.

Closer examination of the properties of the network shows it to be far from ideal. The theory given in the appendix brings out its major defects. First, its selectivity is poor since its effective Q-factor is only ⅓ as against figures between 10 and several hundreds for LC circuits.

At 1kHz centre frequency the 3dB points lie at about 300Hz and 3.3kHz. Along with this the phase changes only slowly with frequency, reaching ± 45 degrees at the 3dB points. One consequence is that a small change in amplifier phase shift, however caused, calls for a relatively large frequency change to maintain the overall loop gain at unity and the total phase shift zero. There is one saving grace in that such oscillators are easily locked to an external source. Against this the frequency stability is poor in the face of variable loading of the output or in the event of supply voltage changes. Buffer amplifiers are essential.

Worse is to come. The maintaining

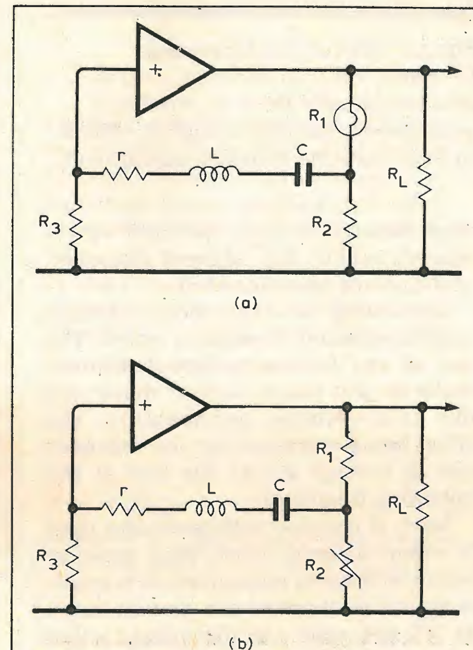
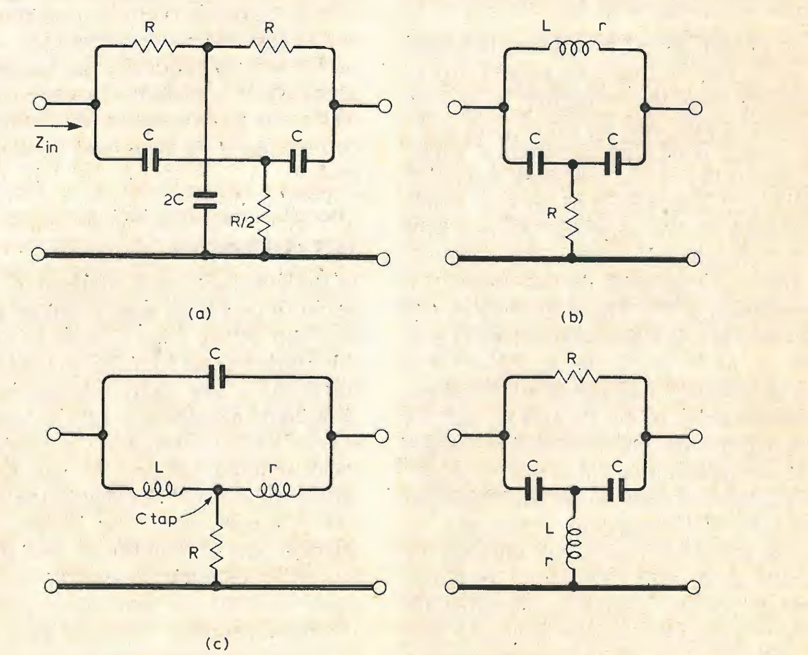


Fig. 1. *Series-tuned LC oscillators: (a) lamp control; (b) thermistor control.*



Parameter at Null	(a)	(b)	(c)	(d)
ω	1/RC	$\sqrt{2/LC}$	$\sqrt{1/LC}$	$\sqrt{1/2LC}$
Z_{in}	R(1 − j)/2	2R	2R	R/2
Q − Factor	1/4	2R/ωL or ωCR	R/ωL or ωCR	2ωL/R or 1/ωCR

Fig. 2. *Typical notch networks: (a) parallel-T; (b) bridged-T; (c) bridged-T with centre-tapped coil; (d) bridged-T with shunt coil.* ▼

amplifier, of gain × 3, must necessarily generate some harmonic output. This is transferred to the input through the feedback network where it is once more amplified by this same factor 3. As already stated the network loss is ⅓ at the centre frequency. At the second harmonic it has only dropped to 0.298 with a lagging phase angle of 26.57 degrees. At the third harmonic the corresponding figures are 0.249 and 41.63 degrees. In these respects the parallel-T network is even worse since its Q-factor is only ¼.

Clearly some better arrangement is required, and the solution is to use LC circuits in the feedback path. At audio frequencies such circuits are not conveniently tunable over wide ranges but several spot frequencies can easily be selected by switched L or C. Plots of distortion versus frequency or output power represent smooth monotonic functions so that checks at a few well-chosen frequencies reveal most of what one needs to know about the amplifier under test.

LC feedback oscillators

Most audio amplifiers give an output which is in phase with the input and the overall voltage gain commonly lies between × 10 and × 100. With amplifiers of more than 2W output an ideal feedback network is a series-tuned LC circuit with amplitude control by means of a filament lamp, which is cheap, effective and virtually noise-free. Below this power level, thermistor control may be preferred. The principles are shown in Figs. 1 (a) and 1 (b). At still lower output powers, field effect transistors can be used as voltage-controlled resistors.

The design of LC oscillators is based on the following considerations, assuming that the amplifier is of low impedance and that its input gain control, if any, is of high impedance. First, the selectivity of the feedback network is determined by the Q of the coil when embedded in the network. At one end the LC circuit sees a resistance equal to R_1 and R_2 in parallel. At the other, the termination is R_3. The actual Q of the coil alone is $\omega L/r$ but its effective Q is in fact $\omega L/(r + R_3 + R_1 R_2/(R_1 + R_2))$. High selectivity thus calls for the lowest possible values of R_1, R_2 and R_3 but, as shown in the appendix, these low values increase the attenuation of the network. It is preferable, then, to set the amplifier gain near its maximum value and to choose resistors just large enough to sustain oscillation. To avoid possible damage to the amplifier, reasonable resistor values should be selected and the input gain control slowly increased from zero until oscillation starts and then remains sinusoidal. Low resistor values result in the maximum possible attenuation of harmonics through the network. This attenuation can easily be made to exceed 40dB but, as will appear in later practical circuits, quite

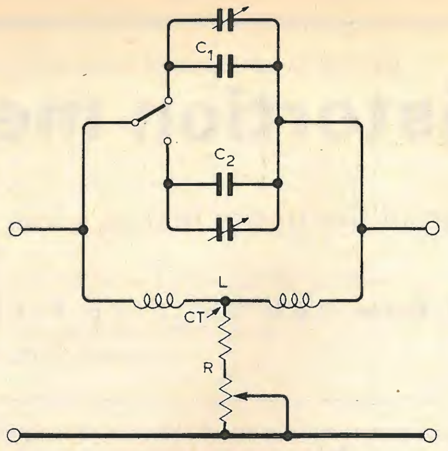


Fig. 3. *Practical notch network: L = 50mH total (air cored); C_1 = 0.5μF plus trimmer for 1kHz; C_2 = 0.005μF plus trimmer for 10kHz; and R = 1200Ω to 25kΩ, variable with fine adjustment.*

large departures from optimum values scarcely add to the inherent distortion of the power amplifier itself.

Continuing with the choice of components, the coil must be air-cored. The use of any ferrite or ferromagnetic material will cause serious distortion due to non-linear permeability, the effect being worsened by the resonant rise of voltage across the coil at the operating frequency.

Next, if rectifier voltmeters are used to monitor signal levels, they must be removed before a measurement is made. A typical multimeter can give as much as 0.5 per cent t.h. distortion when connected across a 600-ohm line.

Ideally the coil should be screened to avoid pick-up from power lines or power supplies but unless it is placed in a large high-conductivity non-magnetic shield the effective inductance and Q-factor will be reduced, the latter quite seriously. It is probably better to place it well away from sources of interference, connecting it up by a long twisted-pair lead.

Test procedures

In the standard t.h.d. method, a notch-network or a high-pass filter, or a combination of the two, is used to supress the fundamental frequency. Ideally, the harmonics are then measured by a wide-band amplifier of known gain and a true r.m.s. voltmeter. In practice, a mean-reading instrument can be used with little error if the distortion is very low. Though useful for testing a production run of amplifiers, the method has obvious limitations. To measure down to 0.001 per cent distortion on a 1V signal requires 100dB of gain to get 1V output of harmonic. Noise is a problem and the method gives no clue to the composition of the harmonic spectrum. Because they combine on an r.m.s. basis the voltmeter reading is almost unaffected by low-level products.

The most commonly used notch network is the RC parallel-T which is a 3-terminal form of the Wien bridge. In its passive form it suffers from all the disadvantages of the regular bridge. Instead of a very narrow notch in an otherwise flat pass-band, the second harmonic is down about 9dB below the zero-loss datum. The third is attenuated by about 5dB. The results, displayed on an oscilloscope or measured by voltmeter, are meaningless. The transmission of an active notch circuit can be made much nearer the ideal but, by definition, this uses an amplifier of which the distortion must be much lower than that being measured, a state of affairs quite difficult to reach because the amplifier operates under rather exacting conditions.

Passive bridged-T LC circuits as shown in Figs. 2 (b), (c) and (d) are much to be preferred, provided one is satisfied to work at a few spot frequencies. As before, air-cored coils must be used. Fortunately the Q is not very critical. Even if it is as low as 3, Terman, (Radio Engineers' Handbook), states that the second harmonic is attenuated by only 0.5dB, though calculations give a figure nearer 0.8dB.

A few of the more important properties of the various networks are also listed in Fig. 2. In some cases, close approximations to the true values are given since the exact mathematical expressions are so cumbersome. The worst errors are of the order of 1 per cent. The choice of a preferred network will be considered later.

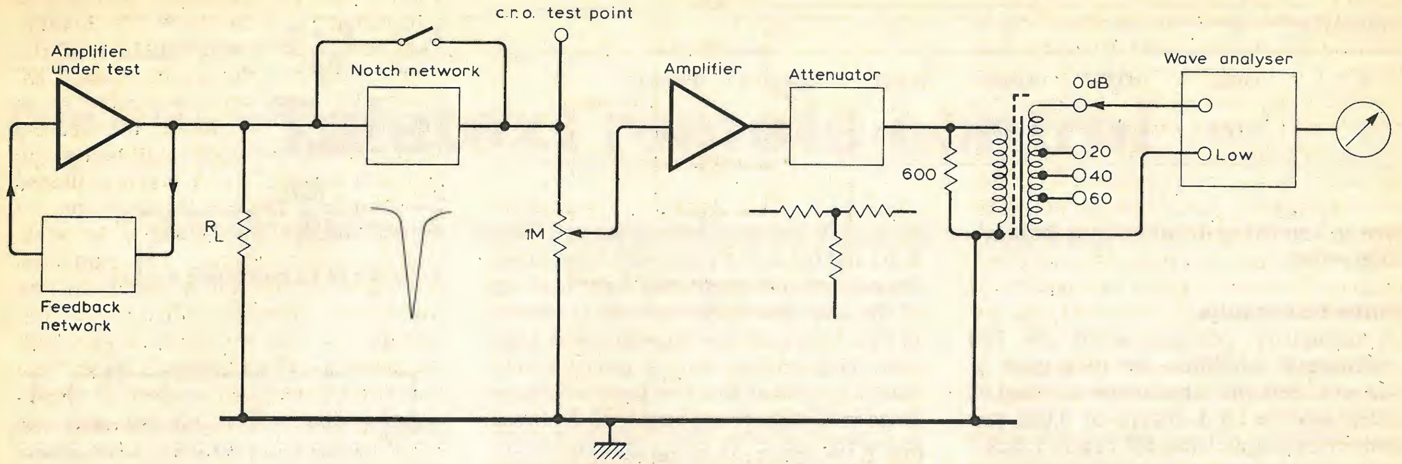
Wave analyser methods

Wave analysers are calibrated selective voltmeters, usually working on the superheterodyne principle. In use they are tuned successively to the fundamental and to each harmonic of the distorted input signal. Internal or external attenuators are adjusted to give a standard reading on the output voltmeter. Distortion figures are then derived directly in terms of the relative settings of the attenuators. Some possible sources of error are:

(i) Non-linearity of the input amplifier.
(ii) Intermodulation and spurious signal generation in amplifiers, filters or mixers.
(iii) Inadequate adjacent-channel selectivity.
(iv) Ground loop effects at high attenuator settings.

Such sources of error become important when measuring distortion levels around 0.001 per cent. The t.h.d. of the input amplifier is seldom better than −85dB referred to the fundamental. This is clearly not good enough when attempting to measure levels at 100dB down. Spurious signals of various sorts may appear at levels between −70 and −90 dB, also causing problems. Adjacent channel responses may be as low as −90dB: still not good enough for ultra-low distortion measurement.

All these difficulties may be circum-



vented by placing a notch network ahead of the analyser and by using an isolated transformer or transformer attenuator after the notch circuit to break any possible ground loops.

In measurements to be quoted later, screened transformers have been used as fixed attenuators at 0, 20, 40 and 60 dB loss, their performance being checked against a 600-ohm resistive attenuator. Here the use of magnetic cores is admissible since the attenuator is used after the fundamental has been suppressed. Any spurious product then causes only a negligible increase of an already low distortion figure. Using this technique it becomes possible to get exactly repeatable results down to 0.001 per cent or to 0.0001 per cent, (−120dB), using wide-band low-noise amplifiers in front of the analyser.

Phase-sensitive synchronous detectors

Here the complex signal to be analysed is applied to one of the two inputs of an analogue multiplier or to a suitable balanced modulator. A square-wave switching signal is fed to the second input and tuned successively to the fundamental and to the harmonics of the test signal. When the switching signal is locked to the component under investigation, sum and difference frequencies appear at the multiplier output. The difference signal is of zero frequency, (d.c.), and has an amplitude proportional to that of the test harmonic. A low-pass filter removes all unwanted a.c. components including noise. This is probably the ideal method of distortion measurement and, though very expensive, such instruments are offered by several manufacturers. Since they use input amplifiers, p.s.ds suffer from the same defects as wave analysers so that when measuring very low distortion levels it is advisable to make use of a notch network as before.

Some practical tests

For these a range of transistor amplifiers with power outputs between 50mW and 40W were used. In one case a quasi-complementary amplifier was built to a Mullard design for which distortion figures had been published

Fig. 4. *Equipment layout for distortion measurement: amplifier under test; oscillator feedback network and amplitude limiter; passive LCR notch network with short circuiting switch; unity-gain amplifier (f.e.t. input, low Z_o 5V r.m.s. output across 600Ω); attenuator, 80dB variable, 600Ω; transformer attenuator (0, 20, 40 and 60dB taps); wave analyser.*

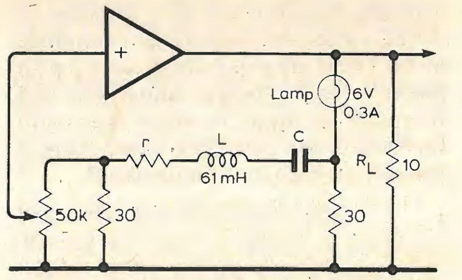


Fig. 5. *Typical oscillator-amplifier: 6W amplifier, ×40 maximum gain; 6V 0.3A filament lamp; C = 0.4μF for 1kHz and 4000pF for 10kHz.*

and which could be checked against results obtained independently. In all cases, brief tests of t.h.d were made by the standard method in order to get an idea of the distortion figures to expect. Wave analyser tests were then made with much more elaborate equipment, most of which, including filters, notch circuits, transformer attenuators, audio oscillators, voltmeters and wave analysers had to be specially built because of the very high cost of professional equipment.

Fig. 4 is a block diagram of the system used while Fig. 5 gives a particular example of a small 6W amplifier-oscillator with its amplitude-limiter and selective feedback network set to operate at 1kHz or at 10kHz by changing the capacitor.

The test procedure is as follows. Connect a resistive load to the amplifier to give the required output power, allowing for the load presented by the feedback network. Start up the oscillator and adjust the input to notch network to such a level that the amplifier D is never overloaded. About 4V is acceptable in the present case. Then tune or trim the notch network to the oscillator frequency and vary the phasing resistor until the deepest possible null is reached, best checked at this stage by an oscilloscope connected to the point shown in Fig. 4.

Switch on the wave analyser, set it to low gain and place both external attenuators at 0dB. Tune to the fundamental, readjust the notch network for the best null and increase the analyser gain to give full scale deflection on the output voltmeter. This represents the notched fundamental residue. Now tune the analyser to the second harmonic and note the corresponding output voltage. If it exceeds f.s.d., reduce the analyser gain, leaving the external attenuators still on 0dB. We now have to compare this harmonic level with the true fundamental amplitude. To do so, set both external attenuators at maximum loss, close the short-circuiting switch across the notch circuit so that the fundamental is applied to the analyser through attenuators only. Re-tune the instrument to the fundamental and set the attenuators to give the same output reading as that observed for the selected harmonic. The attenuator readings then give the amount by which that particular distortion level is below the fundamental amplitude. Repeat for the third and any required higher harmonics.

The accuracy is high because it depends only on that of the external attenuators. The 600-ohm resistive unit will probably be good to over 100kHz but unless well made, the transformer could be in error. In the present case, two windings, each of 1000 turns, were wound on a Mumetal core ½ × ½ inch cross section. The outer winding was tapped at 1, 10 and 100 turns to give 60, 40 and 20dB loss. An earthed inter-winding screen of copper foil was used, insulated in such a way as to prevent the formation of a single-turn short-circuited loop. With a 600-ohm load across the untapped primary and when fed from a 600-ohm source the tapped output on any setting was flat to around 50kHz. The transformer proved effec-

Comparison of two amplifiers, A and B

Harmonic	2	3	4	5	6	7
A	0.022	0.033	0.0009	0.0011	0.00015	0.00025
B	0.062	0.023	0.0094	0.001	0.0052	0.001

tive in removing troublesome ground-loop errors.

Some test results

A carefully compensated μA 709 operational amplifier, set to a gain of ×3 and used with thermistor control at 1kHz gave a t.h.d. figure of 0.002 per cent. The output was 3V r.m.s., loaded only by the feedback network and the notch-circuit input impedance. Its worst failing was the noise level, clearly detectable on the oscilloscope. This feature characterised all the i.c. circuits tested. Next tested was a pre-amplifier built to a design by H. P. Walker but using unselected components and non-preferred transistors. Nevertheless, at 3V r.m.s. output and set to a flat gain of × 10 at 1kHz this gave a figure of 0.011 per cent which would probably have been halved if built to the original specification. With a low source impedance the noise level was the lowest recorded in any of the tests.

At the same test frequency, 1kHz, and when set to a gain × 100, a Fairchild μA 716 gave 0.11 per cent, well within limits quoted by the manufacturer.

More detailed figures, again obtained at 1kHz, are given for two amplifiers in the table above. Type A is a complementary Class B unit with an f.e.t. input stage, built for use as a capacitance-tuned Wien bridge oscillator. The unit B is a modified version of a Mullard quasi-complementary 15W design, run with a reduced supply voltage giving 7W maximum output. Its total harmonic distortion, the r.m.s. sum of the components listed in the table, agreed exactly with figures published by the company but with an 8-ohm load instead of 10 ohms actually used in the present test.

Measurements at 10kHz followed the general trend of those at 1kHz, the actual distortion figure being up to two or three times that at the lower frequency. In some i.c. amplifiers, heavily compensated, the 10kHz figures were actually lower because of the shunting effect of compensating capacitors.

As regards the choice of notch networks, the passive parallel-T may be used for wave analyser measurements provided that its transmission losses away from the notch are taken into account. To do this add 9, 5, 3.3 and 2.3dB respectively to the measured 2nd, 3rd, 4th and 5th harmonic distortion figures. The errors involved in this are considered to be significantly lower than if an active network is used, incorporating as it does an amplifier with an unknown distortion spectrum. Of the bridged-T circuits, those shown in Figs. 2 (b) and (c) are of relatively high input impedance and cause only light loading of the amplifier under test. That shown in Fig. 2 (d) is of low impedance at high test frequencies but is particularly suited for use at low frequencies where large inductances are required. In these cases the effective coil resistances are also very large so that the test amplifier is again lightly loaded. Coils up to 5H with d.c. resistances up to 1000-ohms have been used successfully. For quick experimental tests such coils can be obtained by slipping the wound bobbins off the laminated cores of redundant chokes or l.f. transformers.

Two further points may be mentioned in conclusion. First, it is simple to apply quartz crystal control to the feedback amplifier. Three-terminal crystals generating flexural mode vibrations at low frequencies may be used in the feedback network and such units have been found to work well at 5 and 15kHz.

In the second place, it is possible to use LC circuits in the parallel-resonance mode. These are particularly useful with phase-reversing power amplifiers and they can be made to work well with low-gain units provided these have a medium-to-high input impedance.

Appendix

1. Properties of the Wien network

If $n=\omega CR$,

$$\frac{e}{E}=\frac{1}{3+j(n-\frac{1}{n})}$$

When $\omega CR=1$, $e/E=⅓$; $\phi=0$

At the second harmonic,

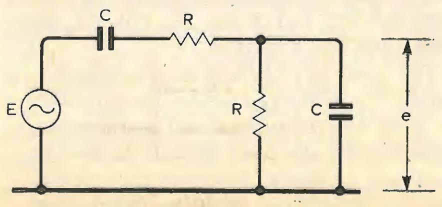
$n=2$; $e/E=2/15\,(2-j)$

Attenuation $=2/15\sqrt{5}$; $\tan\phi=-½$

Loss $=0.298$; phase angle $=26.57$ deg.

At the third harmonic the corresponding figures are 0.249 and 41.63 degrees.

Assuming a centre frequency of 1kHz the 3dB points lie at 3.303 and 0.303kHz with phase angles ± 45 degrees. $Q=⅓$.



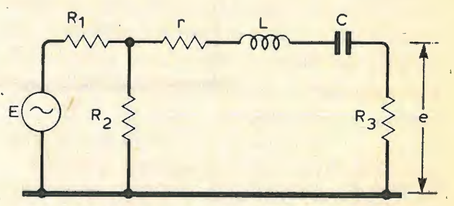
2. Properties of RLC feedback network

$$\frac{E}{e}=\frac{R_1}{R_3}+\frac{R_1+R_2}{R_2R_3}\quad r+R_3+j(\omega L-1/\omega C)$$

At series resonance $\omega L=1/\omega C$ and the network loss is:

$$\frac{e}{E}=\frac{R_2R_3}{(r+R_3)(R_1+R_2)+R_1R_2}$$

Q factor of Lr coil alone $=\omega L/r$



When embedded in the network:

$$Q_1=\frac{\omega L}{r+R_3+R_1R_2/(R_1+R_2)}$$

Assuming r stays constant over an appreciable frequency range, the attenuation of any harmonic n below that of the fundamental is:

$$\text{Loss}=Q_1(n-1/n)$$

Even with poor coils and low gain power amplifiers, harmonic attenuation below the fundamental level at the network output will seldom be less than 20dB and may easily exceed 40dB with good coils and high-gain amplifiers.

Acoustics conferences

The Spring Conference of the Institute of Acoustics is to be held at the Institute of Sound and Vibration Research, Southampton University, April 8-11. There will be sessions on psychoacoustics, sound power determination, building vibration, and sound generated by impact, as well as others organized by specialist groups. Contact: Professor J. B. Large, ISVR, The University, Southampton.

Forthcoming meetings include "Planning and noise control for industrial developments" at County Hall, London, April 26; "Acoustic test facilities and recent work on test methods" at British Gypsum Ltd, Loughborough, May 3; "Noise nuisance" at County Hall, London, May 31; "Source location and active control of noise", Cambridge University, June 28-29; "Speech production modelling" at Leeds University, August 2; "Non-linear acoustics" Bath University, September 10-11; and "Non-physical aspects of noise and noise criteria" at Portsmouth Polytechnic, October 5. Details from the Institute of Acoustics, 47 Belgrave Square, London SW1X 8QX (tel: 01-235 6111).

Teletext remote control

Ultrasonic link for page, time and function selection

by R. T. Russell

A number of articles on the updating and modification of the *Wireless World* teletext decoder have appeared since the original, pioneering, series of articles by J. F. Daniels in 1976[1]. A decoder which has had these modifications carried out should have a performance which in most respects matches that of any other teletext decoder on the market, including those using l.s.i. integrated circuits. There is, however, one facility lacking on the *W.W.* decoder which is provided on nearly all other decoders, and that is remote control.

Whilst the front-panel controls of the decoder are adequate for experimentation and demonstration purposes, they leave something to be desired when the decoder is installed in a domestic environment. A means of remote control is therefore desirable.

A NUMBER of possible ways to provide this feature present themselves. The simplest is probably to remove the page-selection thumbwheel switches and essential function switches (e.g., Clear) to a separate box, connected to the decoder by means of a multiway cable. This, however, makes a fairly bulky item; the cable is of necessity thick and something of a hazard if trailed across the floor. In addition, the capacitance of the cable could deform the fast pulses fed to the thumbwheel switches, possibly resulting in unreliable operation. Another important aspect is the electrical safety of such an installation, since the decoder circuitry is connected to the live television chassis. This having been said, such a scheme is practical and probably the cheapest to implement.

The problem of the bulkiness of the remote unit can be solved by replacing the thumbwheels and other function switches by a small calculator-style keypad. The difficulty with this is that whereas the thumbwheel switches are "self indicating" (i.e. the page number selected is displayed directly on the switches) there is no equivalent indication with a pushbutton keypad. One solution to this would be to incorporate a page-number display into the remote unit, perhaps by means of a small seven-segment display. An alternative solution, adopted in this design, is to indicate the page number as part of the text display on the tv screen. A convenient place for it is the top left hand corner of the page where there is a space of eight characters preceding the service name (CEEFAX or ORACLE).

The problem of the heavy multiway cable can be partially overcome by multiplexing the data into a serial format, thereby allowing the use of a thin two core cable. However, this does not reduce the safety hazard which might even be aggravated by the unsuitability of the insulation on a thin cable not intended for mains use.

The ideal solution to these problems is to use a cordless arrangement to eliminate the trailing lead and with it any safety hazard. Naturally the price of such a solution is complexity and expense, and for those who want to avoid the cost of the ultrasonic link the rest of the circuitry to be described is compatible with a wired system using a two core cable. This could easily be upgraded to the cordless system at a later date.

Transmission characteristics

Having decided to adopt a cordless system, the next choice to be made was of the transmission medium to use (e.g., ultrasound, radio signals, light) and the method of modulation to enable it to carry the desired information. It was decided to use an ultrasonic link, because this has been the choice of most set manufacturers for their remote control systems and it does not require any sort of licence. Piezo-electric ultrasonic transducers for operation at around 40kHz are readily available and these are used in this design.

The choice of a suitable method of modulation was more difficult. A frequently adopted method is to allocate a different ultrasonic frequency to each of the control functions provided and to use a frequency-sensitive detector in the receiver to separate the functions. In the simpler versions, the frequency generation and detection are done using conventional tuned circuits, but in the more complex systems, with a large number of commands, purpose-made integrated circuits usually carry out these functions.

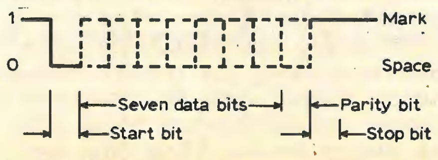


Fig. 1. *Format of serial data. Duration of each bit is 10ms.*

Although this is a well tried and proven system, it has a number of disadvantages in the present application. Firstly, sixteen different frequencies are required for teletext remote control alone in present case, and the number is even larger if provision is made for remote channel-change, etc. Although this number of separate frequencies is possible, without using specialised i.cs, the transmitter and receiver circuits would be quite complex, whether analogue or digital techniques were adopted. Secondly, the bandwidth of the piezoelectric type of transducer is probably insufficient for such a system, since the different frequencies cannot be very close together, and this would necessitate using capacitive transducers which need a large driving voltage and d.c. polarization.

For, these reasons, the multi-frequency approach was rejected and an alternative system devised, which uses a two stage modulation process. Firstly, the control functions to be transmitted are encoded into a serial data stream of 1s and 0s and secondly, the serial data is used to modulate the ultrasonic carrier in a binary fashion. The most obvious method of modulation is simple on-off keying, with the carrier on for logic 1 and off for logic 0. Such a system was tried but was found to be sensitive to short-term reflections from walls and objects in the room. Whilst this problem could be partly overcome by an a.g.c. system in the receiver, with suitable time constants, it was found better to use frequency-shift keying instead, the signal having a constant amplitude to mask reflections. In common with other f.m. systems, this allows the use of a high-gain limiting amplifier in the receiver, which renders it insensitive to the large signal-level fluctuations which can be experienced.

Because of the narrow transducer bandwidths, the maximum modulation rate is limited to only a few hundred bits per second but, since this rate permits a maximum of ten commands per second (faster than one can press the keys), the theoretical system capacity is more than adequate. The method adopted consists of coding each command as a seven bit number, appending synchronizing bits to it and transmitting the whole as a serial signal, at 100

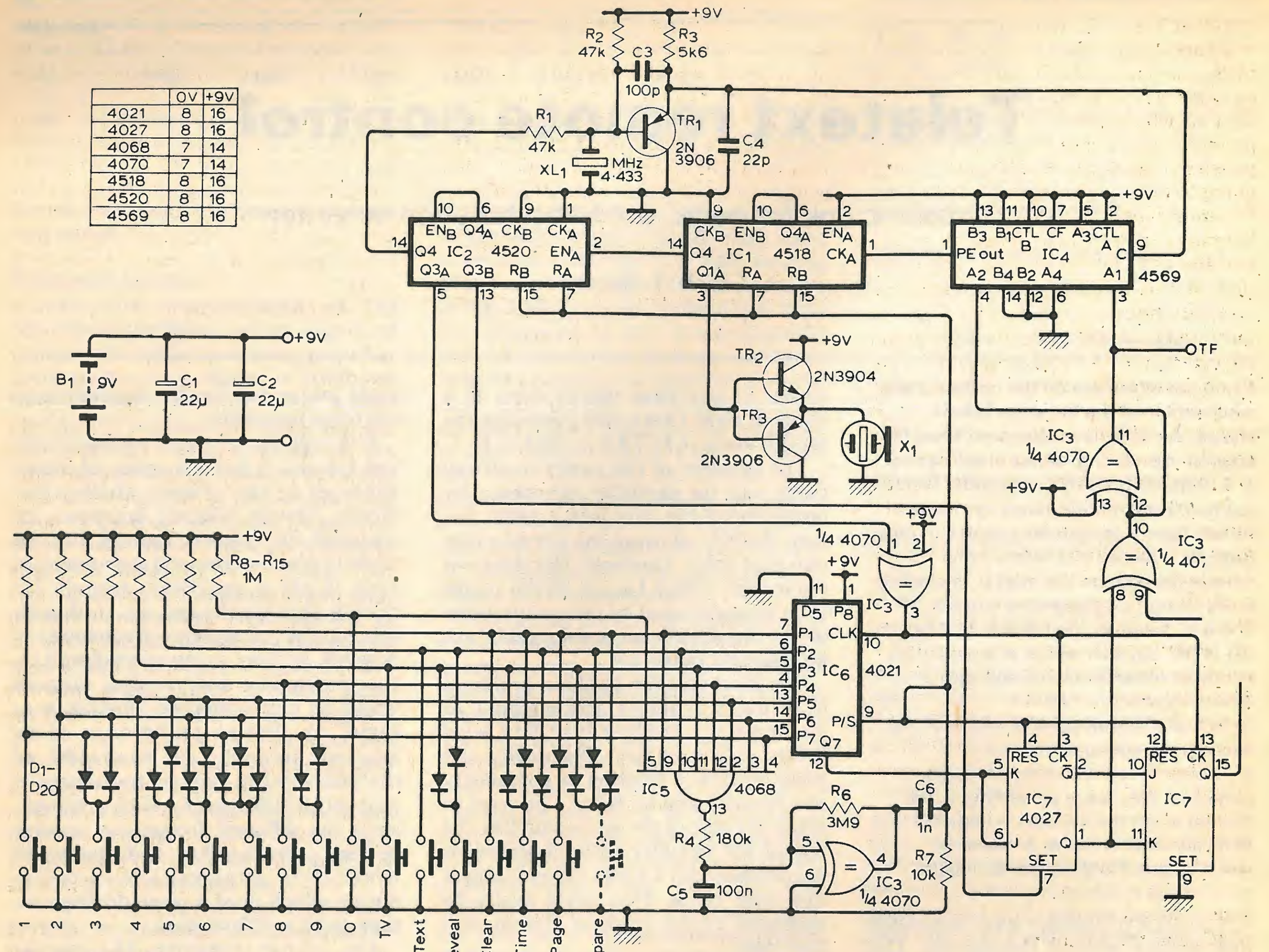


Fig. 2. *Circuit of keypad and ultrasonic transmitter.*

bits per second. Although only sixteen commands are implemented, the system could be expanded to a maximum of 128 functions, with additional circuitry in the decoder. It could, for example, be used to transmit alphanumeric data at up to 10 characters per second.

Data format

The serial data format is shown in Fig. 1 and is the same as that adopted for computer terminals, teleprinters and the like. In the quiescent condition, when no data is being transmitted, the signal rests in the logic 1 or MARK condition. When a command is sent the serial data begin with a logic 0 start bit followed by the seven data bits. After the last data bit, a "parity bit" is inserted. In this case odd parity is used, which means that the parity bit is chosen so that the total number of ones in the seven data bits plus the parity bit is always odd. This allows a measure of error detection when the signal is received. After the parity bit is a "stop bit" to identify the end of the data. If another command is to follow, the new start bit may follow immediately after the previous stop bit, but otherwise the signal remains in the quiescent "stop" condition. Whilst this code may seem complex it is in fact not difficult to generate and because of its common use there are inexpensive integrated circuits available especially designed to decode it.

It is the use of this serial format which allows, if desired, the ultrasonic link to be bypassed and the serial data sent directly to the decoder along a cable.

Compatibility. This remote control system is suitable for all versions of the *Wireless World* decoder and is not dependent on any or all of the previously published modifications having been carried out. It is basically an add-on unit requiring no changes to the original boards or inter-board wiring and therefore can be added with the minimum of disruption, although its performance may be enhanced by a small modification to the original circuitry which will be detailed later.

The remote control splits naturally into three parts; the remote push-button keypad unit, the ultrasonic receiver and the interface board with the teletext decoder. These three sections will be dealt with in turn.

Ultrasonic transmitter

The circuit of the ultrasonic transmitter/keypad unit is shown in Fig. 2. It performs the function of encoding the different keys, generating the serial data signal, and from it a frequency-shift keyed signal to drive the ultrasonic transducer. It is battery powered and uses c.m.o.s. logic to reduce power consumption to a minimum: the quiescent current consumption is so low that no on-off switch is required. The circuitry is crystal controlled and uses a standard colour-subcarrier crystal, resulting in high stability and the absence of any adjustments.

The sixteen keys on the keypad are each encoded into a 7-bit binary word using the diode-matrix D_1-D_{17}. A seventeenth, spare, function may be incorporated with the addition of three diodes, D_{18}-D_{20}. The codes generated are shown in Table 1 and it should be noted that the transmitted data is inverted with respect to the outputs of the diode matrix itself. The encoding system was chosen to minimise the total number of diodes.

The seven data bits are fed to the parallel inputs of a shift-register, IC_6, and also to the inputs of a NAND-gate, IC_5. When no key is pressed these bits

are all at logic 1 by virtue of the pull-up resistors R_8-R_{14}. The "0" key is fed only to R_{15} and the NAND gate, since it is encoded as all zeroes (all ones at the shift register inputs). When any key is pressed, one or more inputs of IC_5 are pulled to logic 0, the NAND gate output going to logic 1. This signal is fed via an RC integrating network (R_4, C_5) to a Schmitt trigger circuit, comprising (3,4) and the associated resistors. The function of this circuit is to suppress the contact-bounce inherent in a mechanical switch. The positive-going edge at IC_3, pin 4 is differentiated by C_6, R_7 to generate a narrow strobe pulse. This pulse performs two functions: it resets the circuit to the correct initial conditions and also parallel-loads IC_6 with the 7-bit data present at its inputs.

By virtue of being reset by the strobe pulse, pin 14 of the binary divider IC_2 goes to logic 0 and turns on the crystal oscillator Tr_1 (since the power consumption of c.m.o.s. is a function of clock frequency, the oscillator is turned off when not in use). The oscillator, running at 4.43 MHz, clocks the high-speed divider IC_4 which is configured to divide the frequency by either 55 or 56. The signal at IC_4 pin 1, at about 80kHz, is further divided by 100 in IC_1 to give at signal of 800 Hz at IC_2 pin 2. This is divided down to 100 Hz, which appears at IC_2, pin 5, and after inversion in (3,3) this signal clocks the shift-register IC_6, so that the seven data bits appear serially at its output pin 12. The function of IC_7 and the exclusive-OR gate (3,10) is to generate the odd-parity bit and to append the start and stop bits as previously mentioned. The serial data produced at (3,10) are fed to IC_4, along with an inverted signal from (3,11), so that the division ratio is set to 55 for logic 0 and 56 for logic 1. This results in a square-wave at IC_1, pin 3 of 40.31 kHz for logic 0 and 39.59 kHz for logic 1. This signal drives the ultrasonic transducer via Tr_2 and Tr_3. Shortly after the data bits have been sent IC_2, pin 14 goes to logic 1, turning off the oscillator and the ultrasonic output.

Table 1. Binary codes corresponding to the 17 keys.

0	0000000
1	0000001
2	0000010
3	0000011
4	0000100
5	0000101
6	0000110
7	0000111
8	0001000
9	0001001
TV	0010000
TEXT	0100000
REVEAL	0110000
CLEAR	1000000
TIME	1010000
PAGE	110000
Spare	1110000

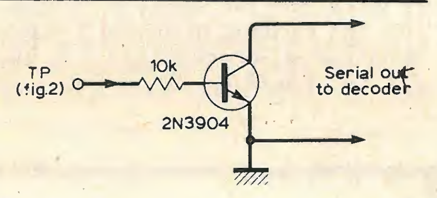


Fig. 3. *Output circuit if cable used instead of ultrasound.*

The battery used is a 9V type, which should last several months in normal use. The transmitter will fail to operate when the battery voltage drops below that needed for IC_4 to divide correctly at 4.43 MHz. This will depend on the particular sample of IC_4, but is typically 6 volts.

Construction of transmitter. By using a miniature 16-key keypad the transmitter, including the ultrasonic transducer and battery, will fit into a small hand-held unit. The printed-circuit layout shown does not include the diode matrix which, in the prototype, was mounted directly on the keypad connexions. Copper strip board is a suitable alternative. The transducer must, of course, have an unobstructed "view" from the end of the unit normally pointing away from the user. The prototype was built into a small die-cast box with the keypad mounted on the lid.

For those wishing to use the "wired" system, Tr_2, Tr_3 and the ultrasonic transducer should be omitted and the circuit of Fig. 3 substituted.

Ultrasonic receiver

The circuit of the receiver is shown in Fig. 4. The function of this unit is to receive the ultrasonic signal, demodulate it and feed the resulting serial data to the decoder. It is intended that it be mounted inside the tv cabinet.

The ultrasonic transducer X_1 receives the signal from the transmitter and feeds it to the limiting amplifier consis-

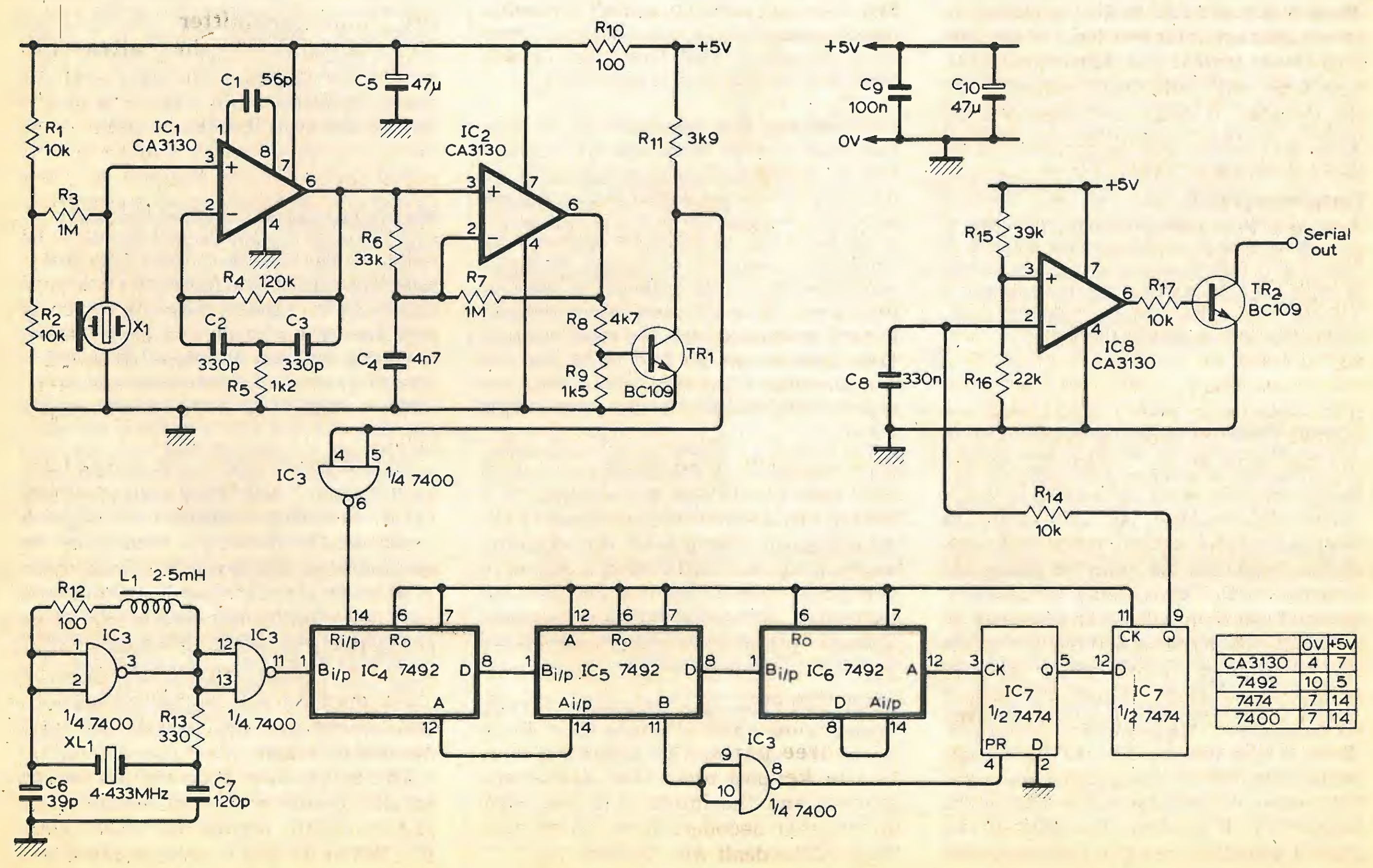


Fig. 4. *Ultrasonic receiver.*

ting of IC_1 and IC_2. The natural selectivity of the transducer is supplemented by the feedback network connected around IC_1 which gives it a band-pass response centred on 40 kHz and a Q of 5. Because of the decoupling effect of C_4, the negative feedback around IC_2 is significant only at low frequencies and there is sufficient gain to give a clipped square-wave output with a normal signal from the ultrasonic transmitter. This 40 kHz square-wave is matched to t.t.l. levels by Tr_1 and buffered by NAND gate (3,6).

The dividers IC_4, IC_5 and IC_6 each consist of separate divide-by-2 and divide-by-6 sections. The 40 kHz signal at IC_4, pin 14 is divided by two in IC_4 and again in IC_5. The output at IC_5, pin 12 is fed to the reset inputs of both IC_4 and IC_5 so that, rather than being a 10 kHz square wave as might be expected, it consists of narrow positive-going pulses at a 20 kHz repetition rate. The duration of the pulses corresponds to the propagation delay from the reset to output of IC_5, and is only 30 nanoseconds or so.

Gates (3,3) and (3,11), along with the associated components, make up a crystal oscillator running at the PAL colour subcarrier frequency, 4.43 MHz approximately. This signal is divided by 6 in IC_4, by 6 again in IC_5 and by 12 in IC_6. This results in IC_6, pin 12 going high 216 cycles, or 48.7 microseconds, after the reset pulse occurs. This signal clocks IC_7, pin 5 to logic 0. Six clock pulses, or 1.4 μs, later, IC_5, pin 11 goes to logic 1 and, via (3,8), presets (7,5) to a 1. Therefore IC_7, pin 5 is at logic 0 during the period 48.7 to 50.1 microseconds after each reset pulse. When the following reset pulse occurs in this "window" it will impose a logic 0 onto IC_7, pin 9. This condition corresponds to an input frequency range of approximately 40 to 41 kHz. This encompasses the logic 0 frequency of 40.3 kHz but not the logic 1 frequency of 39.6 kHz. By this means a demodulated serial data signal is present at IC_7, pin 9. The presence of noise and interfering signals results in some spurious pulses at this point, so these are filtered out by the RC network R_{14}, C_8 and the data signal squared-up by IC_8. Tr_2 provides the serial output with sufficient current drive capability to feed the decoder circuitry.

Receiver construction. The amplifiers IC_1 and IC_2 together have a gain in excess of 80 dB, so care must be taken with the layout of components and earthing to ensure a stable system. It is recommended that the author's board layout be adopted. This board will fit inside a standard die-cast box if interference from (or to) the rest of the television circuitry is experienced, although this was not found necessary with the prototype. The five-volt supply should be taken from a point having adequate decoupling so as not to introduce interfering sinals into the receiver by this route. No setting-up adjustments are required.

For best results the ultrasonic transducer should be mounted in the front of the television cabinet in such a position as not to restrict its natural beam-width of approximately 60 degrees. Being of metal construction it should be mounted behind a protective insulating grille to prevent it being touched. Such a grille should be chosen to have a low attenuation to ultrasound at 40 kHz. The transducer should be connected to the receiver circuit board by a short length of screened microphone cable and should not be grounded other than via this cable. □

Reference

1. Daniels, J. F. "Wireless World teletext decoder". *Wireless World*, November 1975 to June 1976.

Printed circuit layouts can be supplied from this office. Please send a stamped, addressed envelope.

BOOKS RECEIVED

One more in the monumental series of compilations from D.A.T.A. Inc., the updated **Diode D.A.T.A. Book**, is now available. In nearly 800 pages, this first issue of the 1979 two-issue series contains electrical, mechanical and environmental information on over 50,000 types of diode, from 156 makers throughout the world. All types of diode are covered, with supplements on US Mil specifications, outline drawings and manufacturers addresses. This book is one of a set of similar publications which takes in the whole field of semiconductor devices. It costs £48.75 for one year — two issues — and is offered on a 30-day trial. The UK agents are London Information (Rowse Muir) Ltd, Index House, Ascot, Berks SL5 7EU.

System Design with Microprocessors, by D. Zissos. It seems that workers in virtually every sector of science and industry are recognizing the need to study and apply computers, particularly microprocessors and microcomputers. In this book, Professor Zissos, who has the chair of Computer Science at the University of Calgary, employs his non-pedagogic approach to allow workers in widely different disciplines to understand the methods by which these newly-fashionable devices can be made to work to the best advantage. There is virtually no reference to "electronics" — the discussion is of logic systems only, the first chapter being an introduction to logic design, based on a previous book, which was also the inspiration for a series of articles in this journal during 1977-8. Several chapters provide extended problems, with their solutions — in this type of book a very useful feature. References are provided, but are somewhat repetitive and fairly limited. Academic Press Inc. (London) Ltd, 24-28 Oval Road, London NW1 7DX, Pp. 202, £6.50 in paper back.

Understanding Hi-fi Specifications, by John Earl, is an attempt to explain the language used by reviewers of audio equipment in the magazines. Since the author is one of these gentlemen, he ought to be in a good position to do this: it may be asked, though, why the language continues to be used in consumer magazines if it is so evidently in need of elucidation. Since the more incomprehensible the reviews become, the more abstruse these explanations will have to be, and one can envisage a position where only the review writer will know what he is talking about.

The book is an honest try at clarification, but it does seem that a little more care would have been a good idea. For example, it is unlikely that anyone who doesn't understand the expression "output level" will be greatly assisted by the sight of the quantity 200nWb/m, even though it is also spelt out (wrongly). The publishers are Fountain Press, 14 St James Road, Watford, Herts, and the price is £2.95 in limp back.

Radio and Television Servicing, 1977-78 Models is the latest of a very long line of similar volumes, which are probably familiar to most servicing technicians. A representative choice of equipment is covered, each section with a circuit diagram and servicing notes. The compiler has included audio systems as well as television and portable radio receivers, and any servicing information published by the makers during the year is included in a separate section. R. N. Wainwright edited the collection, which costs £10.50. The publishers are Macdonald and Jane's Publishers Ltd, Paulton House, 8 Shepherdess Walk, London N1 7LW.

Modern Instrumentation Tape Recording is a small, though densely-packed handbook intended to help the user of this equipment to select and apply it intelligently. It assumes no knowledge of magnetic recording, beginning as it does with a chapter on the physics of recording on tape, although the reader is treated as an intelligent being and is not "written down" to. In the second chapter, the concepts of direct, f.m. and digital recording techniques are introduced and are then allotted a chapter each, the treatment being exceptionally clear. Tape transports and heads are then discussed in two chapters, which are followed by a section on the selection of an instrument for specific work. A particularly useful chapter indicates possible malfunctions and their prevention or cure and a chapter is devoted to the various standards of format and calibration that exist, with particular reference to the IRIG set of standards. Finally, a section describes some typical applications of the instrument. The book is written by the staff of the Engineering Department of EMI Technology Inc. It is obtainable from SE Labs (EMI) Ltd, North Feltham Trading Estate, Feltham, Middlesex TW14 0TD.

Digital data recording without f.s.k.

Simple interface for audio recorders uses differentiation

by Brian T. Evans, B.Sc., Ph.D., M.I.E.E., M.B.E.S.
St Bartholomew's Hospital, Department of Medical Electronics

Contrary to current belief digital data can be quite easily recorded on unmodified audio reel-to-reel or cassette tape recorders. This can be done via a simple interface unit, and the unit described in this article has been in use for more than five years at St Bartholomew's Hospital, London, for recording a stream of digital numbers corresponding to the inter-beat interval of patients' heart rate. In the hospital system this recorded data is statistically analysed by a minicomputer some time later by replaying the audio data tape at two or four times the initial recording speed through one of the computer's input ports.

IT IS MORE usual to record slow speed digital data onto cassette tape by the use of frequency shift keying. However, our main requirement was that the method of recording and recovering the data from tape should be independent of the tape speed. In this way data originally recorded at low speed could be transcribed into the computer at any convenient higher speed without the need to adjust the interface unit.

Domestic audio tape recorders are usually 'flat' from about 100Hz to 6,000Hz or more. If a digital square wave at, for example, a repetition frequency of a few hundred hertz is first recorded onto audio tape and then examined on an oscilloscope, on replay it is seen to be considerably distorted and, at first sight, useless. However, similar distortion (differentiation) would occur if the square wave were passed through an RC high pass filter whose −3dB frequency was chosen to be the same as the measured overall tape record-replay low frequency −3dB point.

Experiment will show, however, that this overall record-replay low frequency roll-off varies both with tape speed and type of recorder. Let us therefore take a pessimistic view and choose an RC low frequency −3dB point higher than experienced on even poor machines. Let us take a figure of 170Hz, equivalent to an RC time constant of 1ms.

If we now repeat our experimental recordings using the output of the 170Hz RC filter as the signal source it can be seen that whatever tape speed is chosen there is very little difference on replay when compared to the initial differentiated square wave. Even if we replay the tape at higher speed there is little change in wave shape. Thus a suitable differentiated square wave will retain its shape over a wide range of tape speeds and speed-ups. A suitable simple circuit is shown in Fig. 1.

We next require a method of reforming the differentiated pulses to their original 'square' shape. This is not as simple as it first appears since the digital information is not really a 50 : 50 square wave but an unknown run of marks and spaces.

Perhaps the best known source of serial digital data is that produced by and for v.d.us and teleprinters and serve as the example for this design. However, any serial digital data may be recorded, via the interface, whatever the length of marks and spaces.

When no information is being transmitted from a v.d.u. the output line assumes a 'marking' condition, either defined as the flow of current or the continuous generation of digital 'ones'. It is convention to prefix each serial data word with a 'start' bit represented by either a digital 0 or the interruption of line current. Then follows typically eight data bits and a parity check bit that can be used for later error detection. The next data word cannot be sent until there has been a halt in transmission of one or two bit lengths (the 'stop' bits). We may take two examples. In the first serial word all the data and parity

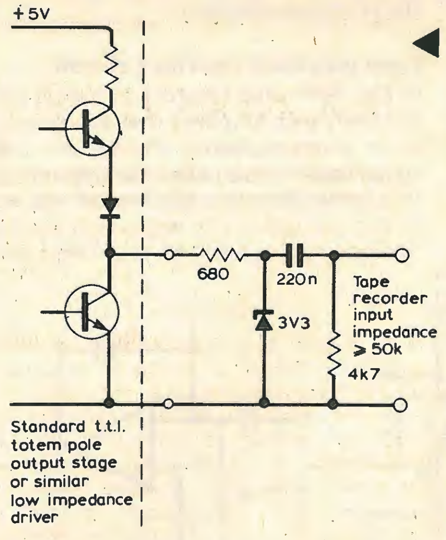
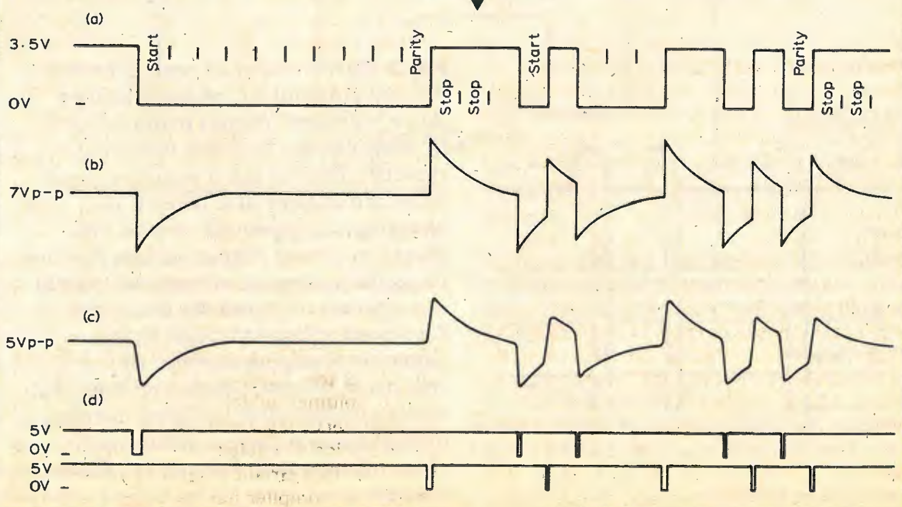


Fig. 1. *Differentiator for serial data. (The 3.3V zener diode and associated 680Ω resistor are optional; they were included to remove supply line noise when the output was high.)*

Fig. 2. *Waveforms in the interface unit: (a) original serial data; (b) square waves differentiated before recording; (c) input to interface from tape playback; and (d) outputs of lower and upper peak detectors.*



bits are set to 0, in the second there is a more typical random pattern of 1s and 0s. If the data has resulted from the manual depression of keys on the v.d.u. there may be a relatively long marking period between successive key strokes and hence data words.

These two data word examples, both prior to and after differentiation, are shown in Fig. 2(a) and (b). It can be seen that the absolute height of each differentiated edge depends on the run of bits before it. Because of this effect it is not possible to reshape the differentiated bits by means of a Schmitt trigger since there is no means of optimally setting the trigger level for changing bit height. The problem is exacerbated by the lack of high frequency response of the replayed tape which serves to increase the rise time of the edges of the recorded waveform. This is illustrated in Fig. 2(c). The only remaining relatively undistorted reference point is the top of each 'spike' and it is the timing of these turning points that must be determined in order to reconstitute the original serial data stream. To accomplish this we require a peak detector.

Peak detector

If a pulsatile waveform is applied to the input of the conventional d.c. restorer, as shown in Fig. 3(a), current flows in the diode only while the capacitor is charging up to the input peak voltage. When the capacitor is fully charged, current ceases and the diode no longer conducts. The same effect is produced if the diode is replaced with the base-emitter junction of a transistor (Fig. 3(b)). We may now estimate the magnitude of the capacitor's charging current by measuring the voltage drop across the collector resistor as shown in Fig. 3(f). This voltage drop falls to zero once the input capacitor is fully charged. This, of course, occurs at the top of the input voltage pulse. However, it is interesting to note that charging current first starts to flow at some point near the bottom of the pulse once the magnitude of this new pulse exceeds the stored voltage remaining across the capacitor. This latter voltage is a function of the d.c. restorer's RC time constant and the immediate past history of the magnitude and timing of previous voltage pulses.

One practical improvement to this circuit is the substitution of an operational amplifier and discrete diode for the transistor configuration (Fig. 3(c)). (Another practical transistor version is employed in the clock frequency doubler circuit described later.) The op-amp circuit provides a constant negative-going voltage pulse during capacitor charging that can be used to drive t.t.l. directly. Circuit operation is improved if a small voltage bias is applied to the non-inverting op-amp input. This avoids spurious outputs when no input signals are applied. This circuit has become a standard building block at Barts, including use as a peak detector of physiological signals such as the electrocardiogram.

Tape playback interface circuit

In Fig. 4 the tape recorder output is fed to a unity gain amplifier that acts purely as an inverting buffer. From there the signal follows two paths; the first direct to a peak detector, the second via an inverter and identical peak detector. Typical waveforms are shown in Fig. 2(c) and (d). The negative-going output of each peak detector is fed to the set and reset inputs of the bistable formed from two cross connected Nand gates. At first sight it would appear that the 'squared' output of this bistable is the reconstituted digital data (Fig. 5(c)). This is not quite true since set and reset are initiated at the start of diode conduction in the peak detectors. We need to delay the operation of the bistable to the end of the peak detector's diode conduction period so that the transistions of the digital output coincide with the peaks of the input waveform rather than occurring indefinitely early.

To achieve this delay the t.t.l. compatible peak detector outputs are also summed in a 7400 Nand gate (now a Nor gate under negative logic) and inverted in a further 7400 gate (Fig. 5(d)). In this way the trailing edge from either peak detector, virtually coinciding with the peak of the input voltage, clocks the 7474 'D'-type flip flop. This procedure delays the S-R bistable transitions to the correct points in time so that the Q output of the D flip-flop now provides the correct reconstituted data (Fig. 5 (e)).

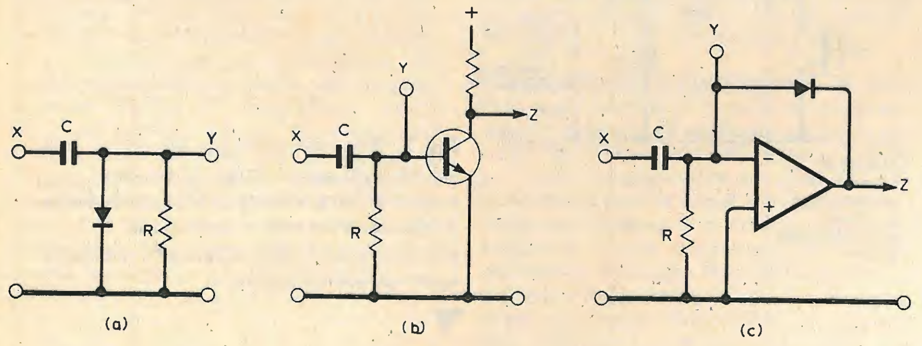
In practice both Q and $\bar{Q}$ outputs are made available via a switch as the recording process may introduce an even or odd number of analogue inversions of the signal.

Optional clock track recording

Although two separate transmit and receive clock oscillators may be employed to feed the parallel-serial and serial-parallel converters that are used to generate and receive the serial data stream, it was thought convenient to add a separate clock track to the stereo tape recorder. The availability of such a signal permits complete freedom in the initial choice of tape speed and final tape speed-up without the need to adjust the interface.

In the original design, parallel-serial and serial-parallel conversions were performed in u.a.r.t. (universal asynchronous receiver transmitter) chips that require a clock input at 16 times the intended serial data rate. Fortunately, since this signal is frequency divided within the chip, the mark space ratio of the clock signal is not critical. The original design specified a serial data recording rate of 750 bits/s thus requiring a 12kHz oscillator for the u.a.r.t. transmitter. Experiments showed, not unexpectedly, that at the lowest tape speed of 4.75cm/s the reproduction of a 12kHz signal was less than perfect. However, when a 6kHz recorded signal was replayed at a 4× speed up (19cm/s) a surprisingly clean 24kHz sine wave was displayed on the oscilloscope.

So, if the transmit clock signal is frequency divided prior to recording is there a simple method of frequency doubling on replay, preferably independent of frequency? The circuit described below operates from sine or square wave input signals over a range wider than 1 to 30kHz and is also not critical of input amplitude. It produces a short output pulse on each occasion the input waveform passes through zero, viz, twice per input cycle.



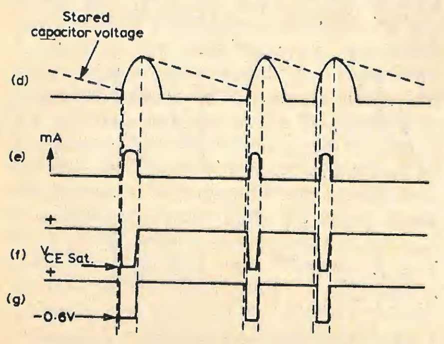
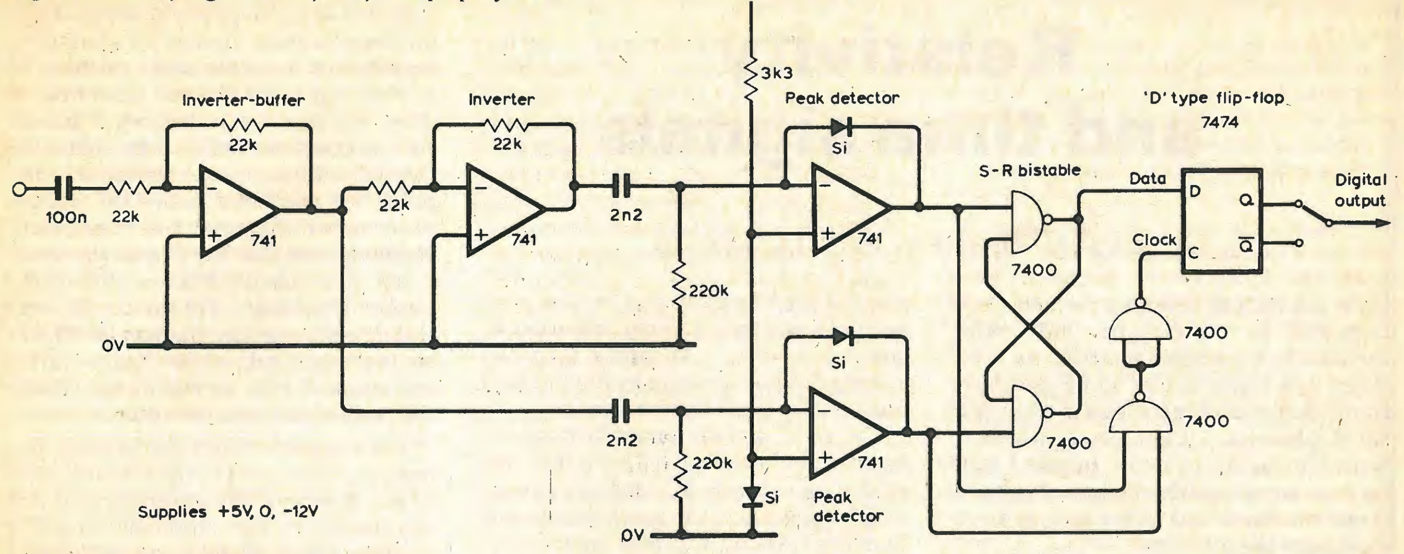


Fig. 3. Development of peak detector: (a) conventional d.c. restorer using a diode; 'restored' output available at Y; (b) base-emitter junction of transistor replaces diode of (a); a negative input pulse is available at Z while C is charging; (c) improved version that gives a constant output voltage for any capacitor charging current; (d) typical input pulses at X and the discharge of C's stored voltage through R; (e) capacitor charging current; (f) transistor collector output voltage at Z, related to capacitor charging current; and (g) op-amp output voltage at Z showing improved rise and fall times over (f).

Fig. 4. *Circuit of digital interface for tape playback.*



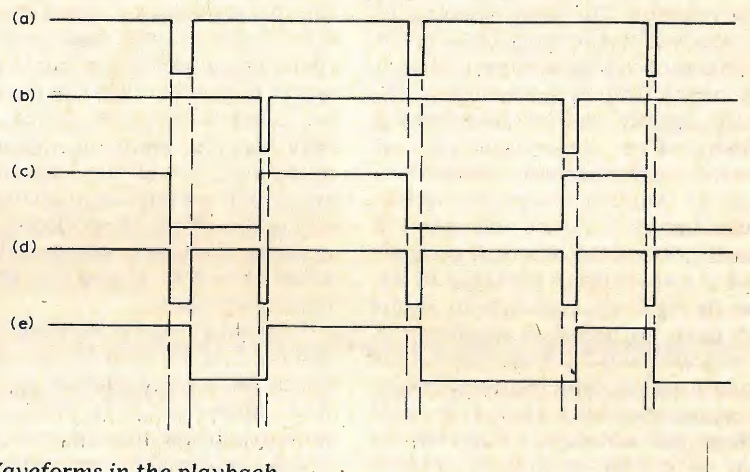
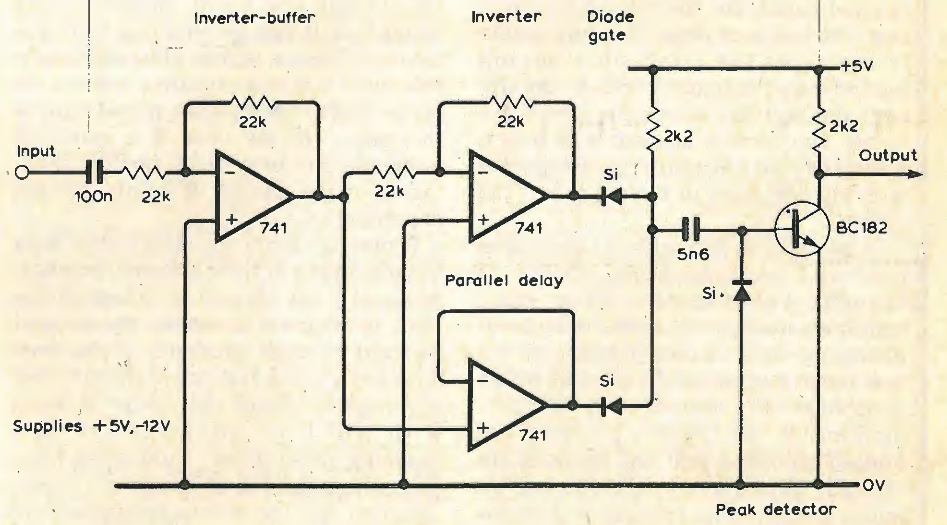


Fig. 5. *Waveforms in the playback interface of Fig. 4: (a) output of lower peak detector; (b) output of upper peak detector; (c) output of S-R bistable; (d) clock input; and (e) Q output of 7474.*

Fig. 6. *Circuit of frequency doubler.*



Clock frequency doubler

In Fig. 6 the unity gain inverting buffer amplifier feeds separate buffer and inverting amplifiers so that identical out-of-phase tape clock signals are presented to a two-diode gate. The output of this gate will always follow the more negative of its two input signals (see Fig. 7(d)). There is thus an abrupt change or turning point in the gate's output as first one then the other, complementary clock signal is tracked. These abrupt changes (or spikes) are detected in the subsequent simple transistor peak detector. The substitution of a reverse diode in place of the conventional resistor across the base-emitter transistor junction permits the peak detector to operate over a wider range of both input voltage and frequency.

The inclusion of the buffer amplifier is not essential if the circuit is to be used on input frequencies below about 5kHz. It is only introduced to counter the short time delay of the parallel inverting amplifier path that results from the well-known voltage slew rate limitation of the 741 amplifier. The alternate use of 748 operational amplifiers using discrete 22pF compensating capacitors permitted trouble-free operation beyond 50kHz input frequency.

Setting up

Some form of error monitoring is required, the simplest being the connection of the parity error line of the serial-parallel digital receiver to a light emitting diode.

Data replay level

A playback output level of less than 1.4V p-p will fail to trigger the peak detectors and the output will remain permanently high or low. Levels in excess of 8V p-p will experience clipping in the buffer and inverting analogue amplifier and will thus destroy the true turning points of the waveform. Such clipping will markedly increase the error rate.

In practice an error trough exists for replayed signals in the range 3-6V p-p whereas outside these limits error rate rapidly increases. It is easy to determine the edges of the trough and to set the level control midway between these limits.

Clock track option

Below a similar replay level of about 1.4V p-p the frequency doubler will not

continued on page 70

Relativity and time signals

Dr Essen replies to his critics

MY ARTICLE "Relativity and time signals" in the October 1978 issue aroused considerable interest. As there were too many letters to be published individually and there was a good deal of duplication I have been invited to write a composite reply. In this I shall try to bring out the points of general interest since our joint aim is to illuminate the problem.

The response was disappointing in several respects. The main purpose of my article was to encourage interest in new theories of electromagnetism which might lead to a method of exploiting cosmic energy, thus saving civilisation from catastrophic decay. Only two correspondents referred to this aspect. Another disappointing feature was that little notice was taken of my description of the practical comparison of clocks. Writers continue to describe thought experiments in terms which have no practical significance. They still use t and t' for the times of the stationary and moving clocks although I have pointed out that four dial readings are obtained. Einstein, in effect, used four at first by adding qualifying phrases to t and t' and his mistake was to omit the qualifying phrase in his thought experiment. He read the wrong dial. This can be checked most simply by reading his original paper, but there is no evidence that this has been done. It is impossible to arrive at the truth by studying second-hand accounts which usually omit the sections where the errors are made. The serious student will find it helpful to read Einstein's paper together with my criticisms in reference 2 of the article.

In my reply to Dr Griffiths (December letters) I expressed my dislike of thought experiments. Their only legitimate use is to illustrate some point of theory: they cannot possibly give a new result and especially a result which contradicts the assumptions and predictions of the theory. Einstein has himself admitted that the result of his thought experiment contradicted his initial assumptions (reference 3 of the article) and it must therefore be wrong. Relativitists seem unable to accept the logic of this statement. Although no further argument is necessary I have drawn attention to the precise nature of the mistake in Einstein's account and, for my own satisfaction, in all other accounts published before my criticisms. Thought experiments continue to convince the unwary, and several have been recommended to my attention by correspondents. Like other forms of science fiction they may be fun but they must not be mistaken for science.

The error is made by performing the experiment incorrectly. This is followed by the logical error of accepting a result which contradicts the assumptions; and in many cases by a further logical error of ascribing to the thought experiment the characteristics of a real experiment. If a clock is actually made to travel in a round trip acceleration must be applied and it is possible that the result would be changed in consequence. But the only way the result of a thought experiment could be modified by acceleration would be to include a term giving the effect of acceleration in the analysis. If no such term is included the result cannot be in any way influenced by accelerations.

A number of correspondents, including J. H. Fremlin, P. Dobbins, P. M. Smith, M. A. Michaelis, W. A. Edelstein, R. J. Sherwood, A. S. Bennett and M. Brown fall into this error. A. M. New states that Einstein's experiment is not a logical application of the theory. This is true and in order to draw any conclusion from it the assumption must be made that accelerations have no effect; and this assumption is made implicitly. He accepts the result, however, and states that it can be obtained from the General Theory, just as Einstein does in reference 3. It is a pity that there is, as far as I know, no English translation of this paper. In my view it is complete nonsense and provides a further illustration of the danger of using thought experiments.

Professors Jennison and Fremlin refer to talks I gave at their universities years ago and I am pleased to acknowledge their willingness to debate the subject in front of their students. I welcome Jennison's partial agreement and although he states that there is much with which he disagrees the outstanding differences could arise from the contradictions in Einstein's paper. The two specific points mentioned are readily explained.

In Jennison's view, which is shared by a number of other correspondents, the whole series of transmitted pulses is received. This is true if time dilation is the result of a change in the units of measurement, which is one interpretation of Einstein's postulates as explained in reference 2, and also if it is regarded as a real physical effect as it is in the Lorentz theory, but if it is regarded as a symmetrical effect as in Einstein's prediction, then I can find no other explanation than a loss of pulses. He also questions my statement that the Doppler effect is not mentioned in the prediction but if he consults the original paper he will find that I have quoted it correctly, and that the Doppler formula is not given until a later section of the paper. Einstein's definition of time which eliminates the Doppler effect was an ingenious but unnecessary device and I used it only so that I could quote the prediction in his own words.

The suggestion that the Doppler formula could be used as the starting point of the theory is an interesting and reasonable one. The classical formulae usually given distinguish between a moving source and moving observer, but according to the postulate of relativity it is immaterial which is regarded as moving. The formulae must therefore be made the same, which is what Einstein does. P. D. Edgley and M. Readdie also use the full Doppler formula.

Fremlin claims that he refuted my arguments (see letter in this issue); but my recollection is that he ignored them and repeated Einstein's thought experiment in a more elaborate form, as he does in his present letter.

J. Blecker raises an important point when he asks why I distinguish between the Lorentz transformations and the special theory of relativity since they are practically equivalent. My answer is that they become equivalent only after Einstein has drawn the wrong conclusion from his paradox thought experiment. Lorentz offered no explanation of his time dilation assumption: Einstein tried to explain it in terms of time and space measurements. I think his explanation is wrong and that a true explanation should be found.

T. Theocharis suggests that history has shown the futility of drawing attention to the mistakes in the relativity theory, but I think it is our duty to keep on trying, especially as I do not think any previous critic has shown exactly where the mistake occurs in the thought experiment. He expresses the view that the theory will die only if and when the aether-drift is observed. Although I am in full agreement with the importance of experiment in general, in this particular case it is my view that the theory is rendered invalid by its own internal contradictions. Moreover, most of the experiments that one can think of involve accelerations and cannot provide a direct check of the effect of uniform relative motion.

G. Machiels recounts a story concerning his work as a "Schlepen" — a kind of sheriff — in his home town. He found that large sums of money and materials were being stolen and prepared a case against the suspects. The case was not brought to court and the corruption continued for another five years before the same suspects were charged and imprisoned in another district. He discovered that the prosecutor had not brought his case because he had been told that it was prepared by a man who must be mad because he had published a book "The end of the Einstein era," which criticised the relatively theory. He offers to send me a copy if I can read Flemish. Although I cannot read Flemish the language difficulty should not prevent the interchange of scientific ideas and if he cares to send a copy I shall do my best with it.

W. Theimer has sent a book "Die Relativitatstheorie" published by A. Francke, A. G. Verlag, Bern 1977, which appears to be a comprehensive and clearly written criticism of the theory. He is trying, so far without success, to publish an English version in the UK or the USA. E. W. Silvertooth agrees that relativity is wrong and supports his conclusion from a consideration of the Doppler equation. He refers to discrepancies obtained in satellite experiments but this is outside my field of experience and I cannot make any useful comment.

M. L. Michaelis sent a long philosophical discussion on logic and understanding in science. Much of what he writes is reasonable, but I do not accept his distinction between logic and commonsense. He admits that students must not expect to understand relativity by using their commonsense and also that many textbook accounts are unsatisfactory. In view of his stress on the importance of logic it is strange that he ignores the lack of logic shown by Einstein and relativitists in their conduct and interpretation of thought experiments.

A number of writers insist that Einstein's theory has been proved by experiment, but the experiments they mention involve accelerations which are not considered in the theory. It is shown in reference 2 that the so-called theory consists merely of a number of contradictory assumptions and experiments can only indicate which if any of these assumptions is correct.

S. H. Rutherford asks what does Einstein mean by the expression clocks running slow. I do not know what was in Einstein's mind but I have tried to interpret his statements in such a way as to make sense in practical timekeeping. A short answer to some questions he asks about the measurement of time is that it consists of the counting of the number of repetitions of some periodic event. The number is recorded on a dial and the combination of periodic event and dial is called a clock. It is thus difficult to distinguish between the two.

J. de Rivas asks whether there is evidence of time jumps in caesium clocks. I expect there is, but the examples he quotes are probably changes of rate of about 1 part in 10^{12} which would give a time change of $1\mu s$ in 10 days. This is a reasonable performance for clocks of that era. It is not a change in the frequency of the spectral line but of the mechanism for using it.

P. Hirschmann writes from "a state of confused time orientation" and concludes from some rather hypothetical considerations that if Einstein were right time could be made to stand still. He is relieved to find that this is unlikely to happen. R. V. Harvey supports my "crusade" and regards the article as a stimulating challenge to students. My hope is that it will also stimulate thought among our mature scientists.

Finally I would like to say a word in favour of my critics. I realise how difficult it is to doubt the validity of a theory which is accepted by many eminent scientists and receives the continuous public adulation from the media and from distinguished people even though most of these are not in a position to judge for themselves. I had one great advantage. I knew from my practical experience of comparing clocks that Einstein's thought experiments were incorrectly carried out.

L. Essen.

Up to the time when Dr Essen wrote the above reply the following people had sent us letters in response to his October 1978 article. We thank them for their interest and are sorry that we have not been able to publish all the contributions in our correspondence columns.—Ed.

T. Barnes, Witham, Essex; A. S. Bennett, Bedford Inst. of Oceanography, Dartmouth, Canada; J. Blecker, Geneva, Switzerland; M. Brown, Aberdeen; S. K. Chatterjee, St Andrews, Fife; P. Dobbins, Maiden Newton, Dorchester; W. A. Edelstein, Univ. of Aberdeen; P. D. Edgley, Handbridge, Chester; J. H. Fremlin, Univ. of Birmingham; A. Jones, Alderney, Channel Isles; R. C. Jennison, Univ. of Kent at Canterbury; R. V. Harvey, Reigate Heath, Surrey; G. F. Filbey, Poly. of the South Bank; D. Griffiths, Imp. Coll. of Science and Tech.; P. Hirschmann, Haifa, Israel; B. L. Kershaw, Birmingham; G. Machiels, Diepenbeek, Belgium; M. L. Michaelis, Mainz/Rhein, G.F.R.; A. M. New, Fishponds, Bristol; M. Readdie, Trinity Hall, Univ. of Cambridge; J. de Rivaz, Porthtowan, Truro, Cornwall; S. H. Rutherford, Aylesbury, Bucks; E. W. Silvertooth, Flintridge, California, USA; P. M. Smith, Swansea; R. J. Sherwood, Erdington, Birmingham; T. Theocharis, Imp. Coll. of Science and Tech.

Register of research

The recent ACARD report on industrial innovation urged the Government to stimulate firms to make more use of the research facilities available in university departments. A new way in which we can find out what actual research is going on at the moment in such places is a register of current projects now being published by the British Library. Entitled "Research in British Universities, Polytechnics and Colleges" and issued in three volumes, it contains information from over 3000 departments in every university and polytechnic and a number of colleges in the UK.

Volume 1, available early in 1979, covers the physical sciences and includes sections on electrical engineering and electronics, mathematics, biophysics, materials technology, information science and other fields of interest to electronic engineers. The book lists research work in progress, with names of investigators for each project or area, duration of the work and sponsoring bodies. Names and addresses of heads of departments are given, and there is also a name index and a detailed keyword index. The volume is available at £15 (or 30 dollars) per copy from The British Library, Boston Spa, Wetherby, West Yorks LS23 7BQ (tel: Boston Spa (0937) 843434).

The other two volumes, No. 2 on the biological sciences and No. 3 on the social sciences, will be issued later. All three will appear annually, and the whole register will also be available later through the British Library Automated Information Service (BLAISE).

● The ACARD report mentioned above criticizes the academic world for having too long ignored the field of manufacturing, although it could in fact make an important and useful contributions. "The Government should stimulate firms without access to research facilities to use university departments by offering incentives, such as special tax relief, for such expenditure. It should also review and evaluate the relative merits of the various schemes for university/industry collaboration, such as Wolfson Industrial Units and the appointment of industrial liaison officers; the UGC might then be encouraged to transfer extra funds to those judged a success."

Electronics courses. Two universities are running flexibly organized courses on the latest technology in electronics. "An introduction to modern digital systems" at Leeds University, 2-6 April and 17-21 September, is broad and introductory and intended not so much for specialists as for a wide range of participants from education, the public services and general industry. The course and its laboratory activities can be tailored to individual needs. (Contact: Director of Special Courses, Dept. of Adult Education and Extramural Studies, The University, Leeds LS2 9JT). Nottingham University are offering a modular course on "Modern electronics," starting in October 1979, in which participants can select those modules appropriate to their work interests. An M.Sc. can be obtained after two years of part-time study. There are ten modules, encompassing computer hardware and software, control theory, microprocessors, signal processing, communications, solid-state devices, computer aided design, power electronics and information systems. (Contact: Mr R. V. Arnfield, Industrial and Business Liaison Office, University of Nottingham, University Park, Nottingham NG2 2RD).

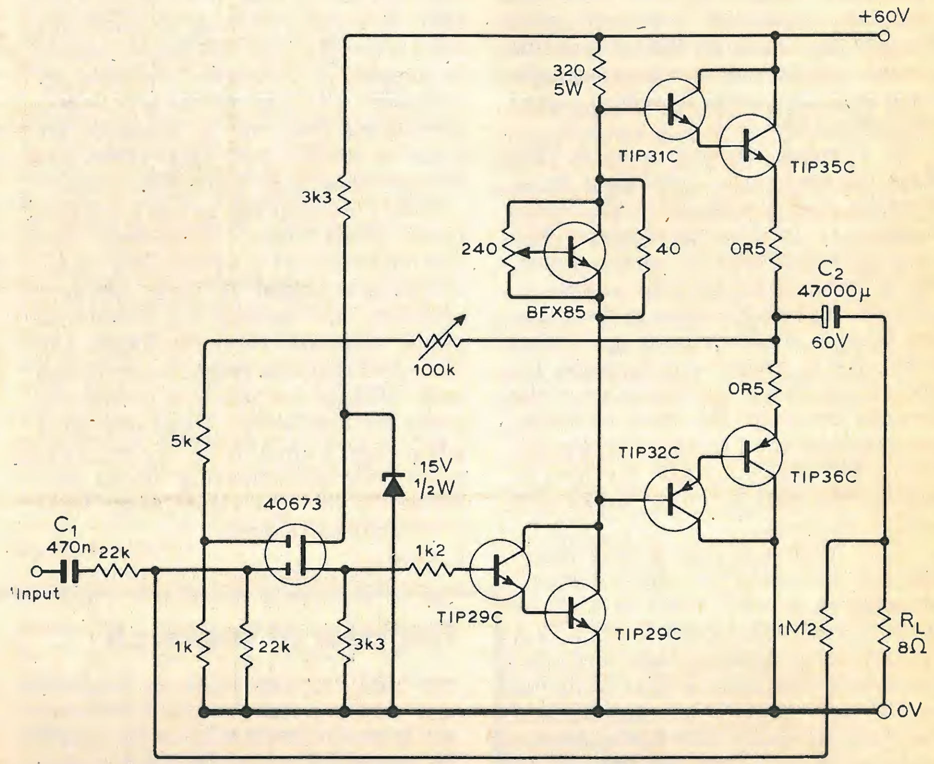
CIRCUIT IDEAS

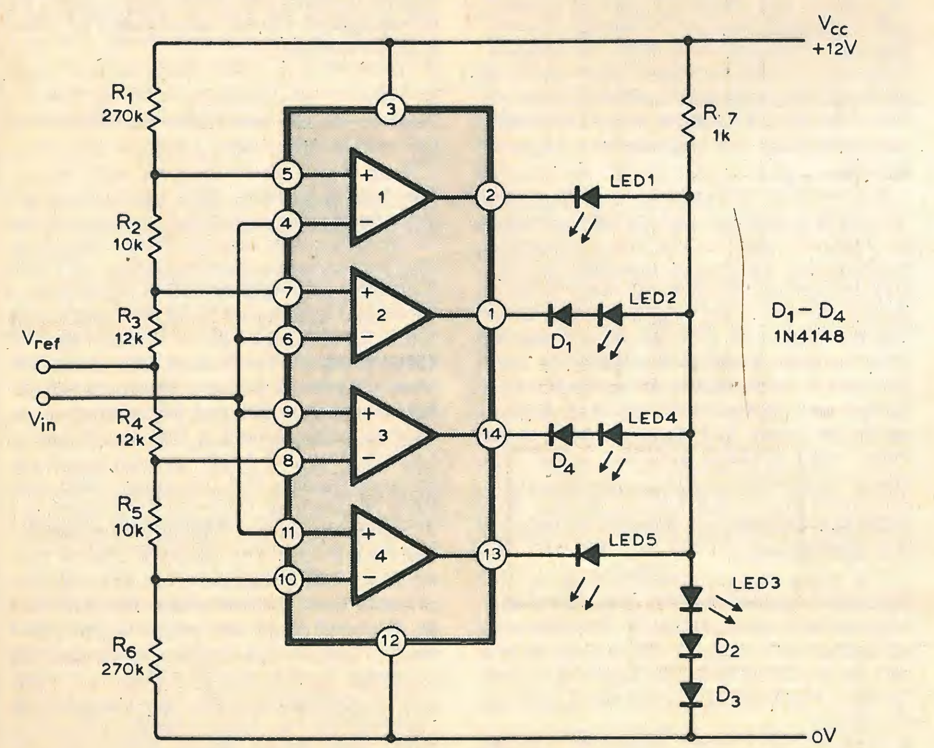
Power amplifier uses m.o.s.f.e.t. input

The normal longtail pair circuit is avoided in this design which offers a high input-impedance by using a m.o.s.f.e.t. input. The —3dB point is set by C_1 and C_2, and d.c. feedback is applied via the 100kΩ variable resistor. Quiescent current is set by the 240Ω potentiometer, and is adjusted for minimum crossover distortion.

In operation, the amplifier has proved to be very stable, and will provide up to 50W r.m.s.

A. R. van Wijgerden
Coventry





L.e.d. tuning meter

Due to their low cost and availability, l.e.d. displays are becoming popular as replacements for conventional meters. This design replaces a f.m. tuning meter with a line of five l.e.d.s, and uses a single MC3302 i.c., which contains four comparators with open-collector outputs. When off-tune, V_{in} from the discriminator equals V_{ref}, all of the comparator outputs are high, and LED_3 is illuminated. Tuning towards a station causes V_{in}, to swing more positive than V_{ref}, which drives comparator outputs 1 and 2 low but only LED_1 turns on. As V_{in} increases further, output 1 goes high, turning LED_1 off and LED_2 on. The on-tune condition turns LED_3 on again when V_{in} is within ±0.25V of V_{ref}. Comparators 3 and 4, with LED_4 and LED_5 behave similarly when V_{in} is less than V_{ref}; therefore the display acts like a centre-off moving-coil movement.

For correct operation, V_{ref} must be around 6V, otherwise R_1 and R_6 must be altered. Also, V_{ref} must have a low impedance source, so buffering may be required.

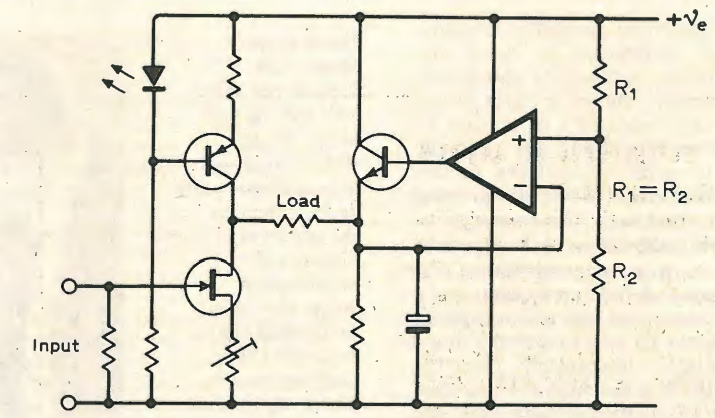
T. P. Hopkins
Haywards Heath
West Sussex

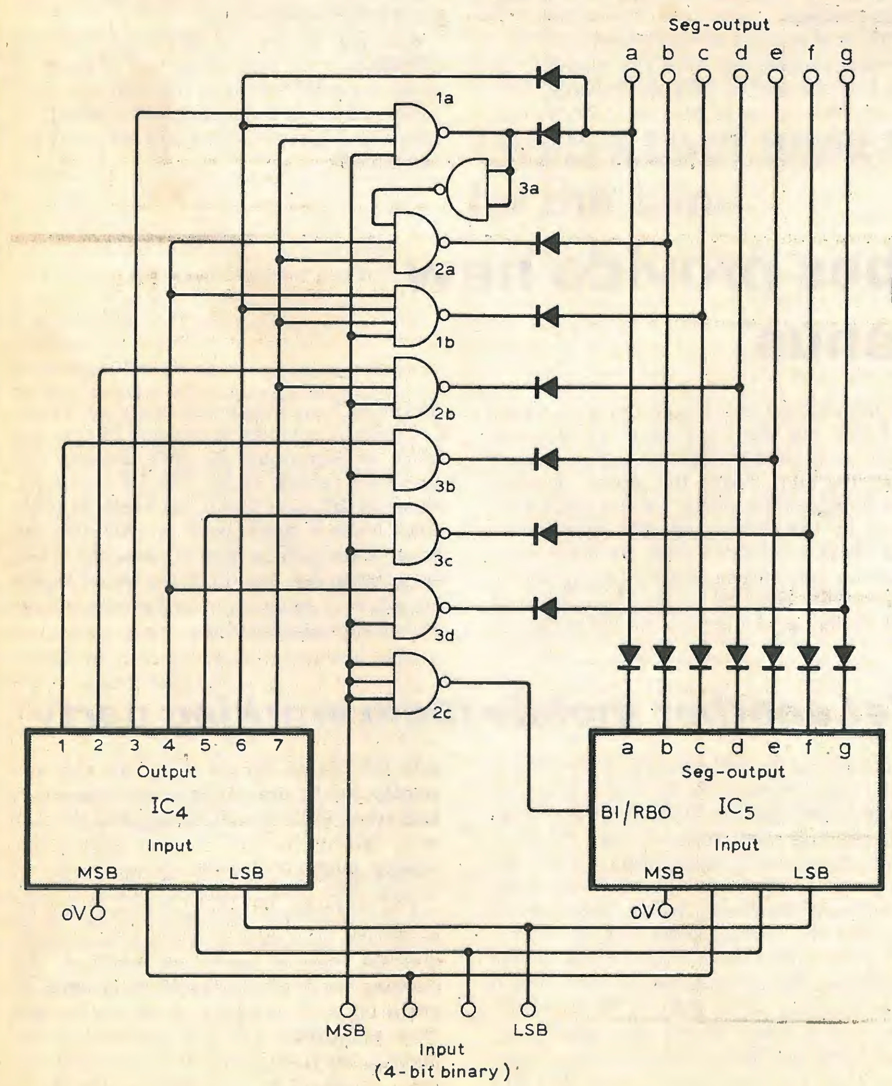
Directly coupled class A headphone amplifier

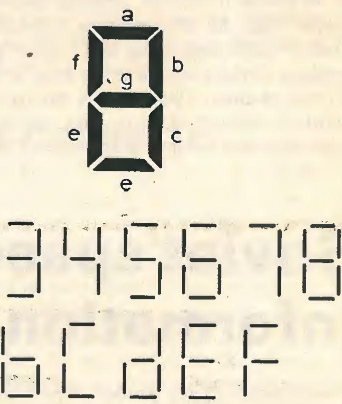
In this headphone amplifier a constant current source for the drain load allows maximum gain to be achieved. The circuitry to the right provides the necessary centre tapped supply from a single rail, and is not required if a centre tapped power supply is used.

The variable resistor is adjusted so that no current flows through the load under no-signal conditions. Circuit values depend on the supply voltage and headphone impedance which can vary from 8Ω to 2kΩ.

G. Nye
Reigate
Surrey







IC_1	SN7422
IC_2	SN7412
IC_3	SN7401
IC_4	SN7445
IC_5	SN7447

7-segment hexadecimal display

This low cost circuit decodes 4-bit binary data and drives a common-anode, seven-segment l.e.d. display, which presents the input in hexadecimal notation. The numbers 0 to 7 are decoded by IC_5 and NAND gates $IC_{1,2,3}$ decode 8 through to F. When one section of the decoder is operating, the other part is inhibited. As the maximum sink current per display segment is 16mA, suitable current limiting resistors must be used. The typical current consumption of the circuit is around 125mA.

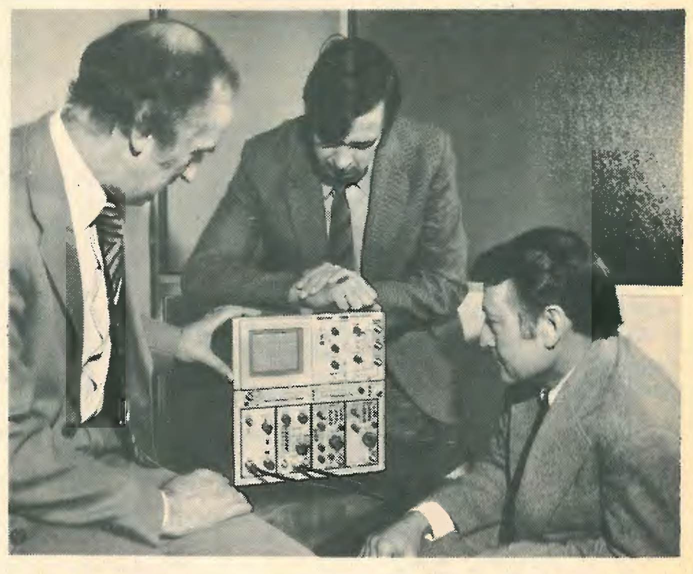
Kunal Sen
Calcutta
India

NEWS OF THE MONTH

First general-purpose 1GHz scope

Five years ago, Tektronix decided to develop a general-purpose oscilloscope to break the magic 1GHz barrier. Although a specialized instrument already offered a 1GHz bandwidth, its vertical sensitivity of around 10 V/cm and a sweep rate of only 2ns/cm made it impractical for many applications. As this performance was close to the limit, using conventional components, three main developments were undertaken. A new, wide-bandwidth c.r.t. was designed with a distributed horizontal deflection system, and a meshless scan expansion lens which expands the electron beam 4½ times vertically and 4 times horizontally, substantially reducing the tube length. A microchannel-plate electron multiplier gives a high writing speed and enables fast transients to be photographed with an average-speed camera and ordinary film. The microchannel-plate, which is a secondary emission device behind the c.r.t., also removes the problem of "blooming" when the beam intensity is high by limiting the brightness just as the plate's electron amplifier becomes saturated.

The Tektronix Model 7104 oscilloscope seen here has the high sensitivity of 10mV/cm in real time at frequencies up to 1GHz, and the ability to display sub nano-second single-shot events in ambient light. Inspecting the oscilloscope are (left to right) Keith Retallick – sales manager, Derek Smith – marketing development manager, and Ed Morrison – managing director.



To overcome the problems of high-frequency amplification Tektronix developed an in-house linear i.c. process called SHIII (super high 3). The process combines very shallow diffusions with ion implantation to produce devices with a unity gain at 6½GHz. To complement these i.cs a micro-stripline printed circuit layout was designed to accommodate each package. The third specialised design was the interconnection system which uses metallized elastomer contacts to reduce reflection losses and mismatching.

The final product of this expensive development programme was the model 7104 which is compatible with the existing Tektronix 7000 series of plug-in instruments. This oscilloscope offers a rise time of 350 ps, an X/Y bandwidth of 350MHz, full sweep triggering up to 1.5GHz, a photographic writing speed of 20cm/ns, and a trace which is claimed to be 1,000 times brighter than usual for one-shot events.

Although the price of between £11,000 and £15,000 puts the instrument out of range of many budgets, Tektronix feel that the development spin-off and intangible benefits from pioneering this specialized area are worth the investment.

Soviet space probes provide new information on Venus

Two Russian space probes which landed on the surface of Venus on December 21 and 25 have provided new information about the planet's atmosphere, according to a January issue of the journal *Soviet News*. They have shown that the ratio of the isotope Argon 36 to Argon 40 is from 200 to 300 times greater than on Earth. Special gas chromatographs which were landed on the surface of the planet have also recorded the presence of carbon monoxide. Chromatographs are usually fairly bulky instruments, but the ones used in this experiment weighed only about 2lb and were known as "Sigma" probes.

The probes were released from two automatic interplanetary stations, Venus 11 and Venus 12, which were launched on September 9 and 14 respectively as part of a continuing programme investigating Venus. The equipment on the space vehicles was developed by Soviet and French scientists.

Although Venus 11 was launched before Venus 12, the latter reached the vicinity of the planet first because it was on a shorter flight path, and its probe was released four days earlier than the other. The probes landed about 500 miles apart and reported atmospheric pressures 88 times greater than those on the Earth, and temperatures in the region of 445° to 460°C, says the journal.

The information from the probes was relayed to Earth via the interplanetary stations which continued in flight in orbits centred about the Sun. During the probes' descent, nine samples of the planet's atmosphere were taken by the chromatograph instruments and these confirmed that its main constituents were carbon dioxide and nitrogen.

An earlier issue of *Soviet News* reported that cosmonauts Vladimir Kovalyonok and Alexander Ivanchenkov, on board the Salyut 6 - Soyuz 31 complex, completed 100 days in space on September 23, 1978, beating the previous record of 96. The cosmonauts, whose health took four to six weeks to settle down while in space, were investigating the ozone layer using a special telescope. They also carried out experiments related to the formation of semiconductor crystals in conditions of weightlessness.

Yet another mobile radio working party

At the annual general meeting of the Mobile Radio Users' Association, held on January 18, it was agreed that the Association would set up a working party, together with the Electronic Engineering Association, to discuss the problems of channel loading within the mobile radio frequency bands. Both parties felt that the present policy of the Home Office on mobile radio would cause severe difficulties, especially in the Greater London area. Secretary of the MRUA, Mr Ron London, told *Wireless World* that what most worried the two parties was the Home Office view that a system which permitted 80% channel loading during busy hours was feasible. The MRUA did not think that this was possible at the present time since members had heard 70% channel loading and this had been "pretty chaotic." In due course this loading might be feasible, when users are familiar with heavy channel loading, he said, but to implement it fairly suddenly would be a mistake, particularly when a number of different types of user were involved. The working party would therefore attempt to come up with evidence to show that 80% channel loading was not practical at the present time. Mr London hoped that the party would report its findings to the Home Office within the next few months.

CB letter to the PM

On January 12, James Bryant, the president of the Citizens' Band Association, sent a letter to the Prime Minister, The Rt. Hon. Mr Jim Callaghan, pointing out the rapid growth of the illegal use of citizens' band radio in this country, and urging him to legalize high-performance v.h.f. c.b. before the pressure of illegal use compels the legislation of the American system in this country. The adoption of the American system would lead to a flood of Japanese equipment into this country, while v.h.f. c.b. radios could be manufactured in Britain. "Four British manufacturers are already prepared to manufacture such sets should c.b. be legalized," he wrote.

In his opening sentence Mr Bryant asked the Prime Minster to reconsider his government's opposition to the introduction of citizens' band radio in this country. Great Britain and Eire, he said, were the only countries left in Europe which did not allow private citizens some form of short range radio communication.

Most of Mr Bryant's letter dealt with the main arguments which had been put forward against c.b. and comments which he had to make on these objections. These arguments are now quite well known and many of his comments reflect what are now common views amongst the pro-c.b. fraternity, views that have already been discussed in *Wireless World*. However, a few of his comments are still worthy of note here.

About the argument that the administration required to control c.b. would be prohibitively complex, Mr Bryant made the point that modern silicon-chip technology made it not only possible but simple to fit every c.b. set sold, at the factory, with a unique identifying signal which could not be tampered with without the resources of a microelectronics factory and without which the c.b. set would not transmit. The extra cost of this advice would be under 50p, he said, and it would reduce the administrative costs of a c.b. service to a low level, and also increase the impracticality of criminal or anti-social use of c.b.

In the letter Mr Bryant claimed that there were many MHz of available frequency spectrum in the v.h.f. and u.h.f. regions which, though allocated were unused. The 220 to 240MHz range, for example, had unused sectors — some never used since 1944. There was also space around 900MHz, and possible space in the near future where the v.h.f. tv channels are now. Very little spectrum was needed for c.b.; according to Mr Bryant, 0.5 to 1MHz would be ample and even 200kHz could provide a reasonable service. He believed that, given political will, the spectrum space could be found.

Mr Bryant stressed that the American 27MHz a.m. standard, as used in most of the countries having c.b., was unsuitable for a small, densely-populated country like Britain, and he reminded the Prime Minister that the NEC, BREMA and the EEA were all agreed on this.

In describing the present seriousness of illegal c.b. in Britain Mr Bryant said that the Citizens' Band Association had estimated that there were now about 15,000 illegal users in this country and that their number was growing by about 1000 every month.* If the growth in illegal operators continued the Government would be forced, as happened in Australia, to legalize what was already being done. There would then be no possibility of introducing a more complex system, or automatic identification, and the Government would be forced to legalize an American-style system, with all its problems. Britain would also miss out on the 'golden opportunity' of leading the world into a new generation of c.b. radio.

* Wondering how any individual or association could possibly estimate the number of illegal operators with any accuracy at all, *Wireless World* asked James Bryant exactly how this was done. His answer was that people go out to the main cities where c.b. operation is known to take place, such as London, Bristol, Birmingham, Manchester and Liverpool, and listen. From this, he said, one can estimate the number and check it against the number of sets which the Association knows have been brought into this country. The latter figure, according to Mr Bryant, is at least 10,000, but there is equipment, legitimately manufactured for the 10-metre amateur service, which is also being used for c.b. *Wireless World* still finds it very difficult to see how these figures can be arrived at. While we know exactly how many radio amateurs there are in this country, we cannot see any way in which this number could be obtained from any amount of listening because the number of amateurs operating at a particular time depends upon so many factors. Indeed, one would expect that the problem is even greater with illegal c.b. operation because the operators, surely, would endeavour, to some extent at least, to keep their identities and locations secret. This would not help the listener who is trying to count the number of people operating at that time. Having said this, *Wireless World* does agree with most of what James Bryant has said in the remainder of his letter.

When asked which four British manufacturers were prepared to manufacture c.b. sets, Mr Bryant said that, for their own commercial protection, they had requested that their names be kept secret.

Conferences and Exhibitions

After two successful conferences at Montreux in 1975 and 1977, the 3rd Electromagnetic Compatibility **(E.M.C.) Symposium and Exhibition,** planned for May 1 to 3 this year, is to be held in Rotterdam, Holland.

The **22nd Salon International des Composants Electroniques** is to be held from April 2 to 7 this year at the Porte de Versailles, Paris. It will be an exhibition of components and electronic sub-assemblies, measuring instruments, and materials and products for the electronics industry. A conference will also be held between these dates.

Communications 80 will be held from April 14 to 18, 1980, at the National Exhibition Centre in Birmingham, England. With an exhibition area of 18,000 square metres, it is expected to be the largest yet held. The international exposition is again being organised by Tony Davies Communications.

A call for papers has been made by the IEE for the 5th **European Solid State Circuits Conference** (ESSCIRC 79) which is to be held at the University of Southampton from September 18 to 21 this year. Abstracts should be submitted by May 2. Further details from the Institution of Electrical Engineers (IEE) Conference Department, Savoy Place, London WC2R 0BL.

A new exhibition for the amateur, hobbyist and small professional buyer is to be held at Alexandra Palace, London, from June 28 to 30 this year. **The Great British Electronics Bazaar,** as it is to be called, is being organized by the Evan Steadman Communications Group, Saffron Walden, Essex.

Twelve hour book-reading cassette for the blind

The Foundation for Audio Research and Services for Blind People has achieved one of its major objectives — the storage of 12 hours' reading on a C90 cassette similar in design to a standard compact cassette. To accomplish this they employed specially-modified cassette recorders which made use of four recording tracks in the mono track order 1, 4, 3, 2, at a tape speed of 1.2cm/s. The significance of this achievement is that it will enable audio books to appear on the shelves of public libraries alongside printed editions, and be available in bookshops at comparable prices.

Mr Arthur Wilson, the honorary director of the Foundation, said at a press conference in November that, apart from people with visual and physical handicaps, there were millions of people who could not or did not take advantage of printed books but who would read audio books. Remploy Ltd, which provided employment for seriously disabled people, had undertaken to manufacture equipment by which these audio books could be read. Mr Wilson concluded his speech with an appeal; first, for general support for the project in principle, and secondly, for financial help to enable the project to proceed as quickly as possible. A sum of £50,000, required to translate the laboratory versions of the cassettes into prototypes, was quoted as the appeal figure in a draft of the conference report. The Foundation's HASLAF award for 1978 was then presented to Mr Malcolm Watford of Hemel Hempstead in recognition of his work in designing modifications which had already transformed the lives of many blind and partially-sighted people now using equipment supplied by the Foundation.

Technical information which has been released about the equipment so far gives a wow-and-flutter figure of less than 0.1% and a frequency response of at least 6kHz, despite the slow running speed.

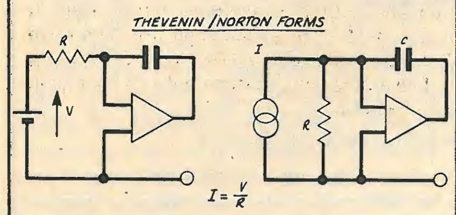
Solar power has great potential in Israel

Experts in Israel say that the Dead Sea has the potential for supplying their country with 150% of its electricity needs. Already, a two-acre solar pond on the shores of the Dead Sea is providing enough energy to satisfy the heating and cooling requirements of a 200 room hotel being built there.

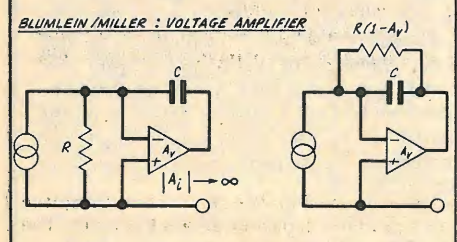
The solar pond idea was conceived by Professor H. Tabor, of the Hebrew University in Israel. Energy in the form of hot water is extracted from the bottom of a specially layered pond without making waves, which could disturb the build up of heat. Each layer consists of water of a different salinity. The hot water is then passed through heat exchangers so that the heat produced may be used with turbines driving electrical power generators or directly for air conditioning or other systems.

Novatexts — 2

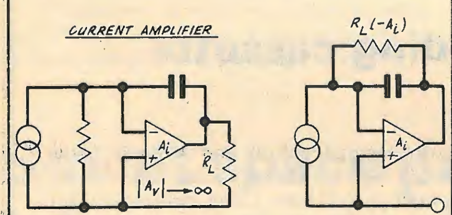
by Peter Williams



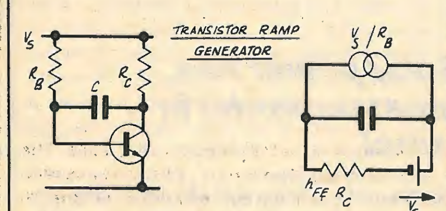
It is now necessary to investigate in more detail the imperfections and sources of error in ramp generators. The discharge part of the cycle is left till later, and the results obtained are equally applicable to triangular wave and sawtooth generators, as to the generation of any waveform having a nominally linear region. The first step is to apply the circuit theorem to the input section comprising the voltage generator in series with a resistor. This is identically equivalent to a current generator in parallel with the same resistor provided that I=V/R. This allows of a different interpretation of the effect of finite voltage gain. The higher that gain, the lower the voltage appearing across the equivalent parallel resistor, and hence the smaller the error current. As the voltage gain becomes infinite so the error current in the equivalent resistor reduces to zero and the circuit behaves as if the current generator were perfect. The circuit only functions correctly for an inverting amplifier — if non-inverting, the regenerative feedback through the capacitor leads to oscillation.



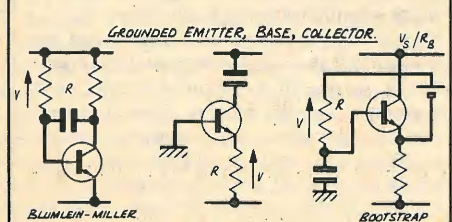
It is simpler and also more practical to consider the effects of finite voltage and current gain separately. At least for first-order terms the effects are additive, while in important practical cases only one error at a time is significant. For finite voltage gains the Blumlein/Miller effect provides a good way of evaluating the error. An impedance Z placed across an amplifier of gain A_v results in a current flow at the input equivalent to an impedance $Z/(1-A_v)$ placed in parallel with the input (a second impedance across the output required to complete the equivalence has no practical effect if $|A_i| \to \infty$ as in the case assumed here). This places a capacitance of $C(1-A_v)$ in parallel with R at the input showing the new time-constant to be $(1-A_v)\tau$; with A_v negative and $|A_v|$ very large the time constant is correspondingly large. The inverse transformation can be even more useful. The resistor across the input is replaced by one across the feedback capacitor to provide the same input current. Its value is found to be $R(1-A_v)$, and the final effect is that of a very high value of leakage resistance: the charging current still depends on R, while the current error corresponds to $R(1-A) \gg R$.



The advantage of the previous interpretation becomes clearer when the errors due to finite current-gain are investigated. In this case we assume an infinite voltage gain so that only one error at a time is under investigation. Hence there is zero voltage drop across the amplifier input terminals and in the Norton equivalent form the generator shunt-resistance, shown in broken lines, introduces no error. The load resistance draws a current that results in a proportional current flow into the amplifier input terminals. This current increases linearly with the output voltages and has the same effect as a resistor placed directly across the capacitor. The value of the equivalent resistor is found to be $-A_iR_L$ where A_i is negative, and $|A_i| \gg 1$ is the ideal condition. Again this allows the resistance determining the error in the slope to be large while the load resistance is small. This form of error is dominant in single-transistor ramp-generators, widely used for simple time-base circuits. The effect of finite voltage gains is apparent in ramp generators using field-effect transistors.



One particular form is considered first to show the application of the theory introduced above. Two other forms, also well-known, are then shown to be of the same family corresponding to a simple shift in ground-point. A capacitor is placed between base and collector of a bipolar transistor with resistors from each point to the supply line (positive for a n-p-n transistor). The transistor is assumed to have V_{BE}=constant corresponding to a high voltage gain, and this may be further simplified to $V_{BE}=0$ since typically $V_S \gg V_{BE}$. The current in R_B is fixed and the majority of it charges the capacitor with a small portion flowing in the transistor base to sustain the required output. Initially the input is shorted, the output is at V_S and the capacitor is fully charged. Hence the voltage across R_C is zero and when the short is removed $1_B \to 0$. The inverting gain results in a negative-going ramp, increasing the voltage across R_C and the collector and base currents. Thus while the change in output voltage produces a change in slope attributable to a shunt resistance $h_{FE}R_c$ (where $h_{FE} = -A_i$) a voltage V_S has to be added in series with it to account for the fact that for $V_C = V_S$ $V_{RC}=0$ and vice-versa.



Three apparently different ramp generators appear in the technical literature: the Blumlein/Miller integrator, the constant-current circuit and the bootstrap circuit. These differ greatly in detail but form a closed family with all essential points in common. The active device has three terminals any one of which may be grounded. In one mode (grounded emitter, source, cathode) the stage inverts and the magnitudes of both voltage and current gain are $\gg 1$. In the second mode (grounded base, gate, grid) the stage is non-inverting with approximately unity current gain. In the third mode (grounded collector, drain, anode) the stage is non-inverting with approximately unity voltage gain. The capacitor is placed between base and collector or the equivalent locations for f.e.t.s and valves, with a resistor and voltage bias in series between base and emitter. The bias voltage may be provided directly by the supply, by a separate but grounded bias voltage or by a floating battery. Thus the circuits differ in convenience but are internally similar. Each forces a constant current to flow in a capacitor generating a linear ramp.

Linear ramp generators

THEORY

The voltage generator can be replaced by the current generator provided each provides the same open-circuit voltage and short-circuit current. Let the current generator have a resistor R in parallel.

$V/R = I$ short-circuit current
$V = IR'$ open-circuit current
Result holds for $R' = R$

• • •

The Blumlein-Miller effect postulates the replacement of a feedback impedance by input and output terminating impedances that draw the same currents from source and output as does the feedback impedance and are hence equivalent to it. Commonly the impedance across the output can be ignored: with a high-gain amplifier it is almost equal to the feedback impedance while the output impedance is low. Similarly an impedance across the input can be replaced by a feedback impedance of appropriate value.

Let i, i′ be currents drawn from the source in the two cases

$i = v/r$
$i' = (v - A_v v)R'$
For $i = i'$
$v/R = v(1-A_v)/R'$
$R' = (1-A_v)R$

For A_v large and negative
$R_1 >> R$ and the time constant is
$\tau' = RC(1-A_v) = (1-A_v)\tau$
$\tau = |A_v|\tau$

This is identical with the value obtained by the usual Blumlein-Miller calculation where C is replaced by $C(1-A_v)$ across the input.

To complete the equivalence the current flowing in the notional feedback resistance has to be cancelled by a resistance across the output carrying an equal and opposite current. In the high-gain case the voltage is large and the resistance correspondingly so. For op-amp circuits the loading effect is negligible and only input/feedback equivalence need be observed.

• • •

For $|A_v| \to \infty$ the input voltage $\to 0$, a true virtual earth that prevents the source resistance from contributing to the non-linearity. The current gain is A_i and is negative for negative feedback.

Load current V_o/R_L

Input current $\dfrac{V_o}{A_iR_L}$

Replace R_L by resistor R′ between input and output. This resistor is to divert the same current away from the capacitor as did the amplifier input, the gain of the amplifier now being considered infinite.

Current in $R' = -\dfrac{V_0}{R'}$

$\therefore \dfrac{V_0}{A_iR_L} = -\dfrac{V_0}{R'}$

and $R' \to \infty$ for A_i large and negative.

• • •

For $V_{BE} \to 0$, charging current is V_s/R_B.

Initial conditions $V_c = V_s$
and $I_{RC} = 0$
$I_B = 0$
$h_{FE} = A_i$

Error current $= \dfrac{V_s - V_c}{h_{FE}R_c}$

This current has an initial value of zero ($V_s = V_c$) and a maximum value of

$\dfrac{V_s}{h_{FE}R_c}$ for $V_c = 0$.

$\therefore$ Max% error is $\dfrac{V_s}{h_{FE}R_c} \Big/ \dfrac{V_s}{R_B} = \dfrac{R_B}{h_{FE}R_c}$

EXAMPLES

1. An amplifier has a voltage gain of −500 and negligible input current. It is used as a ramp generator with a 10nF feedback capacitor. The drive current is obtained from a 10V source through a 10kΩ resistor. What is the approximate time to complete a 20V ramp? Estimate the % change in slope from beginning to end of the ramp.

Input current ≈ 1mA

$\therefore \dfrac{\Delta V_c}{\Delta t} = \dfrac{10^{-3}}{10^{-8}}$

$\Delta t = \dfrac{20.10^{-8}}{10^{-3}} = 2.10^{-4}s$

$\Delta t \approx 200\mu s$

Circuit is equivalent to perfect current generator but with resistor $10k\Omega[1-(-500)]$ in parallel with capacitor ≈ 5MΩ.

∴ With V_c 20V, $I_R \approx 4\mu A$. Thus the charging current is (1−0.004)mA. But $dV_c/dt \propto I_c$ i.e. the slope is reduced by four parts in a 1000 or 0.4%.

2. Repeat the previous question using the Blumlein-Miller effect to replace the feedback capacitor by an equivalent capacitor across the input. The results can be obtained by expanding the exponential term.

$V_o = AV$
$V = V_1(1-\exp -t/\tau)$

$V_0 = -500.10.(1-\exp -t/\tau)$

$\dfrac{dV_0}{dt} = \dfrac{-5000}{\tau} \cdot \exp -t/\tau$

$\tau \approx 10^4.10^{-8}[1-(-500)]$
$\approx 5.10^{-2}s$

For $\Delta V_0 = 20V$ and the relatively high gain, ΔV is small compared with V_1 i.e. $t << \tau$

$\exp -t/\tau \approx 1 - t/\tau$.

$\dfrac{dV_o}{dt} \approx \dfrac{-5000}{\tau}(1-t/\tau)$ and $V_0 \approx \dfrac{5000t}{\tau}$

i.e. the fractional change in slope is

$\approx \dfrac{t}{\tau} = \dfrac{20}{5000} = 0.4\%$

3. An amplifier having $|A_v| \to \infty$ and $A_i = -100$ feeds a 5kΩ load. The feedback capacitance is 1μF and the input is an e.m.f. of 5V in series with 1kΩ. Determine (i) the initial slope of the output waveform (ii) the % change in slope at an output of −10V if the load is removed.

The initial slope $\dfrac{dV_0}{dt} = \dfrac{-dV_c}{dt} = -\dfrac{I}{C}$

$= \dfrac{-5.10^{-3}}{10^{-6}} = -5{,}000V/s$

When the output is −10V, load current is −2mA.

$\therefore$ input current is $\approx \dfrac{-2.10^{-3}}{A_i} = \dfrac{-2.10^{-3}}{-100} = 20\mu A$

On removing load, the slope changes in proportion to the current i.e. ≈ 20μA is 5mA or 0.4%.

Alternatively take the load resistor as equivalent to a resistor of value $R_L(-A_i)$ across capacitors i.e. 500kΩ. At 10V out the current is again 20μA reducing the charging current and hence the magnitude of the slope by 0.4%

Low-cost logic analyser — 2

Construction and application

by B. C. Adams

THE LOGIC ANALYSER may be built into any suitable instrument case, preferably with a tilt-up stand as shown in the photograph, the prototype incorporating a separate front panel and removable chassis for ease of servicing. The circuitry was wired on stripboard using self-fluxing, insulated copper wire, and the l.e.ds were mounted on 0.1in pitch Veroboard about ¼in clear of the board. By drilling 3/16 in diameter holes in the front panel with the same pitch as the l.e.d.s, the display can be mounted behind the panel without the need for individual l.e.d. mounting clips and wiring. The display matrix for the sample channel can also be mounted on Veroboard and supported behind a rectangular slot, cut in the front panel and covered with a tinted plastic screen.

The data inputs use 2mm connectors mounted directly beneath each respective indicator, and an extra socket is used for the 0V connection. Trigger input, sample channel and external input use BNC sockets, which allow the use of existing oscilloscope coaxial leads and screen interference signals. Slide switches are used for the selection of positive or negative waveform edges and the external input, and miniature thumbwheel switches preset the hexadecimal comparator and delay sections. The threshold control potentiometer should be linear to within ± 5% so that approximate calibration via the front panel can be achieved.

All wiring between input sockets, comparators, data latch and sample channel sections should be as short as possible, and the trigger input should be connected to the D type latch via coaxial cable.

The power supply shown in Fig. 8 uses regulator i.cs to give +5V at 2A, +12V at 200mA, and −5V at 100mA. Supply leads to the comparators must be as short as possible to reduce unwanted inductances which can cause the comparators to oscillate. Leads should also be decoupled with 0.1μF low voltage ceramic capacitors between the +12V to 0V to −5V rails for each comparator, and a 10μF 35V tantalum capacitor for every six comparators. The t.t.l. supply must also be decoupled with one ceramic 0.1μF capacitor every three packages.

Applications

The following section describes some typical applications for the logic analyser. Unless a storage oscilloscope is available it is very difficult to view a one-shot event or series of events. The sample channel can store the logic signals if data information rather than signal parameters such as rise time are needed. To detect and store a single pulse, the sample channel is linked with the external trigger input and connected to the signal point. The trigger threshold and sample channel threshold are set for the logic family in use, and trigger edge setting is made, dependent on whether the input signal is normally low or high and whether the trigger delay is being used. Typical waveforms that can be stored are shown in Fig. 9. After the correct edge of the input pulse has occurred, the trigger inhibits the sample channel and the pulse is displayed. By using the delay mode, the display will also store the state of the input signal after the trigger signal has occurred. The period of the pulse may be calculated by counting the number of sample clock periods that have switched the input. Each l.e.d. position represents the input logic state at the time of one sample clock edge: therefore, if the pulse is shown high for 22 l.e.d. positions and low for the remaining 10, the pulse period is 22 times the sample clock period. It should be noted that there can be an error of ±1 sample clock period on each displayed transition of the input signal, and pulses of a shorter duration than the sample clock period may be missed.

It is often necessary to design interface circuitry for a mechanical contact and a logic system. With such circuitry the approximate period of any contact bounce may be required and this can be measured by connecting the contact to the logic analyser, and using the sample channel to store the bounce waveform. By using the delay mode, the display will show the bounce signal after the initial trigger edge has been received. The sample channel can also be used to display serial data from synchronous or asynchronous systems. By using the output clock of a teleprinter as the sample clock of the analyser, ASCII codes can be stored and displayed.

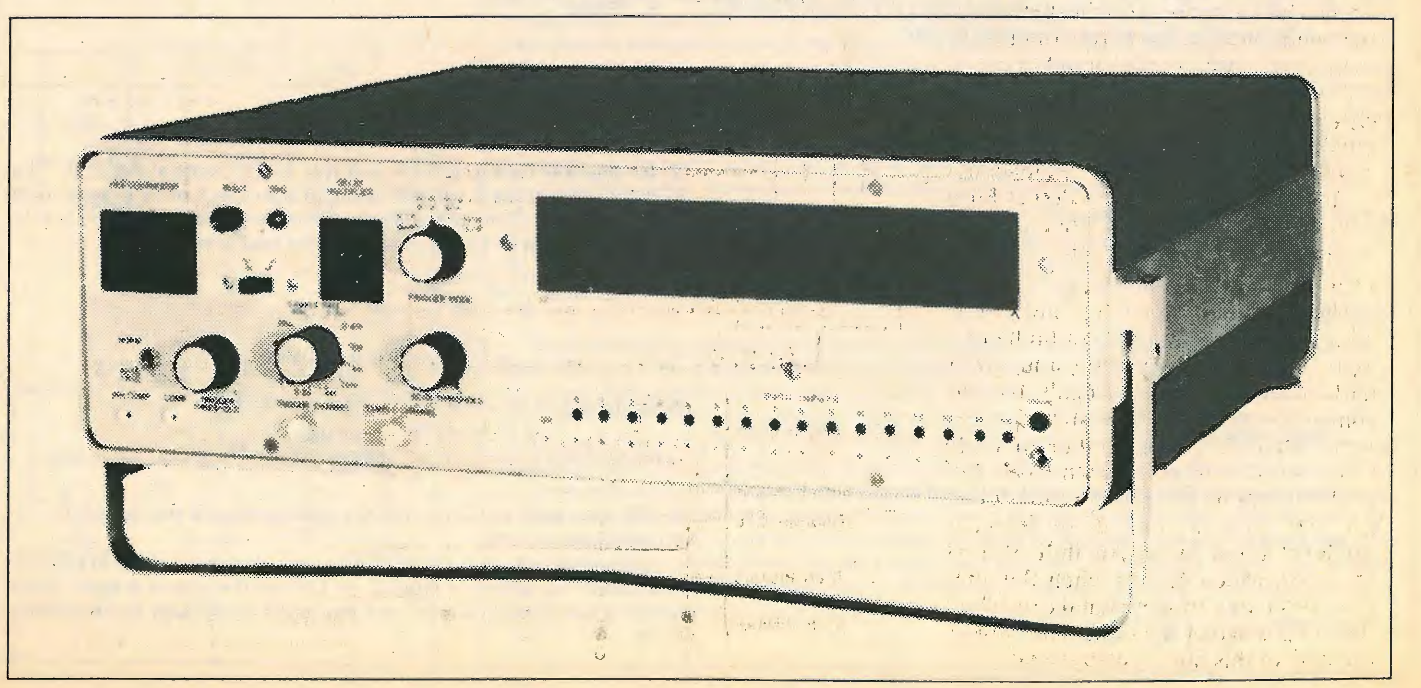
If the data latch inputs and sample channels are used as shown in Fig 10, serial to parallel converters can be easily checked.

Often, in logic systems, faults cannot be detected by a single step process because they are caused by the dynamics of the systems, e.g. decoding a delay in a counter which causes an incorrect count. In such cases a sampling technique is necessary, but it can be difficult to ascertain the state of a number of signal points at a predetermined time. However, the data latch allows the sampling of signal points without interrupting the system.

The data latch can also be used when function checking data buses, i.c. outputs, b.c.d. decoders, counters and memories. The delay mode adds to the flexibility of the analyser by enabling the latch to sample data at a preset time after the arrival of a trigger signal. For example, if it is necessary to check the contents of a counter after it has received a number of count pulses, the counter outputs are connected to the data latch, the count clock is connected to the external clock input and trigger input, and the delay mode is selected for the number of pulses required. When the count starts, the analyser will trigger and wait the preset number of pulses before inhibiting the data input latch. The latch display will then show the count value stored after the preset number of pulses as shown in Fig. 11.

A similar system can be used for checking memory contents against the number of write pulses received by the memory. In addition, the hexadecimal comparator can be used to detect false codes produced by the memory, and the sample channel can record the state of a memory control line.

The problem of detecting and evaluating random or intermittent faults in a logic system is a common and often difficult one. This is especially true in complex systems such as microprocessors, where a large number of logic codes are produced. In such cases the analyser can be left on-line to monitor the logic system, and set to detect a predetermined fault. An indicator is provided, which flashes when the analyser receives a trigger signal caused by the occurrence of the fault. The data at the time of this fault is also stored.



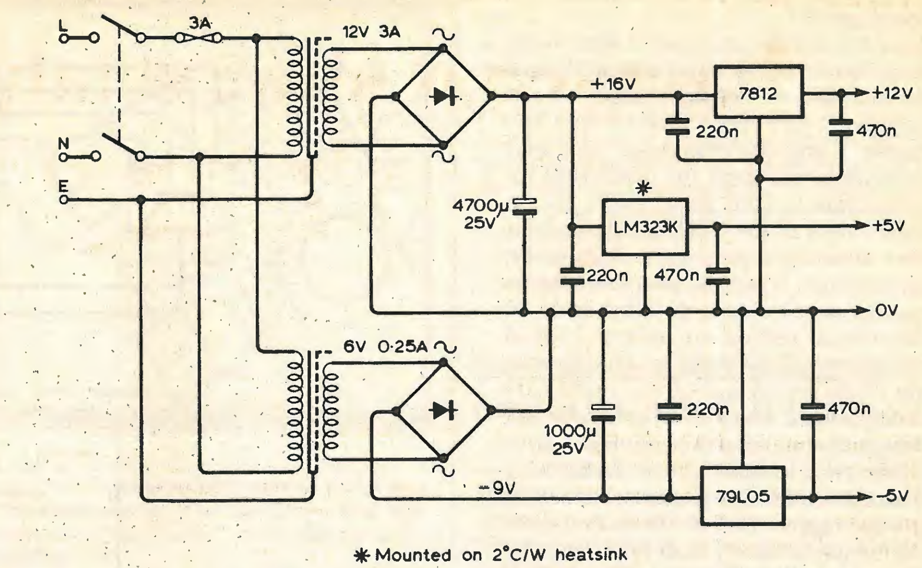


Fig. 8. *Power supply.*

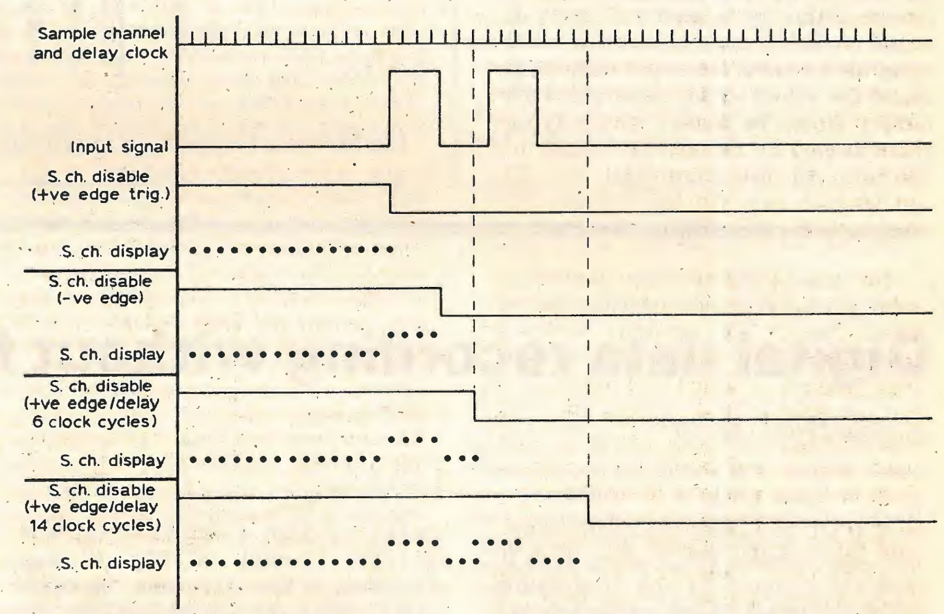


Fig. 9. *Typical sample channel displays.*

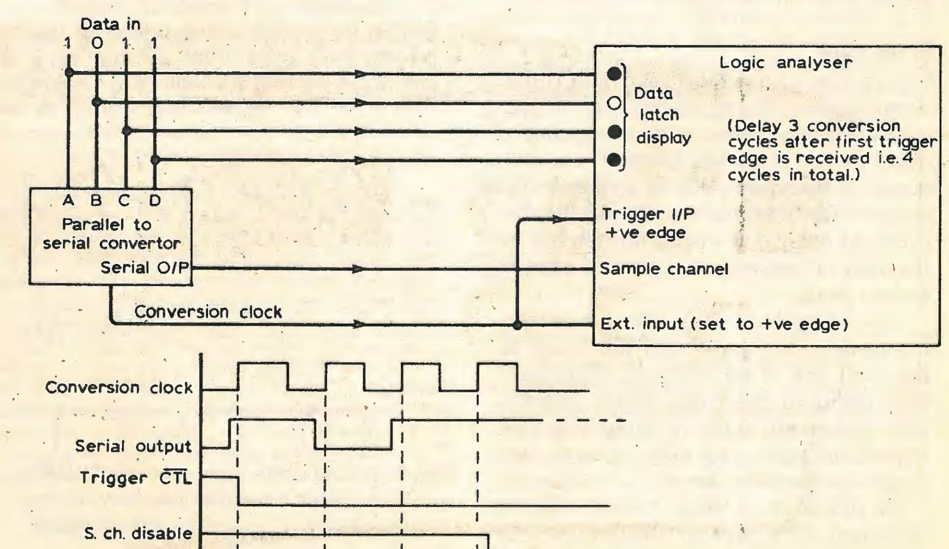


Fig. 10. *Test system for checking a parallel-to-serial converter.*

Conclusion

Since I built the analyser it has more than repaid the initial investment, and has enabled me to solve many more diagnostic problems than I had intended. Using the equipment has also given me some ideas for improving its performance. One suggestion is the replacement of the clock oscillator by a more accurate crystal type. It must be remembered, however, that the sample channel always has a possible error of one clock period on every stored transition, and the delay counter can be one clock period out at the end of its timing period. The l.e.d. display for the sample channel could be replaced by a single row of indicators, and the number of sample channels increased, each with its own trigger-control selection to provide signal or data phase relationships. This would also permit the simultaneous storage of triggered and delay triggered waveforms. The data latch section could be expanded so that it stores, for example, 16 bytes clocked into the store by a separate input. It would not be necessary to display all 16 bytes at the same time, but each byte could be selected for display. This facility would be useful for verifying truth tables or recording blocks of machine code instructions etc. □

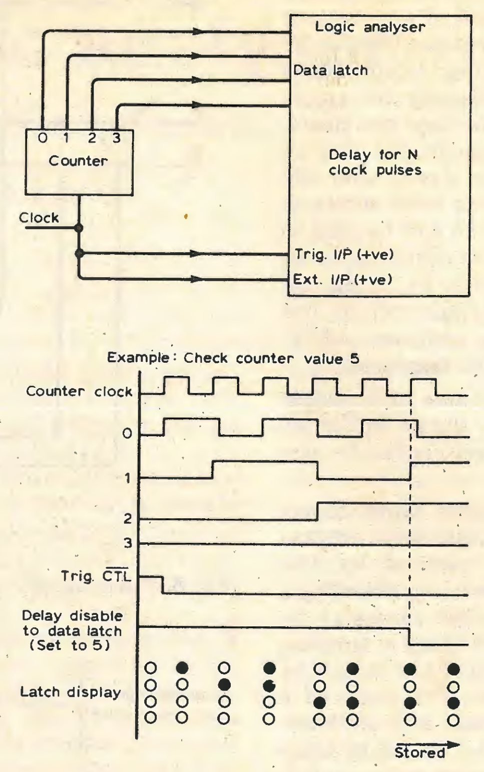


Fig. 11. *Using the analyser to verify a counter's operation.*

Digital data recording without f.s.k.

continued from page 59

work at all. Any signal above this minimum will operate the doubler even if severely clipped in the preceding buffers/inverters. However, for reliable high frequency operation it is best to operate the operational amplifiers within their linear region.

Error rate

Errors are caused by imperfections (drop-outs) in the recording tape. If the tape drop-out time is as long or longer than the bit duration then errors will occur. If the drop-out is appreciably shorter than this the system will only be prone to error if the drop-out occurs in the interval between the onset of a pulse and its peak.

Tape drop-outs that occur between the peak of one pulse and the onset of the next are of no concern. Drop-outs that occur in the rising pulse interval may either advance or delay the true transition time and may or may not result in a received error.

In practice it was found that a recorded data rate of 750 bits/s produced 15 to 20 bit errors per 1800ft reel of 3M's 2106 ¼in audio tape. The recording was made at 4.75cm/s and the errors determined at a four-times speed up (19cm/s) on a Sony stereo tape recorder (model TC252). It was reassuring to see that using the clock track option no errors resulted from the

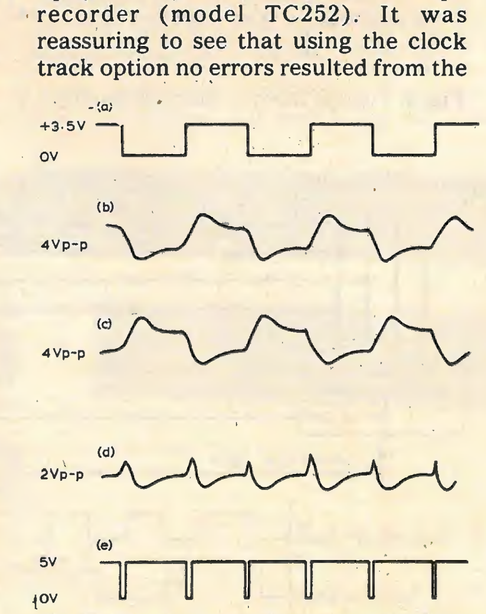


Fig. 7. *Waveforms in frequency doubler of Fig. 6: (a) original 6kHz square wave clock signal; (b) typical playback signal fed to upper diode; (c) inverted playback signal fed to lower diode; (d) diode gate output; and (e) collector output.*

deliberate slowing of the playback speed by injudicious finger pressure on the tape supply reel.

Expressed more conventionally, error rate was about 1 in 5×10^5 recorded bits. The total storage capacity of a single track of an 1800ft reel is about 750K 8-bit bytes in which each byte is assumed to be formatted with start, stop and parity error bits.

Errors can be dealt with in two ways: (1) The played back information in error may be ignored. (2) The information may be monitored by means of a separate playback head as recording is taking place. If an error is detected the last block of information can be rewritten.

In the Barts heartbeat interval data logging system it was thought that the occasional loss of a data word could be tolerated without seriously jeopardising the statistical results. The receiving computer's software notes that an individual word is in error and deletes it from the statistical calculations.

However, if it is essential to ensure that each and every data word is correct then it would be necessary to adopt the second, more complicated, approach. □

LETTERS TO THE EDITOR

RELATIVITY AND TIME SIGNALS

I would like to comment on the article by Essen on relativity and time signals in your issue of October 1978. I would like first to say that Dr Essen is quite incorrect in saying that "No one has attempted to refute my arguments." A number of refutations have been provided, over more than two decades, including for example a letter written by myself in *Nature* in 1957 of which I enclose a reprint. Furthermore, Dr Essen came himself to this Department in November 1968 and he and I debated the problem with an audience of students. During this debate I gave a detailed and calculated refutation of his thesis. The problem is not that there has been no answer to his arguments, but that he has failed to understand the answers which have been repeatedly given.

In each case the main discussion was concerned with the "twin paradox"; according to Einstein's theory of one pair of twins who remains on earth will have aged more by the time they meet than one who travels fast to a distant point and then returns. Dr Essen's statement that the Einstein theory implies that more ticks are transmitted than received by either Traveller or Stay-at-home, each of which has with him a clock ticking at a standard rate, is nonsense. One of the ways of refuting Dr Essen's arguments is to show that if Traveller goes at very high speed from earth to a distant point, turns round in a short period and returns at the same high speed, his clock will in fact have ticked fewer times than has the clock on earth which is operating throughout Traveller's hourney. The fact that *all* ticks emitted by each individual are received by the other is the solid evidence for the asymmetry of ageing. There is of course no *a priori* reason for assuming symmetry of results; one twin has never accelerated and the other has suffered a major acceleration on starting and a major deceleration and re-acceleration at the goal. The asymmetry is clearly shown by an extreme example. If Traveller moved at such a speed that he took only an hour longer to reach Sirius (a distance of 12 light years from Earth) than a beam of light would have, Stay-at-home will observe his recession not just for 12 years + 1 hour but for an hour more than 24 years since Stay-at-home will see Traveller's arrival and deceleration 12 years, in earth time, after it actually occurred. Stay-at-home will watch Traveller's return from a distance of 12 light years for a period of only one hour since Traveller will arrive at earth only an hour behind the light emitted from Sirius at the time of his turnaround. If Traveller is broadcasting the ticks of his clock during his outward journey these will be returning to earth at a very much slower rate owing both to the Döppler effect and to the relativistic differences of the rate of the clocks. This slow rate will be observed by Stay-at-home for 24 years and an hour. During Traveller's return the rate of receipt of ticks on earth will be enormously greater but this very much greater rate will be observed for only one hour.

The observations of Stay-at-home's clock by Traveller, however, are quite different. From Traveller's point of view the amount of slowing down of the ticks from Stay-at-home's clock during the earth's recession from him will be identical with the slowing down observed by Stay-at-home during Traveller's recession. On Traveller's return, similarly, when he sees the earth approaching him rapidly Stay-at-home's clock will appear to him speeded up by just the same amount as Traveller's clock had appeared to be speeded up as seen by Stay-at-home.

Now, whatever the time may be which is recorded by Traveller on his outward journey*, i.e., the time that it appears for him for Sirius to reach him, exactly the same time period will be recorded by Traveller for the earth to reach him on the return journey since at the moment of his deceleration when he is stationary with respect to Sirius and to earth, the distance away from earth will clearly appear to him identical with the apparent distance of Sirius from earth just before he started.

Accordingly, while Stay-at-home saw a slow tick rate for a very long time and a fast tick rate for a very short time Traveller sees the slow ticks and the fast ticks from earth for equal times and the total number of ticks received will therefore be very much greater. For ticks we can read heart-beats, and accordingly Stay-at-home and his clock must have aged more than for Traveller and his clock. It is easy using Einstein's equations to work out exactly both these times and the total number of ticks in each case but even without this it is evident that the experiences of the twins are not symmetrical and that there is no reason at all to suppose that they should have aged by equal amounts.

Finally, it should be pointed out that we have found experimentally that a fast moving particle which in the laboratory frame moves away at high speed and then returns will appear to age very slowly. π mesons that revolve in a big accelerator at speeds approaching that of light do, on the average, survive for a very much larger number of rotations and do show a half-life for decay very much longer than do similar mesons which remain more or less stationary in the laboratory. It is thus quite certain that the universe does not give a symmetrical answer to the twin paradox whatever Einstein or Essen may theoretically predict. Since I find no difficulty in calculating the increased half-life of the π mesons by using exactly the same Einsteinian formula as I would have in finding the age difference of the twins, I am also convinced that Einstein's theory is correct and Essen's theory is wrong.

J. H. Fremlin (Professor)
Department of Physics
University of Birmingham

*38 hours. This time is easily calculated. All parties to the controversy – so far as I know – accept that objects moving fast with respect to an observer will appear to that observer to be reduced in length along the direction of motion – the Fitzgerald-Lorentz contraction. The amount of this is: $\sqrt{(1-v^2/c^2)}$ so that the case under consideration where $v=c(1-1/(12\times365\times24))$ or $c-v=9.5\times10^{-6}c$, the contraction is to $\sqrt{(1.9\times10^{-5})}$ or 0.0044, times the original length. Accordingly, while Traveller is in transit, the dimensions of the Universe along the earth-Sirius line is reduced by this amount and to him the earth-Sirius distance is only 0.0044×12 light years, or 38 light hours. Accordingly, Sirius which is approaching him at nearly the speed of light, will reach him in about 38 hours and earth will require a similar period to return to him after his retardation and re-acceleration.

MEDIUM WAVE SPURIAE

After the medium-wave frequency changes on 23rd November 1978 I noticed an "extra" BBC Radio 1 signal on 729kHz; careful listening revealed that Radio 2 was in the background, obviously indicating an intermodulation product of some sort. A further spurious signal was discovered on 963kHz consisting of Radio's 1 and 3. The prime suspect was of course the receiver, but after various checks with attenuators and retuning, trying another receiver and getting other people to try with their own receivers in different locations, it seemed likely they were transmitted spuriae. This impression is reinforced by the fact that the two frequencies can be explained by simple intermodulation of the Brookmans Park transmitters:

729kHz = 2 × 909kHz (R2) — 1089kHz (R1)

and

963kHz = 2 × 1089kHz (R1) — 1215kHz (R3)

A telephone call to the BBC Engineering Information Department on 28th November indicated that they were well aware of these problems and that other people had reported them. I was told the problem stemmed from the fact the transmitters and aerial arrays were all new and that these unwanted interactions would be resolved as soon as possible. While I appreciate there may be considerable practical difficulties in curing this effect the fact remains that over two months later the spuriae are still being radiated. A second telephone enquiry to the BBC (E.I.D.) in mid-January revealed a very different attitude. While they were aware of the situation they had not been notified of it by any "official" body and until they were it was unlikely that anything would be done. This seems a somewhat regrettable attitude for two reasons. Firstly the signal on 729kHz especially is quite strong and the medium-wave band is sufficiently congested without spuriae of this magnitude. Secondly the BBC has always set extremely high engineering standards which are the envy of the world and it seems sad they should fail so noticeably in their country's own capital.

Roland C. Pearson
Benfleet
Essex

The BBC comments:

The changes we made on November 23rd involved the commissioning of many new transmitters and aerial systems. At stations where several programmes are radiated at high power, it is not always easy to avoid combinations of this kind. We are now engaged in a tidying-up and fine tuning operation at all of our transmitting stations, in the course of which these two spurious emissions will be eliminated – or at least reduced to an acceptable level.

AN OVERSIGHT IN COSMOLOGY?

I ask you to accept *a priori* two things: that the red shift can be explained in the system to be proposed and that the frequency spectrum of light is quantized; there is some experimental evidence as to the latter. If light is quantized in this way then there is a limited number of frequencies in any electromagnetic spectrum.

My question concerns Oblens's paradox which is said, by some, to mark the origin of modern cosmology. Oblens asked: Why is the sky dark at night? He had already shown by good reasoning that is should not be dark at all. *Mathematically* the sky could be represented as a continuous shell of incandescent matter whose temperature, as near as makes no odds, was that of the sun. *Ergo* the Earth would soon be as hot as the sun. The obvious contradiction stood unanswered for about a century and a half.

The astronomer Hubble observed the red shift, which cosmologists then combined with the Doppler effect and drew the neat conclusion that the sky is dark at night because the universe is expanding!

I suggest that this particular piece of elegant simplicity was possible only because there had been an oversight which indeed persists to this day. The law of averages has been disregarded. It can be shown that the *size* of Oblens's sphere is at least 10^{20} light years in radius. On a sphere of such size there will be a near infinite number of point sources of radiation in any small solid angle of the sphere that is observed. Practically, the solid angle is determined by the limits of the observing instrument.

It follows, dare I say, as night follows day (?), that an observer will see none of the light. Due to the law of averages the radiation will arrive in balanced phase/antiphase relationship at the detector and, even though there is about 5×10^4kW/metre^2 at the Earth's surface, it will be neither seen nor felt.

My question is: Has there or has there not been an oversight in this problem? If there has then the universe is not expanding and certain readjustments to our concepts are long overdue.

Alex Jones
Swanage
Dorset

COMPUTER BUSES

Ian Witten's article on computer buses (February issue) is right to point out certain key factors when designing a bus system. For example, t.t.l. totem pole gates cannot be connected together in a wired AND function for the precise reasons he states.

Then he discusses two alternatives, tri-state and open collector. He dismisses the latter because of alleged slowness. This is not true. Any switching edge which appears slow is due to the quality of the interconnection, it is not an inherent property of the transistor circuit. I have achieved switching speeds of about 6-8ns, with the positive edge being slightly faster than the negative. Additionally, crosstalk calculations need to take into account the transmitting element, the receiving element and the interconnections. element, the receiving element and the interconnections.

The possibility of excessive current as shown in the totem pole configuration also applies to tri-state if two enables happen to be true at the same time.

For a comprehensive explanation of open collector bus driving see the June 1978 issue of *Wireless World*, p. 61.

M. F. Davidson
CAM Consultants
St Albans
Herts

The author replies:

Malcolm Davidson raises the interesting question, to what extent should a bus be treated as a transmission line? If really high switching speeds are required, then of course the transmission line approach is mandatory, and if the line is properly terminated at both ends, open-collector gates can indeed be fast. However, one great attraction of a bus structure for interconnection of computer subsystems is the flexibility it offers for reconfiguration by inserting or removing modules, or extending the bus without adverse effect on the rest of the system – and this rules out the possibility of exactly matched termination. Fortunately, most commercial microcomputers are slow enough to allow one to get away with this! Under conditions of incorrect line termination tri-state devices give more robust and reliable performance than open-collector.

He is quite right to point out that two tri-state gates driving the same bus line should not be enabled at the same time. This means that some lines cannot be tri-state driven. The "bus request" signal illustrates this – one cannot guarantee that bus requests will not occur simultaneously. In practice, computer buses usually have some tri-state and some open-collector lines, tri-state being used when the protocol guarantees that no two devices can simultaneously drive the line. This means, of course, that failure of a device to observe the protocol may result not only in logical breakdown of communication along the bus, but in physical breakdown as well – due to multiple gates driving the line. As Mr Davidson notes in the article he cites, this is a considerable disadvantage of tri-state driving.

Ian H. Witten

MILITARY ELECTRONICS

Many readers of *Wireless World* will have paused to think about the issues raised in the January leader, "The death delivery business". Some may have wondered how they personally could become less involved in production for military use, or how to break the vicious circle of "organic intercourse" between electronics firms and the military. Obviously there are no easy answers, but there are sources of information and support for people who would like to consider these issues more deeply.

The Campaign Against Arms Trade was set up by several peace and internationalist groups in 1974, to work for an end to British involvement in the arms trade and for the conversion of British military industry to peaceful, socially useful production. It distributes a wide range of books and pamphlets, and has produced a wide range of factsheets, leaflets, and campaigning materials. It is in close touch with shop stewards and others who are putting forward alternatives to military production in their companies, and with individuals who have chosen not to work on military products. We would be pleased to hear from *Wireless World* readers who would like more information.

Sandy Merritt
Campaign Against Arms Trade
5 Caledonian Road, Kings Cross
London N1 9DX

In your January editorial you quoted J. K. Galbraith as saying "no faith sustains this (military) competition". May I suggest that at least some of those whom you claim "are not really aware of what they are doing" are in fact sustained by the insight that however many things there are that we don't know there are some things we *do* know? They assume that some questions are closed and that our survival as a nation depends on acting bravely on those assumptions, the most crucial of which is that our military capability keeps the Soviet Union from doing to us what it did and is doing to Poland, E. Germany, Latvia, Estonia, Hungary, Czechoslovakia and Cambodia.

D. J. Richardson
Stotfold
Hitchin
Herts

STATUS OF ENGINEERS

Mr Wilson's letter in the February issue contains, I believe, a clue to the lowly status of the British professional engineer. Our more affluent professional brothers—accountants, doctors, solicitors *et al.* – have never tolerated the unqualified dabbler in their midst, and have often joined battle to rid themselves of these pests.

While it might be argued that the use of technical jargon, euphemisms and "buzz" words and the worship of complicated techniques serves no useful purpose, I would like to suggest that such methods have served to "repel boarders" from the aforementioned professions since their inception.

The logical, fair-minded engineer of today sits on the lower rung of the rewards ladder clad in his dungarees, clutching his oily spanner – for such is the public image of him – peering myopically upward. The view at these higher altitudes is fine: a procession of "T" registration automobiles driven by doctors, lawyers and accountants clad in Savile Row suitings – a procession to which John Public rushes to doff his hat and offer his open wallet.

These opulent gentry have no need of a trade union; they have welded themselves into neat respectable units ideally suited to make money out of their skills. These professional gentlemen have secured the unassailable right to "do their thing" to the exclusion of all other persons. Unqualified is unclean!

Surely there's a lesson to be learnt here. Surely the engineering profession must exclude the unqualified dabbler from its ranks. The C.Eng. label is a joke compared to the respected M.D., F.C.A., and F.R.C.S.

This may seem irresponsible, unfair, grasping, etc., etc., but . . . who wants to drive a '74 banger, dress at Oxfam, and pay their legal and medical fees on the old never-never?

M. C. Heard
Hullbridge
Essex

OSCILLOSCOPE WAVEFORM STORE

R. H. Fastner's excellent design for an "Add-on oscilloscope waveform store" (Nov., Dec. 1978 issues) has an in-built handicap. The store uses 16 shift registers whose total cost, if a supplier can be found, approaches £100. Contrary to the statements near the beginning of the article it is not difficult to replace these shift registers with r.a.ms and some extra chips at a total cost of less than £20. We have a p.c.b. design which uses readily available 2102 static r.a.ms. The board is used in place of Mr Fastner's shift register board. The 5V supply current is increased by about 120mA and the —8V supply is no longer needed. No other changes are necessary. It may be possible to arrange for a supply of p.c.bs (and components) if interested parties write to me.

J. Ward
Department of Physics
University of Oxford
Clarendon Laboratory
Parks Road
Oxford

FURTHER USE OF RADIONAVIGATION SYSTEMS

THE modulating waveforms for the VOR (VHF OmniRange) and ILS (Instrument Landing System) signals can be generated digitally, using sources such as the Wavetek Model 175. The information from both waveforms can be recovered by means of the discrete Fourier transform. The quantization error associated with these techniques has been determined with simulations run on a Commodore 2001-8 computer. Mean and peak error and standard deviation of error were computed for more than 100 independent sample timing offsets. The results are summarized here.

For 1024 samples with 256 levels (8 bits) of resolution, the standard deviation of VOR error is 0.012 degrees (0.0024 dots, on many cockpit displays). Localizer error is 42 millionths of a d.d.m. (difference in depth of modulation) (0.00054 dots), and glideslope error is 84 millionths of a d.d.m. (0.00096 dots). The error in general is inversely proportional to R times the square root of *S*, where *R* is the number of levels of resolution and *S* is the number of samples. Peak error is approximately three times the standard deviation and mean error is less than the standard deviation, for both VOR and ILS signals.

The Nyquist sampling theorem requires 11 samples of the ILS modulation and about 700 samples for VOR. However, both include voice and Morse identification in practice. A VOR/ILS demodulator that took 1024 samples would reject these modulation frequencies. It appears possible to build an inexpensive 1024-sample 8-bit demodulator that would make nearly 30 readings per second with some new microprocessors. One could build a single receiver that would recover full ILS data up to 15 times per second, by storing and resetting a.g.c. voltage digitally. The same receiver could scan up to 30 VOR channels per second while indicating one or more bearings plus the number of usable signals available.

These techniques are applicable to the monitoring of VOR and ILS transmitters. If Fourier demodulation were to be used in both monitors and receivers, the VOR and ILS systems could become cost-effective backups or alternatives to the Global Positioning System (GPS) and Microwave Landing System (MLS).

Robert G. Huenemann
San Bruno
California, USA

SCIENCE AND THE ELECTRON

Your editorial in the February issue on the nature of truth falls, in its last sentence, into an inexplicably common fallacy when it says, "We still don't *know*, for example, whether the electron is a particle or a packet of waves." (My emphasis.) That it is not the duty of science to answer such questions is best illustrated by a simpler example:

"Is it true that the planets revolve around the sun in ellipses?" Of course.

"Is it therefore untrue that the sun and the other planets revolve around the earth in complex paths which may be calculated to any required accuracy by considering wheels revolving within other wheels?" Of course not.

I can calculate the trajectory of a rocket to the moon no less accurately using the latter hypothesis, and someone looking at our solar system for the first time could equally well believe either hypothesis depending on whether their view fell firstly on the sun or on a planet.

Similarly with particulate or wave electrons and with all other mathematical fictions. We may decide, at times, to obey Occam's Razor and accept the simplest hypothesis but we should not call this the "true" hypothesis.

C. W. Hobbs
Apeldoorn
Netherlands

The word "science" is derived from the Latin *scientia*, meaning knowledge. – Ed.

BIRDS' GEOMAGNETIC SENSE

I. A Seath's spinal cord model (December 1978 letters) shares some objections to the flapping wing model, but suffers others alone. Taking first the latter: a magnetic sense of heading has been demonstrated by Wiltschko, Keaton, Walcott, Emlen, Fromme, Bookman, Southern and others in the robin, gull, swallow, pigeon and bunting.

Bringing the spinal cord model into concordance with this fact seems to need: (1) A neural discrimination of 1 part in 10^7 (the change in induction due to the alteration in dip across a 1m cage) to provide a north-south orientation. (2) Some means of providing east-west orientation. (3) A means to judge air-speed to at least the accuracy given in (1). (4) A means to judge wind speed to the same precision. The last two are requisite to direction-finding on the wing.

A. M. Roberts published a theoretical critique of this model [1] which attracted several responses [2, 3]. To summarize, briefly, his view: an unchanging electric field due to electromagnetic induction is sensible only by reference to external factors in relative motion to the bird, e.g. leakage currents through the surrounding air.

It is not obvious to me that the neural logic needed to decode, for example, a 10° (electrical) signal change for a 20° (compass) bearing change is complex.

Turning to some shared objections, I note: (a) the noise due to muscular activity; (b) thermal noise; (c) electrostatic induction arising from rolling motion in the atmospheric electric field; (d) piezo-electric voltage from feather quill strain; and (e) tribo-electric voltage on feathers.

It transpires, however, that Ad. J. Kalmijn[4] (Woods Hole) working with sharks, skates and rays, which in a sense are ideal animals for geomagnetic sense experiments, has given unequivocal demonstrations of their sensitivity to fields, induced magnetically, of values down to 1μ V. m^{-1}.

Although it is true that they exhibit dedicated receptors, the Lorenzinian ampullae they too suffer from two important factors cited as shared objections above, viz. (a) and (b). The remaining factors are believed to be confined to the surface of birds.

I come to the same view as Kalmijn: sensory perception of the electric field depends upon the imbalance between the induced electric field and the charge movement which tends to neutralize it but which depends upon tissue conductivity for its occurence. Where an insulated conductor exists within the animal, a p.d. as high as the modulus of the electric field strength is available across this insulation barrier for some time constant.

B. Whatcott
Addlestone
Surrey

References

1. A. M. Roberts, *Physics Education*, 1977, 12, pp. 221-3.
2. P. Lorrain, *ibid*, 1978, 13, pp. 203-4.
3. B. Whatcott, *ibid*, 1978, 13, pp. 397-8.
4. Ad. J. Kalmijn, "Animal Migration, Navigation and Homing". Springer-Verlag, Berlin 1978, pp. 347-353.

VIDEO RECORDERS FOR MICROCOMPUTERS

I have been very much aware of the explosive evolution of microcomputers and their accompanying peripherals. One of the available devices, the video recorder, I think has been left out, in spite of its great capabilities in access time and bulk storage.

In addition the technique of video recording (with the use of a closed loop cartridge and helical scan) could give rise to the evolution of a new generation of peripherals.

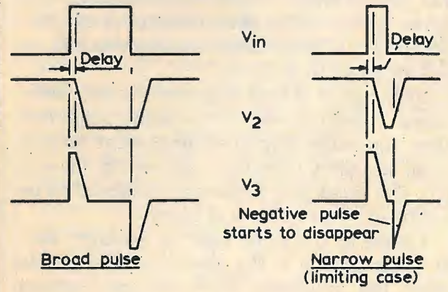
Has anyone given any thought to this interface?

Lazazos Labzianidis
Athens
Greece

HIGH FREQUENCY DIFFERENTIATOR

With reference to Mr Andrew E. Romer's comments (Letters, December 1978) concerning the "High frequency differentiation" described by S. Cussons (Circuit Ideas, August 1978), I should like to point out that the operation of Mr Cussons's circuit does not merely depend on the direct mathematics of the circuit elements.

In practice all operational amplifiers introduce some delay between a change in the input and a corresponding change in the output. In the example of Mr Cussons's circuit, the output of the "low pass filter", V_2, will be also a delayed as well as filtered version of V_{in}. Mr Romer does correctly point out that his own circuit is mathematically equivalent to that of Mr Cussons, assuming perfect operational amplifiers in each case.



The inherent finite delay would allow the value of C, the feedback capacitance, to be reduced, giving better high frequency performance. At high frequencies the circuit generates pulses at the leading and trailing edges of the given narrow input pulse.

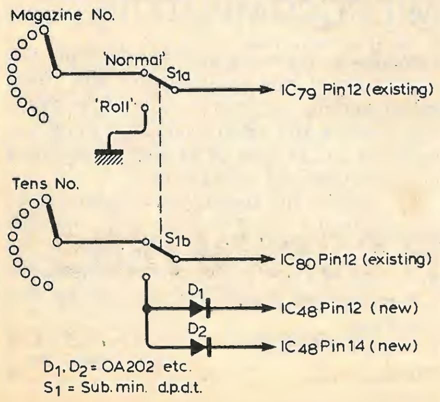
Lastly, the circuit can perform up to 5MHz (as long as the input signal is not too great) because the LM381 amplifiers are only slew-rate limited, a gain-bandwidth product of 15MHz being possible for small signals.

The waveforms which should relate to Mr Cussons circuit are shown here.

Roger Green
Postgraduate School of Electrical Eng.
University of Bradford.

WW TELETEXT DECODER — MODIFICATIONS

As will have been appreciated, the present "roll-mode" facility possessed by the *Wireless World* teletext decoder is of little use, due to the rapid scan rate. In fact, the later teletext kits have omitted the "roll-mode" for this reason. However, the teletext pages have been arranged in the form of a book and the



ability to "browse" through the pages is a desirable feature.

The accompanying simple modification (see circuit) enables the user to display every page whose units number agrees with that of the "page-units" selector. This provision allows the user to sequence through the entire magazine whilst giving, in most cases, adequate time to obtain the page number and an idea of the contents.

It is suggested that the present "roll-mode" switch be replaced with the double switch (S_1) and the diodes may be mounted on the terminals of this switch.

A. J. Jameson
IBA Mounteagle Transmitting Station
Conon-Bridge
Ross & Cromarty

ENGINEERS, PUT ON NEW HATS

With regard to recent correspondence about the standing of engineers, might I make the following points? Engineers' salaries have now fallen so far behind that they are unlikely to ever catch up again, rate of growth being limited by the constraints imposed by pay policies designed for the good of society as a *whole*. Lack of growth in British industry (and one should not confuse growth with conglomeration — the former is a creative process, the latter merely acquisitive), lack of growth will necessarily limit the rate of occurrence of promotional opportunities.

Possible solutions are: (a) Becoming a contract engineer or technician. This has been common practice for technical writers and draughtsmen for some time. (b) Becoming a consultant. This is the common mode of operation for many doctors, accountants, architects, etc. Why not engineers? (c) Becoming an entrepreneur. Having worked in both the UK and US I know how much the entrepreneurial spirit has helped to create not just new facets of technology, but even complete "micro-cultures", such as Silicon Valley. And the interesting point is that those entrepreneurs were *engineers* – perhaps not so different from the reader.

Indeed, as a significant proportion of them are British, it is likely that they too were readers of that renowned institution, *Wireless World*!

A. Macrae
Socionics
Aberdeen

REVISE PREFERRED VALUES?

We've inherited a legacy of awkward component values from the days when accuracy was rare and expensive, but now that tolerances of 5% and even 1% are becoming inexpensive and common so that it becomes meaningful to combine values for intermediates, I would urge a revision of the scales of preferred values. I would suggest the scales below, displayed to the right of the present scales, as the best compromise.

The great advantage of such a revised system is that, in the E24 series, all the integers, 1, 2, 3, 4, 5, 6, 7, 8, 9 (and their decades) are present, which simplifies arithmetic and also allows easy switching. The second advantage is that even down to the E6

Present values			Suggested values		
10	10	10	10	10	10
11			11		
12	12		12	12	
13			13		
15	15	15	14	14	14
16			16	16	
18	18		18		
20			20	20	20
22	22	22	22		
24			24	24	
27	27		27		
30			30	30	30
33	33	33	33		
36			36		
39	39		40	40	
43			45		
47	47	47	50	50	50
51			55		
56	56		60	60	
62			65		
68	68	68	70	70	70
75			75		
82	82		80	80	
91			90		
100	100	100	100	100	100

series, the key values of 1, 2, 5 appear which, like weights in a box for a balance, can be added to form any value from 1 to 9.

There are demerits of course. In the E6 series, the greatest ratio is 1.67 instead of the present 1.50 (optimum 1.47); in the E12 series, the greatest ratio is 1.33 instead of the present 1.25 (optimum 1.21); the E24 series, however, is little affected, the greatest ratio being 1.14 which is slightly better than the present 1.15 (optimum 1.10).

The scales suggested also preserve the many-factored numbers 6, 12, 24.

Tony Kelly
Llanwrda
Dyfed

CITIZENS' BAND IN THE USA

The citizens' band situation here in the USA, particularly in the vicinities of large cities, is nothing short of disastrous. Naturally, with only 5 watts and no facilities for adequate tuning of sets or installation of good aerials, it is difficult to transmit much farther than 10 miles at most, which is what it was intended for. Naturally the Yanks with an almost unlimited amount of dollars at their disposal — even the lowest of the low (income wise) – can afford to finagle their power up above the legal.

Naturally the FCC has countered the linear amplifier problem by making them illegal to purchase but not before millions of factory wired pre-amps have got onto the market. It is the same with marijuana exactly. It is now legal to possess *x* number of ounces but illegal to sell it, yet 'everyone' seems to possess it (marijuana) except for those who are still considered God fearing, and we seem to be in the dejected minority.

The population explosion takes its toll in more ways than protein scarcity — example, the crowded radio spectrum.

I am certain I can command quite a following of so called 'old-timers' who came by their licences the hard way and by no means want what they toiled perilously hard for given away to the undeserving.

John Teale KA6CRB
La fayette
California, USA

H.f. amateur band frequency synthesizer — 2

Circuit description, construction and commissioning

By **M. Small**, B.Tech (G4DVI)

THE SYNTHESISER, shown in block form in Fig. 7, consists of two major parts: a phase-locked loop and an interpolation oscillator and mixer. The phase-locked loop is capable of producing frequencies at 500 kHz intervals over a frequency range which is greater than 3 to 1, the actual range used being from 7.0 MHz to 23.0 MHz. The output of the phase-locked loop is fed into a mixer, where it is combined with a signal from the interpolation oscillator to provide continuous coverage from 1.5 MHz to 28.5 MHz in selectable 500 kHz bands. For amateur use only six of these bands are needed.

Reference oscillator

The reference-frequency oscillator in Fig. 8 is the key component which determines the frequency stability of the phase-locked loop. The oscillator circuit is taken from a design by L. Nelson-Jones in reference 3, although the oven, also described in this article, was not used. The use of such an oven would give rise to an order of magnitude improvement in the stability obtainable. The oscillator uses a quartz crystal to produce a 1MHz, t.t.l.-compatible, square-wave output. This is divided by 20 by one half of a 7474 and a 7490 to produce the 50kHz reference frequency. It would be theoretically possible to use a 500kHz reference frequency to obtain 500kHz frequency steps, but then the programmable frequency divider would have to operate at the full v.c.o. frequency — difficult without using schottky t.t.l. It would limit the maximum usable frequency to less than ⅓ of that obtained by the current design, which is 50 MHz.

Voltage-controlled oscillator

The voltage-controlled oscillator, shown in Fig. 9, uses a Motorola MC 1648 i.c. and an MV 1401 hyper-abrupt junction tuning diode. This combination gives a tuning range which approaches 4 to 1 and is usable to a frequency of well over 50 MHz. In fact, the oscillator MC 1648 can operate up to 200 MHz. It provides four key attributes:

- low peak-to-peak a.c. on the tuning diode (500 mV),
- automatic gain control of oscillations and output essential for such a wide tuning swing,
- availability of both sinusoidal and logic-compatible outputs,
- high spectral purity close to the carrier by the use of a LC tank circuit. This is not usually the case with RC oscillators.

The i.c. is from the e.c.l. family and produces e.c.l.-compatible output levels. However, it is quite acceptable to operate it on a 5V rather than −5.2 V power rail with no degradation of performances. The output is translated to t.t.l. levels by single-transistor stage and the 74S00 gate acts as a buffer. A sinusoidal signal is taken from the tank circuit, which is buffered and used as the output.

The MV 1401 hyper-abrupt junction tuning diode provides a guaranteed capacitance ratio of 15 to 1 for a 10 volt reverse-bias voltage swing. The typical swing is said to be greater than 25 to 1. Whilst this component is fairly expensive, reasonably cheap diode pairs intended for a.m. radio tuning are becoming available (MVAM2), and these would serve equally well with appropriate minor circuit modifications.

The output from the v.c.o. is prescaled by the 74196 high-speed divide-by-10 circuit in Fig. 8 before input to the programmable divider. This extends the frequency range of the system upwards to 50 MHz, or beyond 100 MHz if an e.c.l. device were to be used.

Programmable divider

The programmable divider of Fig. 8 is fairly conventional, consisting of two stages using 74192 synchronous up/down counters in the count-down mode. It is unfortunate that, with these

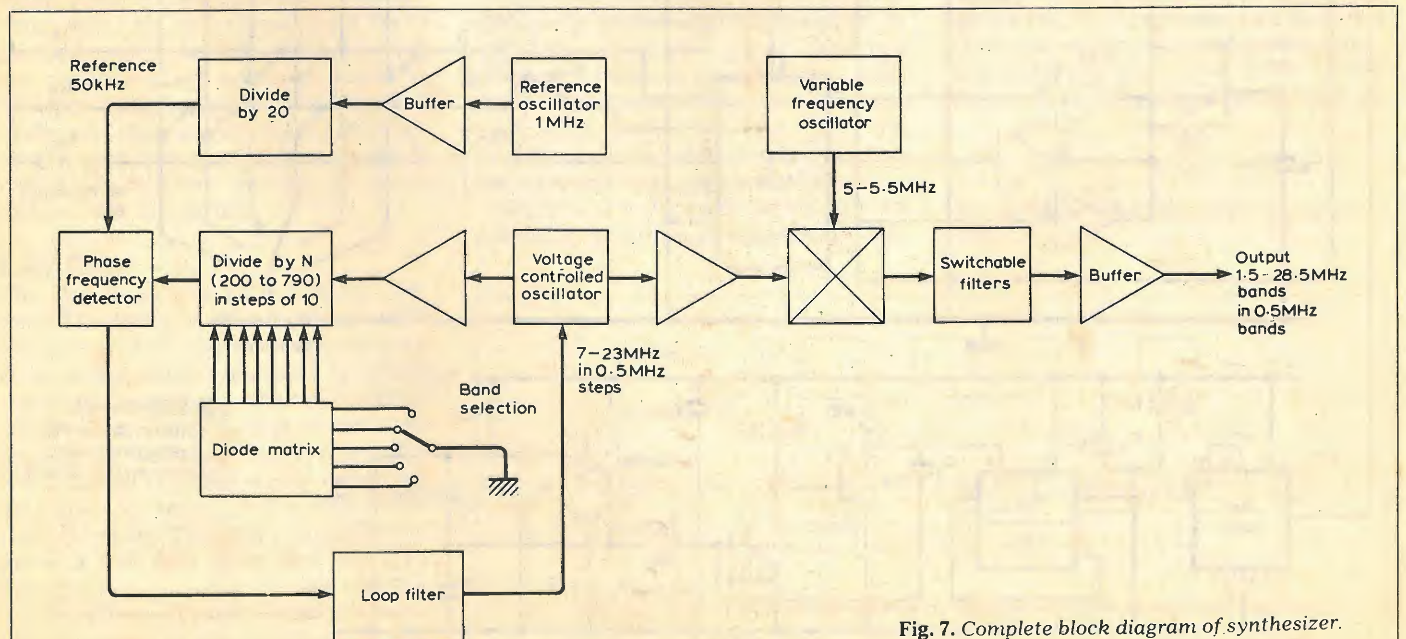


Fig. 7. *Complete block diagram of synthesizer.*

devices, the carry/borrow pulse is formed directly from the state of the counter and the incoming clocks. This makes these signals unsuitable for use directly as a "load preset data" signal. The circuit operates as follows, assuming that preset data has just been loaded. Each input pulse causes the counters to decrement until the logic of the 7405s connected to the outputs detects that a count of 2 has been reached. This causes the D input of the 7474 to be set high so that the next input pulse sets this state (count now −1). The inverse output from this state going low causes the preset data to be loaded into the 74192s and disables their clock. Since the 74192 outputs are no longer set to 2, the D input to the 7474 is again low. Hence the next input pulse unsets this state (count now equal 0) and releases the counters, which commence decrementing on the subsequent clock. The Q output from the 7474 is taken as the output of the programmable divider and fed to the phase detector.

A diode matrix is used to select the division ratio of the programmable divider with a single-pole, 6-way switch. To allow the selection to be by a remote connection to earth, the output from the diode matrix is inverted by a set of SN 7404 gates before being connected to the programmable dividers.

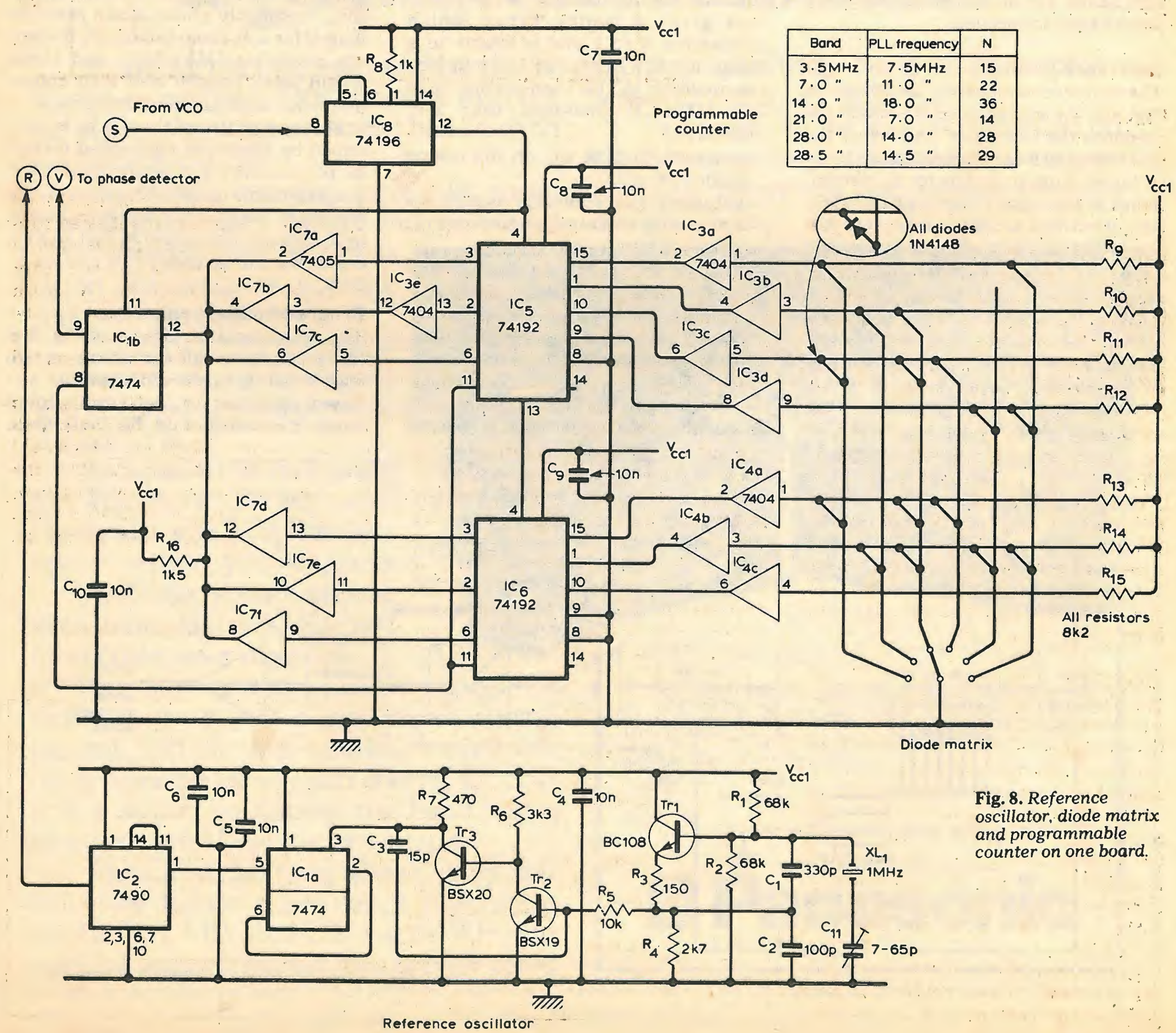
Phase detector

The phase detector in Fig. 9 is the Motorola MC 4044, which has the advantages that it is both a phase and frequency detector, and that a complete system including filter amplifier is available in the one package. It is essential that a phase frequency detector is used in this application, since the frequency range covered exceeds 2 to 1 and straightforward phase detectors can register zero phase error on harmonics. The MC 4044 also gives an output which is independent of the duty cycle of the two input wave forms. The phase detector consists of two parts, a phase frequency detector and a diode-pump arrangement. The former produces two logic outputs indicating 'go up' and 'go down' and the latter serves to invert one of these and combine the two in analogue form. The operation of the phase detector can be seen from the following state-transition table.

Current state	Next state after transition R V 0 0	R V 0 1	R V 1 1	R V 1 0	Output
A	A	B	B	A	Up
B	C	B	B	F	Up
C (start)	C	D	E	F	—
D	G	D	E	H	—
E	C	B	E	H	—
F	A	B	E	F	—
G	G	G	H	H	Down
H	C	D	H	H	Down

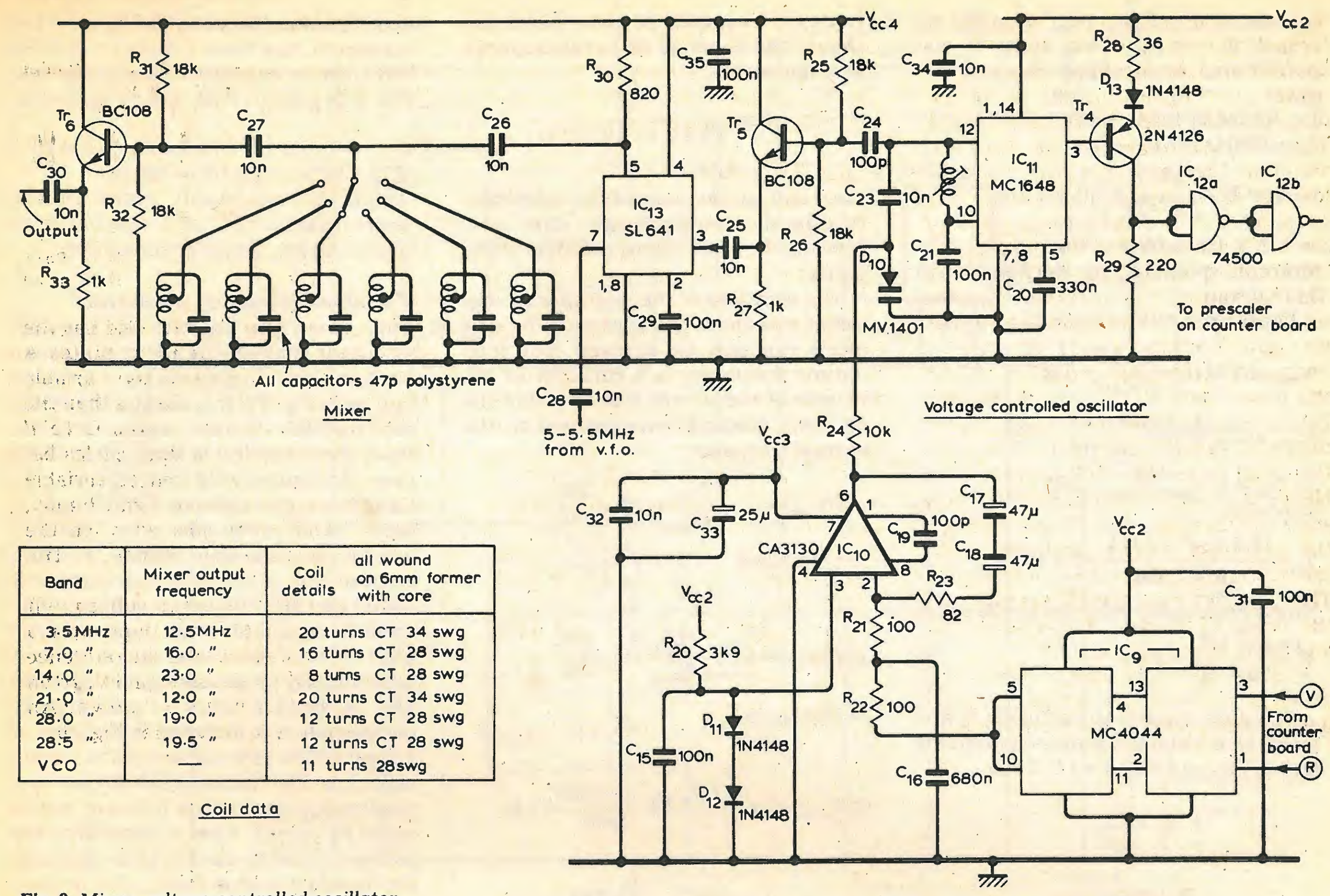
This shows that the MC 4044 has the eight internal states A to H. States A and B are entered when the variable frequency is detected to be less than the reference frequency, states C to F accommodate differing duty cycles between otherwise synchronized variable and reference frequencies and finally, states G and H are entered when the variable frequency exceeds the reference.

The table shows what subsequent state the MC 4044 will adopt after a transition on its inputs of the reference signal R and the variable signal V, given that its current state is known. An example of its use is shown in Fig. 10.



Band	PLL frequency	N
3·5MHz	7·5MHz	15
7·0 "	11·0 "	22
14·0 "	18·0 "	36
21·0 "	7·0 "	14
28·0 "	14·0 "	28
28·5 "	14·5 "	29

Fig. 8. *Reference oscillator, diode matrix and programmable counter on one board.*



Band	Mixer output frequency	Coil details all wound on 6mm former with core
3·5MHz	12·5MHz	20 turns CT 34 swg
7·0 "	16·0 "	16 turns CT 28 swg
14·0 "	23·0 "	8 turns CT 28 swg
21·0 "	12·0 "	20 turns CT 34 swg
28·0 "	19·0 "	12 turns CT 28 swg
28·5 "	19·5 "	12 turns CT 28 swg
VCO	—	11 turns 28swg

Coil data

Fig. 9. *Mixer, voltage-controlled oscillator and phase detector, all on second board.*

In this example the phase detector is assumed to start in state C. The first transitions of R and V going to one are simultaneous and the device adopts state E. Since the device attempts to synchronize negative-going transitions of R and V, when R goes to zero and V remains high, the device adopts state B "go up", indicating that it has detected that V is lagging R. It remains in this state until V also goes low, when it again takes up state C, giving no output. Thus the "go up" signal lasts for a period equal to the difference between the negative going edges of R and V. This process is repeated on subsequent cycles but the "go up" signal lasts for longer each time as the frequencies V and R are different and so the phase difference is increasing.

Loop filter

The loop filter uses a CA 3130 f.e.t. op. amp. This has the advantage that both the inputs and outputs can operate very close to the power rails and a balanced supply is not required. The built-in filter amplifier on the MC 4044 is not used because the voltage swing required for the varicap (10 volts) would cause the maximum V_{cc} rating of this component to be exceeded. The filter comprises two parts, a low pass filter and the loop integrator.

As has been discussed previously, the characteristics of the loop filter largely determine the performance. In this case, two performance criteria were to be met: first, that in-band spurious outputs (reference feedthrough) should be suppressed by at least 60 dB and second, that the transient response time should be unnoticeable by the operator. This latter aim can be met providing the time is less than about 0.1s.

The design of a filter to meet these requirements is an iterative process. The lock-up time requirement is usually in conflict with that for reference-frequency feedthrough suppression. In this case it is also clear that the frequency range is so great that most steps will exceed the maximum phase error limit of the MC 4044. Thus the Laplace analysis will not usually define the transient response characteristics.

So, for a starting point, let us take the reference feedthrough suppression. If it is necessary to have an additional low-pass section to obtain the desired suppression, this section should have a turnover frequency of at least one tenth of the reference frequency, to obtain reasonable benefit, and should also be 10 times the natural frequency of the loop, so as to have minimal unwanted effect on the loop phase margin.

Let us say that if $f_{ref} = 50$ kHz, a loop natural frequency of 150 Hz would well satisfy the above conditions. This would give us $\omega_n \sim 10^3$ rads/sec. and since the transient response for reasonable damping factors is $5/\omega_n$, $t_l = 5/10^3 \sim 5$ ms. Hence, the time constant T_1 can be

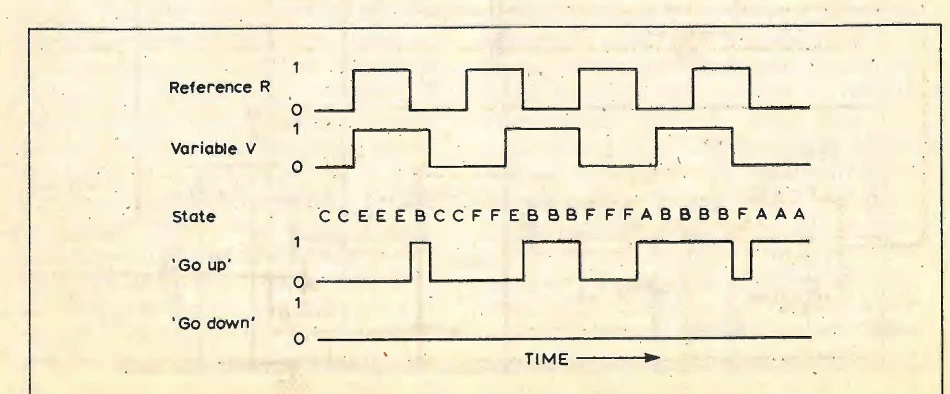


Fig. 10. *Example of use of state-transition table.*

calculated: $T_1=K_pK_v/N\omega_n^2$. For this we require K_v and K_p. The quantity K_v was determined from experiments which gave:

$f_{vco}=23$ MHz for $V_c\sim10$V.
$f_{vco}=7$MHz for $V_c\sim1$V

so $K_v=2\pi\times\frac{23-7}{(10-1)}\times10^6$

$=11.2\times10^6$ rads/sec/volt.

Motorola specify K_p for the MC 4044 at 0.111 V/rad.

The divider ratio $N=\omega/\omega_{ref}$.

N_{min} at 7 MHz $=\frac{7\times10^6}{5\times10^4}=140$.

N_{max} at 23 MHz $=\frac{23\times10^6}{5\times10^4}=460$.

So $N_{av}=\sqrt{N_{min}.N_{max}}=250$.
Therefore

$$T_1=\frac{11.2\times10^6\times0.111}{(10^3)^2\times250}=5\times10^{-3}\text{s}.$$

Now a reasonable value for $C=25\ \mu$F, so

$$R_1=\frac{5\times10^6}{25\times10^3}=200\Omega.$$

The next stage is to calculate T_2 and for this we require to propose a damping factor. Let us define $\zeta=1.0$. Then

$$R_2=\frac{2}{\omega_nC}$$
$$=\frac{2\times10^6}{10^3\times25}$$
$$=82\Omega$$

Now the typical reference frequency suppression can be determined.

$$\text{Sidebands}=20\log_{10}\left(\tfrac{1}{2}\times\frac{82\times0.1\times11.2\times10^6}{10^6\times2\times\pi\times5\times10^4}\right)\text{dB}$$
$$=70\text{ dB}.$$

To ensure that this is bettered, an additional low-pass filter may be added by dividing R_1 into two sections and connecting a capacitor from this point to earth. If the filter so formed has a turnover frequency of about 5kHz this should add about 20 dB to this suppression figure.

$$C_1=\frac{4}{2\times\pi\times5\times10^3\times200}$$
$$\sim0.68\mu\text{F}.$$

The total suppression of the reference-frequency feedthrough will now typically be 90 dB below the level of the carrier.

The variation of the loop characteristics at maximum and minimum division ratios can now be checked. The loop natural frequency is a function of the inverse of the square foot of N and the damping factor is proportional to the natural frequency.

$$\omega_n(N_{min})=\omega_n\sqrt{\frac{N_{av}}{N_{min}}}=10^3\sqrt{\frac{250}{140}}$$
$$=1350\text{ rad/s}.$$

$$\omega_n(N_{max})=\omega_n\sqrt{\frac{N_{av}}{N_{max}}}=10^3\sqrt{\frac{250}{460}}$$
$$=750\text{rad/s}.$$

$$\zeta(N_{min})=\zeta\times\frac{\omega_n(N_{min})}{\omega_n}=\frac{1\times1350}{1000}=1.35.$$

$$\zeta(N_{max})=\zeta\times\frac{\omega_n(N_{max}}{\omega_n}=\frac{1\times750}{1000}=0.75.$$

This illustrates how the settling time will increase as the division ratio gets larger. As N increases, the loop natural frequency and the damping factor reduce. This causes the loop to settle more slowly and in a more oscillatory manner.

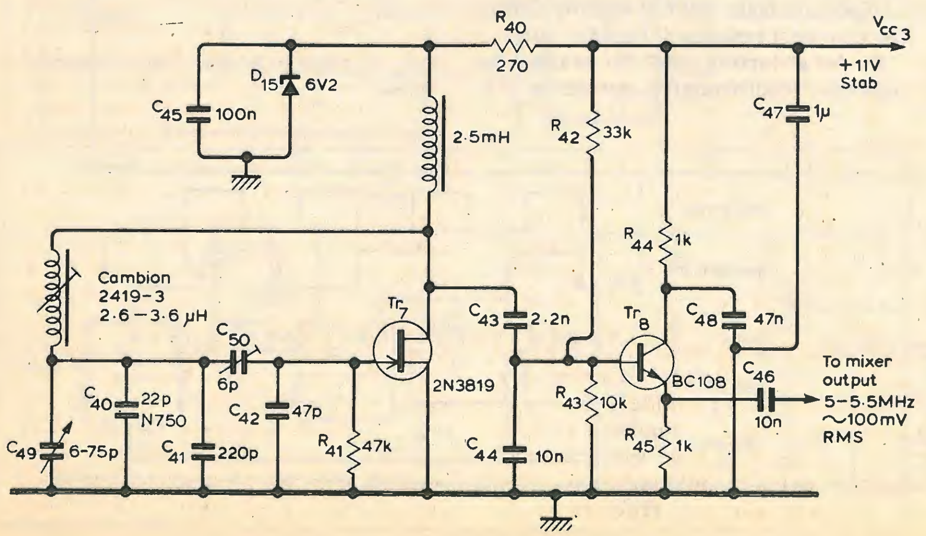
The maximum frequency step which can be made within the $\pm2\pi$ radians limit of the MC 4044 can now be checked. The time T can be determined with reference to the normalized time domain response plots. This can be taken to be $T=t_L/5\approx1$ ms. so $f_{ref}.\ T=5\times10^4\times1/10^3=50$.

So the maximum step is about $\pm4\%$. This corresponds to 280kHz at 7 MHz and 920 kHz at 23 MHz. The time for the maximum step from 7 MHz to 23 MHz can thus be calculated, assuming that this $\pm2\pi$ radians limit will be exceeded.

$$t_c=2\times\pi\times200\times25\times16\times10^6/(0.35\times10^6\times11.2\times10^6)=130\text{ ms}.$$

This is reasonably close to the original target of 1/10 s, and has been confirmed by computer simulation.

Fig. 11. *Variable frequency interpolation oscillator.*



Variable-frequency oscillator

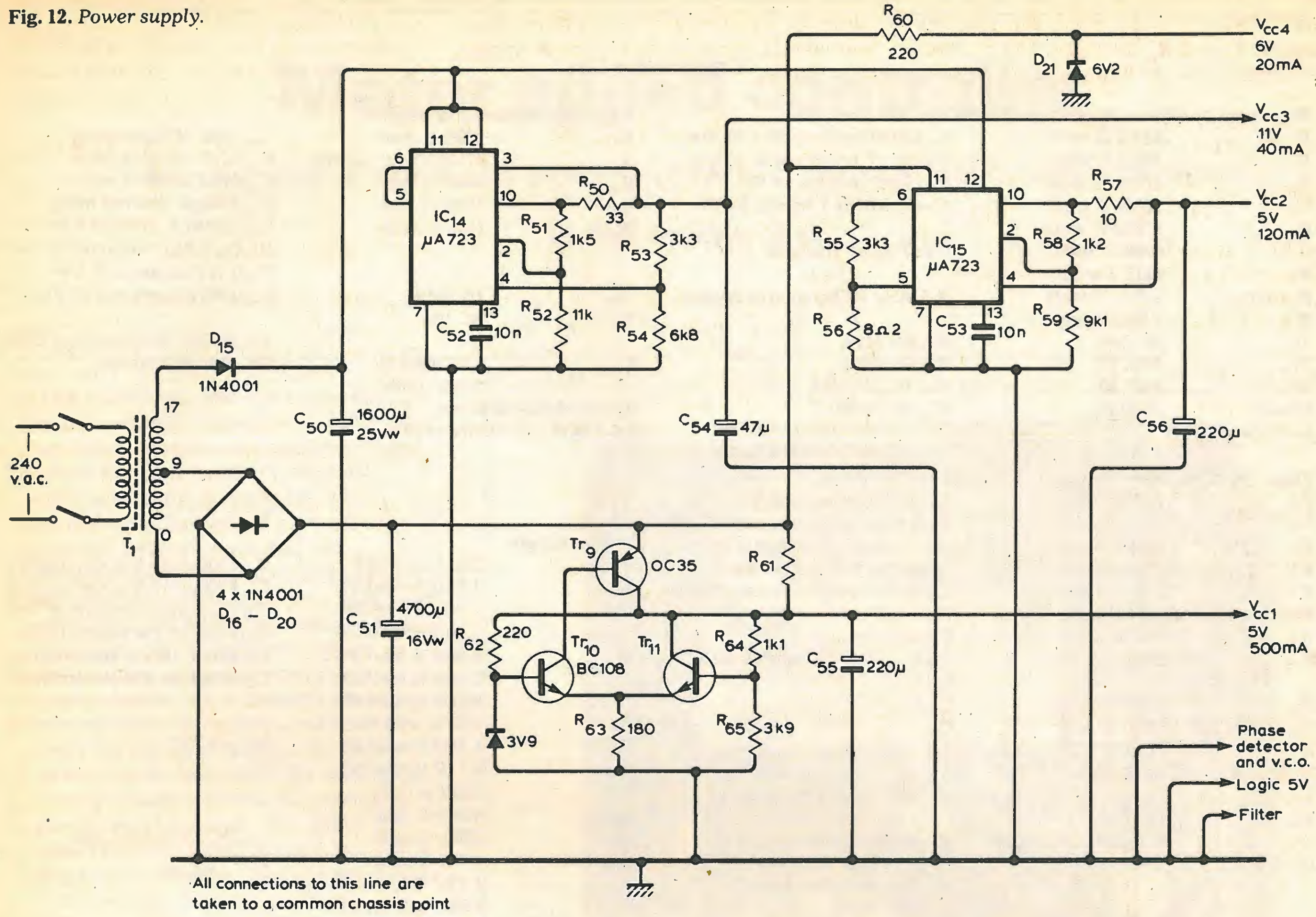
This covers 5 to 5.5 MHz and provides an output of about 100 mV rms. It uses a Vackar circuit incorporating a junction f.e.t. as in Fig. 11. It is adequately stable for reception of s.s.b. signals and the short term stability is better than 50Hz over 15 minutes. The coil used was by Cambion (type number 2419-3) and is made of silver-plated wire, tension wound on a ceramic former. A more modest coil could be constructed but would sacrifice frequency stability. The variable capacitor is the Jackson Type U101 6-75 pF s.l.c. law, which gives a substantially linear calibration over 500 kHz. A small amount of temperature compensation is included in the form of a 22 pF N750 capacitor across the tuning capacitor. The oscillator is buffered by a single transistor emitter follower, which takes its output from a capacitive tap across the tuned circuit, thus reducing the loading and defining the output amplitude.

Heterodyne mixer

The mixer, shown in Fig. 8, combines the output from the phase-locked loop with the signal from the v.f.o. By this means, continuous coverage is obtained from 1.5 to 28.5 MHz in 500 kHz bands. The only disadvantage with this arrangement is that the tuning of the bands from 1.5 to 12 MHz is reversed from that for those from 12 to 28.5 MHz.

The circuit uses a Plessey SL 641 double-balanced mixer, which provides adequate suppression of both v.f.o. and phase-lock loop feed through. The required sideband is selected by means of a tuned circuit. The Q of this is defined by the 820-ohm resistor across it, to ensure at least 500 kHz bandwidth for each band. The calculated suppression of all unwanted mixer components exceeds 30 dB, the best obtainable from a single tuned circuit. This is quite adequate for out-of-band components when used as the local oscillator in a superhet since there is effectively extra suppression provided by the r.f. tuned circuits. In addition, theconversion efficiency of the receiver mixer drops off rapidly for small oscillator levels. A more general method of achieving this selection would be to use a series of bandpass filters with their pass bands carefully chosen to exclude major unwanted products. It is possible that a greater degree of suppression could be achieved if these filters were more complex. The output from the mixer is buffered by a single-transistor emitter follower.

Fig. 12. *Power supply.*



Power supply

The power supply in Fig. 12 provides four voltage rails, two at 5 volts, one at 6 volts and one at 11 volts. The unit uses a standard charger transformer giving 0, 9 and 17 volts a.c. Stabilization is by i.c. and discrete component regulators. This reflects component availability at the time of construction, but there is no reason why standard three-terminal regulators could not be used. The most significant detail of its construction concerns the earthing arrangements, which are essential to ensure isolation between the rails. Each regulator has a single earth point and these in turn are all connected to a common earth point, the earth-return rail for each supply from the logic also being returned to this common point. In this way, the earth return currents of each supply are isolated from those of all others.

Two individually stabilized power rails are provided, one to supply the phase detector and v.c.o., and the other the rest of the logic. These separate supplies, together with the earthing arrangements mentioned above, are essential to prevent power supply noise generated by the counters from modulating the output signal.

Construction

The unit was constructed on three pieces of 0.1in Veroboard and was incorporated into the author's amateur band transceiver. One board of 2½in × 5in contained the power supply components except for the transformer, another of the same size containing the phase detector, loop filter, v.c.o. buffer and heterodyne mixer. The final board of 3½in x 5in contained the reference oscillator and dividers, together with the prescaler programmable divider and diode matrix. The coils and transformer were mounted on a chassis which also formed an enclosing screen. These parts occupied a space 7in × 4½in × 4½in. The v.f.o. had previously been built in a diecast box which was located outside this volume.

The order of construction that the author would recommend is as follows. First build up the power supply to give at least 5 volts at 500 mA. Then construct the reference oscillator to provide a convenient source of pulses with which to check subsequent circuit groups. The reference oscillator divider comes next and can be tested using an oscilloscope to monitor the output or alternatively, if one is not available, a frequency counter or general coverage receiver with the latter receiving a suitably attenuated version of the 50 kHz reference frequency, harmonics should be received throughout the h.f. spectrum. Now assemble the prescaler and the programmable divider, which is most conveniently tested using a frequency meter, taking the reference oscillator as input and confirming that the correct output frequency is obtained for various division ratios. It is now necessary, if this has not already been done, to commission the 11 volt and second 5 volt supplies. The v.c.o. level charger and output buffer should next be constructed, again being commissioned in conjunction with the programmable divider and a frequency meter. It is useful at this stage to confirm the range of the oscillator by feeding the varicap diode from a suitable high-impedance, variable-voltage source.

The phase detector comes next, being commissioned with the 50 kHz reference. If this is fed to both pins 3 and 1, i.e. no phase error, the output at pins 5 and 10 should be about 1.5 volts. If this feed is made only to pin 1, leaving pin 3 open circuit, the output should fall of 0.8 volts, i.e. go up. Conversly feeding only pin 3 the output should rise to 2.2 volts.

Next the loop filter can be assembled, bearing in mind that the CA 3130 is a m.o.s. device and that care should be taken to avoid damage due to voltage transients during soldering or capacitive charge effects during handling. With this the loop can now be closed and, with any luck, frequency lock obtained. Checks on the output wave form can be made with a spectrum analyser, if one is available, or failing that, a general-coverage receiver with an "S" meter. The reference feed through may be detected as low level signals 50kHz on either side of the

Components List

Reference oscillator, programmable divider and prescaler

$R_1 R_2$	68kΩ ⅓ watt	C_1 330 pF polystyrene 30 Vw
R_3	150Ω ⅓ watt	C_2 100 pF polystyrene 30 Vw
R_4	2.7kΩ ⅓ watt	C_3 15 pF ceramic 30 Vw
R_5	10kΩ ⅓ watt	C_4-C_{10} 0.01μF ceramic 30 Vw
R_6	3.3kΩ ⅓ watt	
R_7	470Ω ⅓ watt	CT_1 7-65 pF trimmer
R_8	1kΩ ⅓ watt	
R_9 to R_{15}	8.2kΩ ⅓ watt	X_1 1MHz HC6U quartz crystal
R_{16}	1.5kΩ ⅓ watt	
Tr_1	BC 108	IC_1 SN 7474
Tr_2	BSX 19	IC_2 SN 7490
Tr_3	BSX 20	IC_3, IC_4 SN7404
Diodes in diode matrix.	1N4148	IC_8 SN 74196

Variable-frequency oscillator

R_{40}	270Ω ½ watt	C_{40} 22pF N750 ceramic
R_{41}	47kΩ 2 watt carbon	C_{41} 22pF silvered mica
R_{42}	33kΩ ⅓ watt	C_{42} 47pF silvered mica
R_{43}	10kΩ ⅓ watt	C_{43} 2200pF silvered mica
$R_{44} R_{45}$	1kΩ ⅓ watt	C_{44} 10000pF silvered mica
		$C_{45} C_{46}$ 0.01μF ceramic 30 Vw
		C_{47} 0.1μF ceramic 30 Vw
Tr_7	2N 3819	C_{48} 0.047μF ceramic 30 Vw
Tr_8	BC 108	
		Vc_1 6-75pF Jackson type U101
D_{15}	6.2V 400mW zener diode	CT_2 3-30pF trimmer
2.5mH choke Repanco		
2.6-3.6μH coil Cambion 2419-3.		

Phase detector, loop filter v.c.o. and heterodyne mixer

R_{20}	3.9kΩ ⅓ watt	C_{15} 0.1μF ceramic 30 Vw
$R_{21} R_{22}$	100Ω ⅓watt	C_{16} 0.68μF polycarbonate 30 Vw
R_{23}	82Ω ⅓ watt	$C_{17} C_{18}$ 47μF electrolytic 25 Vw
R_{24}	10kΩ ⅓ watt	C_{19} 100pF ceramic 30 Vw
$R_{25} R_{26}$	18kΩ ⅓ watt	C_{20} 0.33μF polycarbonate 30 Vw
R_{27}	1kΩ ⅓watt	C_{21} 0.1μF ceramic 30 Vw
R_{28}	36Ω ⅓ watt	$C_{23} C_{25}$
R_{29}	220Ω ⅓ watt	$C_{26} C_{27}$ 0.01μF ceramic 30 Vw
		$C_{28} C_{30}$
R_{30}	820Ω ⅓ watt	$C_{31} C_{32}$
$R_{31} R_{32}$	18kΩ ⅓ watt	C_{34}
R_{33}	1kΩ	C_{24} 100pF silvered mica
Tr_4	2 N4126	C_{29} 0.1μF ceramic 30 Vw
Tr_5	BC 108	C_{33} 25μF electrolytic 25 Vw
Tr_6	BC 108	
D_{10}	MV 1401 Motorola	IC_9 MC4044 Motorola
$D_{11} D_{12} D_{13}$	1N4148	IC_{10} CA 3130 RCA
		IC_{11} MC 1648 Motorola
		IC_{12} SN 74500
		IC_{13} SL 641 Plessey

Coils and tuning capacitors see circuit diagram inset.

Power supply

R_{50}	33Ω ⅓ watt 5%	C_{50} 1000μF 25 Vw electrolytic
R_{51}	1.5kΩ ⅓ watt 5%	C_{51} 4700μF 16 Vw electrolytic
R_{52}	11kΩ ⅓ watt 5%	$C_{52} C_{53}$ 0.01μF ceramic 30 Vw
R_{53}	3.3kΩ ⅓ watt 5%	C_{54} 47μF 25 Vw electrolytic
R_{54}	6.8kΩ ⅓ watt 5%	C_{55} 220μF 16 Vw electrolytic
R_{55}	3.3kΩ ⅓ watt 5%	C_{56} 220μF 16 Vw electrolytic
R_{56}	8.2kΩ ⅓ watt 5%	
R_{57}	10Ω ⅓ watt 5%	
R_{58}	1.2kΩ ⅓ watt 5%	IC_{14} μA 723
R_{59}	9.1kΩ ⅓ watt 5%	IC_{15} "
R_{60}	220Ω ½ watt	
R_{61}	470Ω ½ watt	
R_{62}	220Ω ⅓ watt	Tr_9 OC 35 on heat sink
R_{63}	180Ω ⅓ watt	Tr_{10} Tr_{11} BC 108
R_{64}	1.1kΩ ⅓ watt 5%	
R_{65}	3.9kΩ ⅓ watt 5%	
		D_{15}-D_{20} IN 4001
T_1	0-9-17 volt 1 amp charger transformer	D_{21} 6.2V, 400mW zener

wanted signal. Finally the v.f.o. and heterodyne mixer output coils peaked, using an r.f. volt meter, in the centre of their respective bands. □

References

3. Crystal oven and frequency standard. L. Nelson-Jones. *Wireless World* June 1970 pp. 269-273.

4. 10-80 Metre Amateur Transceiver. D. Bowman. *Wireless World* June, July, Aug, Sept 1972.

Police communications aided by microcomputer

A recent demonstration of a police communications headquarters in Leicestershire which has been converted to microcomputer control may well indicate new trends in Post Office/Home Office/police relations.

The "Consort 2" computer-based network is a development by Burndept Electronics of Erith and Biggleswade. As reported in our March 1979 issue, the company was previously a part of the Ever-Ready (Berec) Group, and is now partly under the control of the National Enterprise Board, which holds 51% of the equity. The new system replaces a v.h.f. communications centre which was functional but, according to a police spokesman, "out-dated," consisting of a manually-switched exchange in contact with mobiles and handportable units on the beat.

Although by no means revolutionary in concept, the new process has some unusual features, not the least of which is the facility it provides to the driver of a patrol car or other observer to check in a few seconds the name, address and age of the owner of any car. This is effected by means of a direct link through the carrier-operated main station to the national police computer in Swansea. While such a facility could conceivably be used to harass a motorist, its usefulness as an instant check on stolen cars must be undisputed.

Briefly, the system comprises a v.h.f./u.h.f. linked switching exchange with facilities for monitoring, independent selection, and talk-through (via a main station), linking mobiles to base and to each other. It is also possible to patch in to local PAX/PABX lines, rendering the telephone network open to use by the police.

Even though a Leicestershire chief inspector suggested that the Post Office is reticent where the provision of a personal telephone service for the copper on the beat is concerned, the official Post Office line is that as the telephone service is free to everyone else, it must also be free to the police.

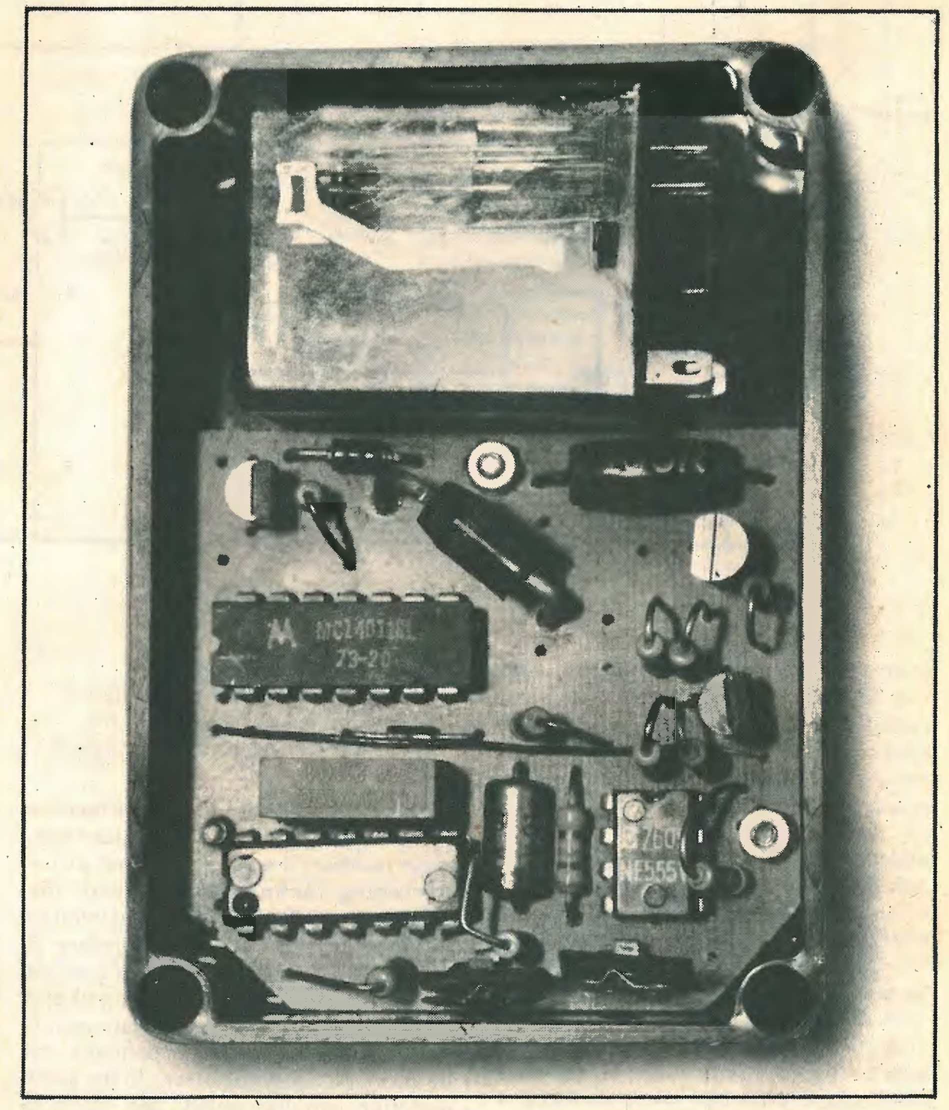
With the recent changes which have taken place in Post Office regulations, permitting interface of private mobile radio with the telephone network, specifically to Air Call Ltd, Burndept has unquestionably struck while the iron is hot. Linking a microprocessor to a basic switching circuit is hardly a systems breakthrough, but the Home Office, which selects and checks equipment for the police (and pays for it from the public purse) is clearly satisfied with the result since it has already equipped both Northampton and Nottingham as well as Leicester with the "Consort 2." A further 11 systems have been ordered by the Home Office for other police forces, at an approximate cost of £100,000 for each installation.

Motor speed controller

Inexpensive home-made alternative to £20 commercial model controllers

by **J. D. Stumbles,** B.Sc.

This motor controller is a cheap and effective home-made alternative to £20 commercial devices performing much the same function. The total component cost is under £5. It is considerably lighter and more efficient in terms of battery power than the servo-operated rheostats of the past. It also has some unique features of especial value to model boat enthusiasts. Because the motor control transistor derives its base current ultimately from the receiver power supply, it is impossible to set the boat off with the receiver switched off. Also, it is possible to set up the controller so that the off position of the transmitter control is biased toward the reverse speed end of its travel. This allows full speed to be achieved forward, but only a low speed in reverse. This not only looks more realistic, but also avoids the propeller unscrewing itself in mid-pond!



A FELLOW RADIO-CONTROL boat enthusiast wanted a device to control the electric motor in one of his scale boats. Ideally he wanted proportional speed control in forward and reverse, from one channel of his "digital" radio control outfit.

The modulation in these digital systems is similar to that described by M. F. Bessant in his multi-channel control system (*Wireless World*, October 1973). A number of width-modulated pulses of 1 to 2ms duration are sequentially transmitted, with a synchronization pulse for the decoder. The repetition period of this train of pulses is typically 15 to 20ms. The system used by Bessant and others is shown in Fig. 1 (a), with a slightly older variant at (b). In the last-mentioned system the sync pulse is longer than the control pulses, and the cycle repetition rate is usually independent of the widths of the control pulses; in the modern system the cycle time can vary over a wide range, depending on the settings of the controls.

The frames of pulses are transmitted

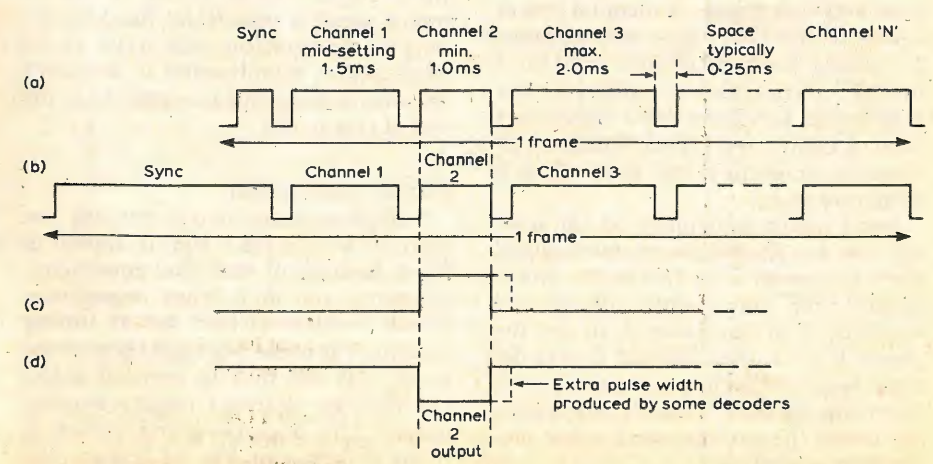
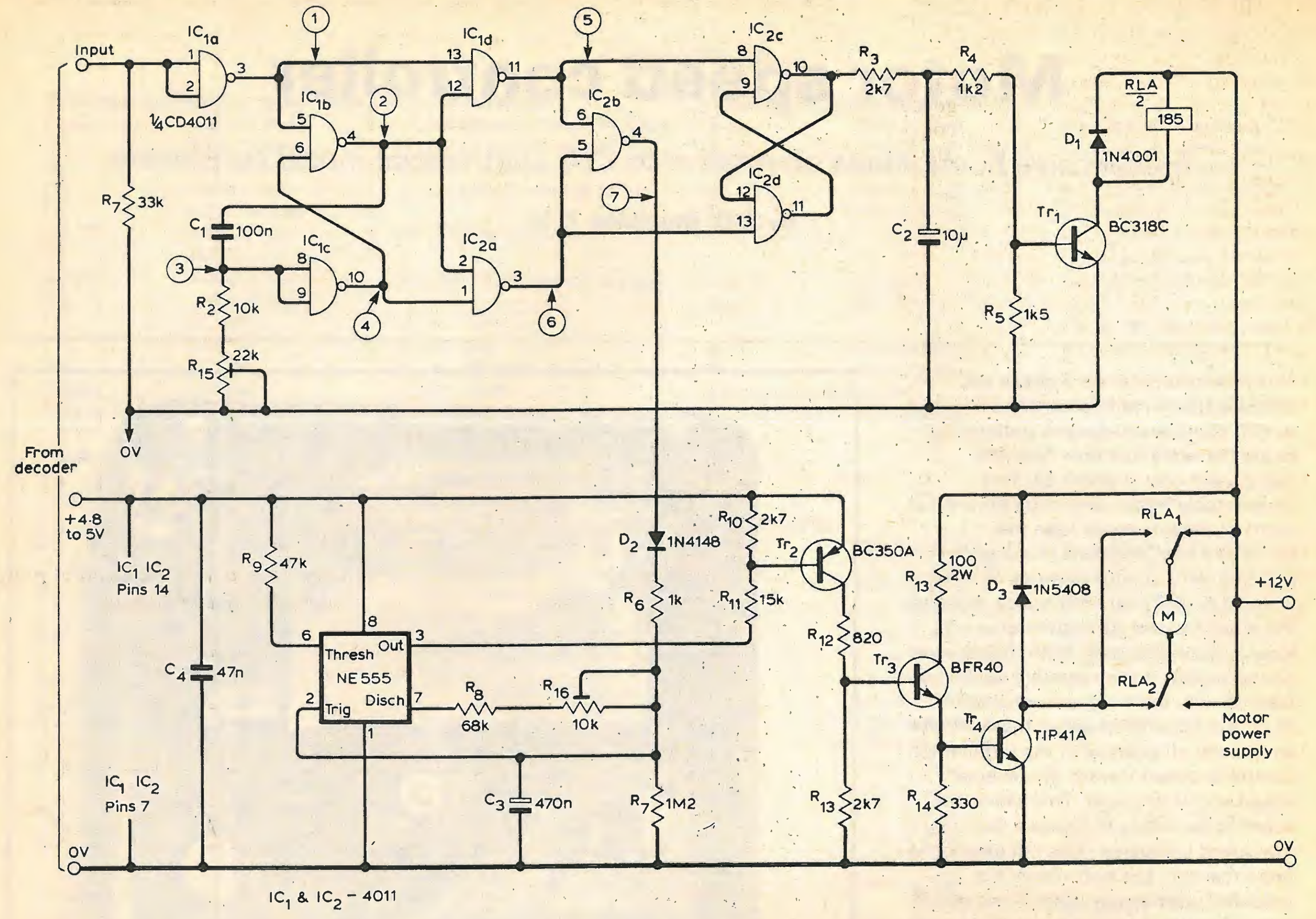


Fig. 1. *Examples of modulation systems used in digital radio control are M. F. Bessant's multichannel system using short sync pulse (a) system using long sync pulse used in some radio control outfits (b), while (c) & (d) show outputs from different decoders for given channel.*



over a suitable data link (a 27MHz carrier for model radio control) and decoded at the other end. The decoder splits up the pulse train, presenting pulses for each channel at the appropriate channel output, as in Fig. 1 (c) or (d). In some decoders the "space" is added to the width of the output pulses, although this appears merely as a fixed offset, which can be allowed for in setting up the servo or motor controller. The polarity of the output pulses also varies from one system to another.

In deciding on a suitable method of controlling the motor, the obvious approach was some form of variable mark-space switched control, using a power transistor. As the motor only drew about two amps when stalled, from a 12-volt supply, a medium power device of the TIP41 type was suitable. To obtain forward/reverse control a bridge circuit was considered, but rejected as the three extra transistors (two of them p-n-p types) would not be cheaper, or occupy less space than a miniature relay.

Some motor controllers on the market use a standard electromechanical servo to operate a control on the motor control unit. This seemed clumsy, and wasteful of an expensive servo and the power it consumes. Instead it was decided to use the width-modulated pulses from the decoder, suitably processed, to control the variable mark-space motor drive waveform.

Fig. 2. *Circuit of the c.m.o.s. motor-speed controller that is lighter and consumes less power than the "servo-operated rheostats of the past."*

The system chosen to do this has the advantage of simplicity. Its disadvantage is that, because of the pulse stretching technique employed, the motor speed is inversely proportional to the overall frame length. Therefore in systems such as Fig. 1 (a) there is slight interaction between other channels and motor speed. Since in most systems it is unlikely that all the other controls will be at their extreme positions in the same direction simultaneously, the effect is hardly noticeable. In systems where these conditions do occur, or where motor speed is important, fixed frame-length modulation will have to be employed. A modification to Bessant's encoder to allow this is suggested at the end of this article.

Circuit description

Complementary m.o.s. devices are used in the complete circuit, shown in Fig 2. because of their low power consumption and high input impedance, which facilitates their use as timing circuits. The incoming signal is inverted by IC1 (a) and may be omitted where the decoder delivers negative-going pulses. The negative-going pulses at point 1 (see also Fig. 3) trigger the monostable circuit made up of IC1 (b) & (c). In the discussion that follows assumes that the input pulses are of 1 to 2ms duration, and the frame repetition period is 15ms. The normal output pulse-width of the monostable is adjusted to 1.5ms by R_{15}.

Operation of the circuit with pulse widths shorter than, equal to, and longer than, 1.5ms is shown in Fig. 3. For short pulses the output of IC1 (b), point 2, is a constant 1.5ms positive-going pulse. This is compared with the input in NAND gate IC1 (d), whose output is a negative-going pulse of length equal to the difference between input and reference 1.5ms pulses. When the input pulse is longer than 1.5ms the output of IC1 (c), point 4, is a fixed 1.5ms negative pulse, whilst the output of IC1 (b) reproduces the input pulse. NAND gate IC2 (a) produces a difference-pulse.

The lower part of the circuit in Fig. 1 (a) consists of the pulse-stretching and driver/output circuits. The operation of the pulse stretcher is shown in Fig. 4. When the input pulses are very short, as in (a), the charge put on C_3 through D_2 and R_6 is so small that the bleed resistor R_7 keeps the voltage on C_3 below the trigger point of the 555 IC. This is connected as a comparator, with the threshold input held high by R_9. The comparator works in an inverting sense, so its output is high when the voltage on pin 2 is below the internal reference of

⅓V_{cc}. In this state Tr_2, Tr_3 and Tr_4 are off and no power is applied to the motor.

As longer input pulses are applied, C_3 begins to charge above the trigger point, so the comparator output goes low. Resistors R_8 and R_{16} are now connected to ground through pin 7, discharging C_3 until its voltage is below the trigger point once more. During this time the drive transistors are on and the motor is driven. Fig. 4 (c) shows the operation of the circuit when the difference pulses are half of their maximum length, 0.25ms. The pulse stretcher drives the motor for half the frame period, 7.5ms, thus giving half-speed control. When the difference pulses are at maximum length, 0.5ms, the voltage on C_3 never drops below the trigger point, so there can be a slight dead-band at full-speed setting.

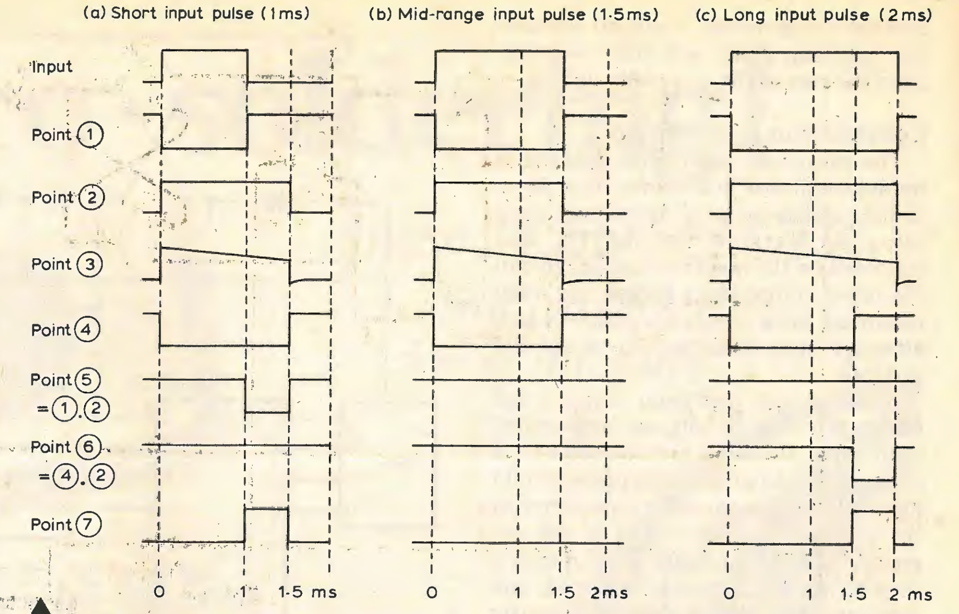
The forward/reverse function is determined by the R-S flip-flop IC2 (c) and (d). Figures 1 & 2 show that pulses occur at point 5 only for inputs shorter than 1.5ms, and at point 6 only for longer inputs. The flip-flop therefore latches on whichever of these signals is present, and gives a steady signal to drive Tr_1, the relay drive transistor. Inclusion of the network C_2, R_3 and R_4 avoids the relay switching over briefly for a couple of frames, in the presence of radio interference. This is obviously unnecessary if a noise-free data-link is used.

Since the relay switches over at the centre dead point of the speed control, i.e. when the motor is off, the relay contacts can safely be used to pass considerably more than their rated direct switching currents. Thus in the prototype, one of the popular miniature 12V relays with a 185 ohm coil and nominal 2 A contacts is used to pass the full rated current of Tr_4 (i.e. 6A) and could be used for much more.

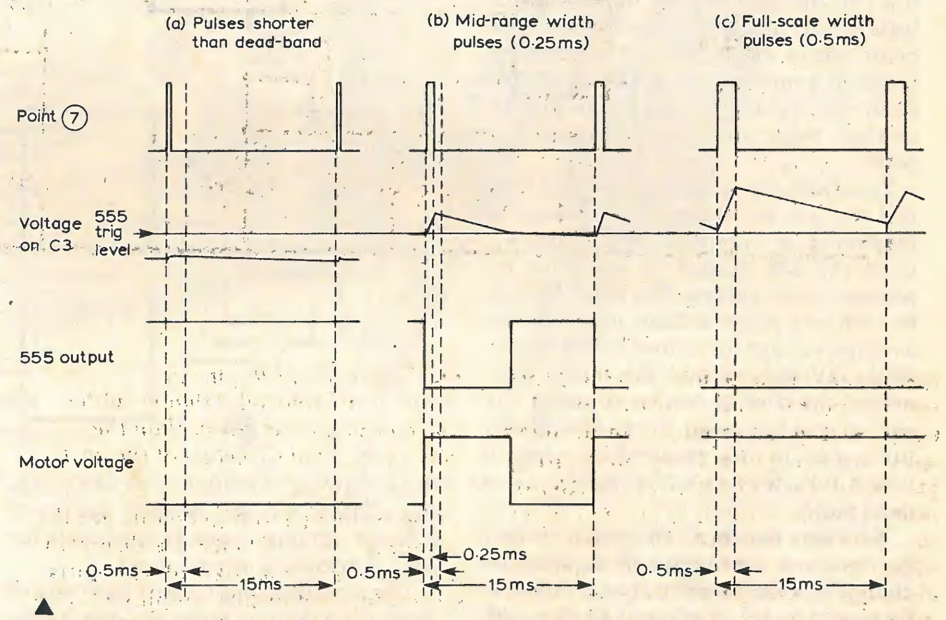
The drive current into Tr_4, about 100mA and set by R_{13}, has been chosen for a mid-range gain selection for this device of about 4A collector current.

Modifications and extensions

To use the controller for much higher currents, Tr_4 could be used as a driver for a larger n-p-n silicon power transistor in the Darlington configuration or for a hefty p-n-p germanium device. In the last-mentioned case it is essential to provide a low-value base-emitter resistor, to ensure the device turns off, even when hot. For currents much over 10 amps a larger relay should be used, although Tr_1 may have to be replaced with a Darlington pair to drive a lower resistance coil. To minimize interefence – it would be wise to place these high-



▲ **Fig. 3.** *Operation of the monostable and pulse-difference circuits with short input pulse of ims (a), mid-range input pulse of 1.5ms (b), and long input pulse of 2ms (c).*



▲ **Fig. 4.** *Operation of the pulse-stretching circuit with pulses shorter than dead-band (a), mid-range width pulses (b) and full-scale width pulses (c). Time is scale distorted for clarity.*

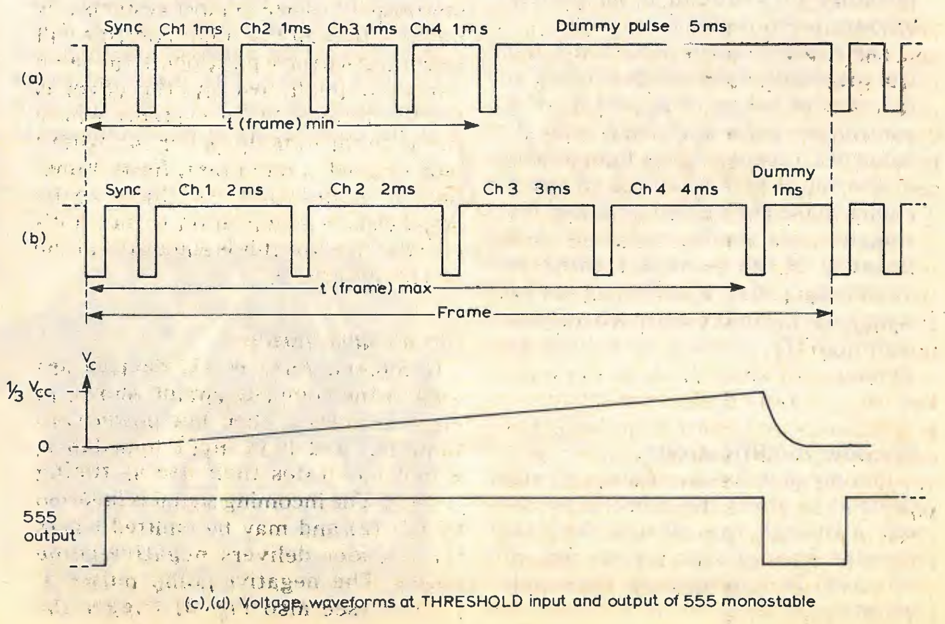


Fig. 5. *Insertion of dummy pulse into* ▶ *frame equalizes frame lengths. Example shows four-channel system with controls at shortest pulse-width setting (a), and at longest pulse-width setting (b).*

current components – output transistor, catching diode and relay – away from the rest of the controller circuit.

Construction & setting-up

The prototype was constructed in a miniature plastic box, about 70 × 48 × 25mm, with a piece of aluminium doubling as heatsink and lid. Tr_4 was mounted on the inside of this lid, and all the other components except the relay mounted on a printed circuit board, although strip-board would be equally suitable.

If the circuit has been constructed correctly it can be aligned without instruments, although a multimeter or a c.m.o.s. – compatible logic probe would help. With the controller connected to the correct channel output of the decoder, and the encoder/transmitter's control for that channel centred, the monostable/pulse-difference circuits can be checked and aligned. Adjust R_{15} until no pulses appear at the output of IC2 (b): this can be seen on a scope or logic probe, or the direct voltage at this point can be measured on the sensitive range of a multimeter. If 12V is applied then the relay should be heard to change back and forth around this point.

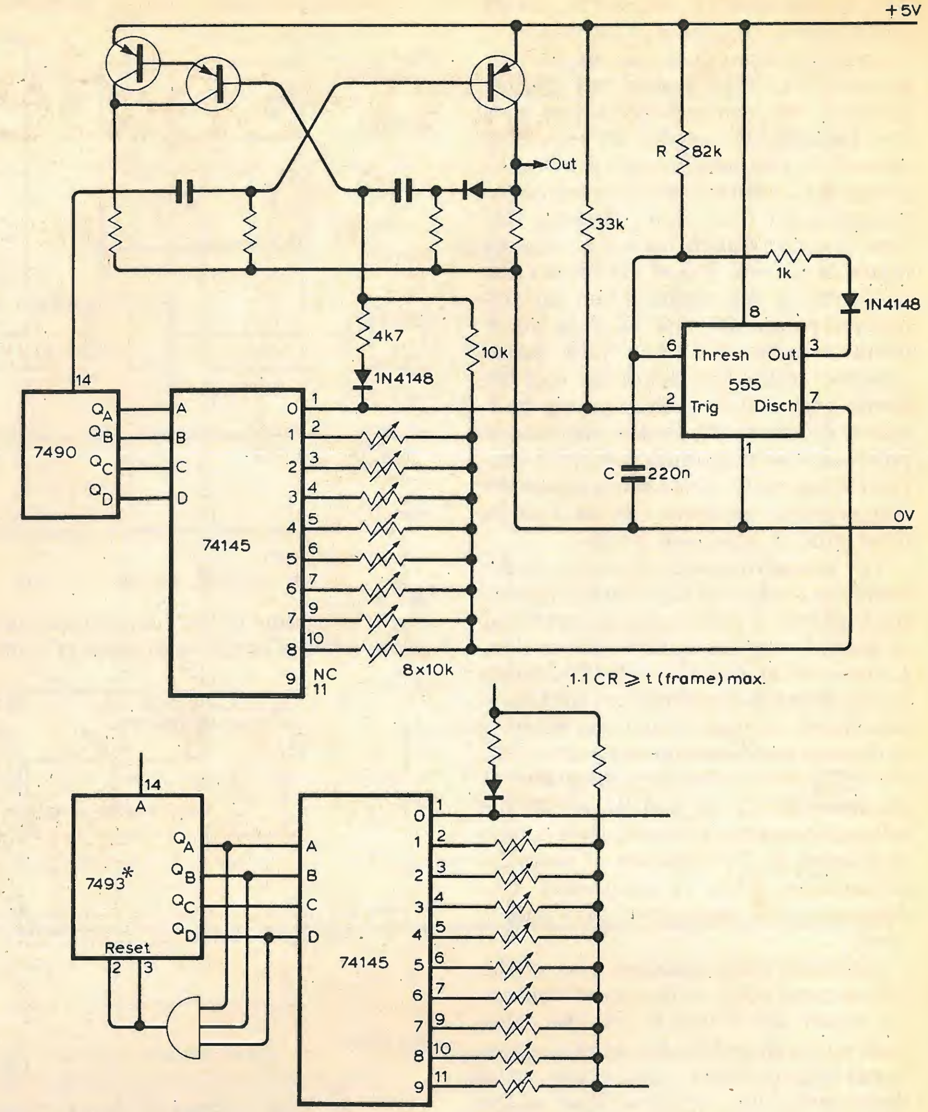
To adjust the pulse-stretch ratio control R_{16}, set the transmitter control to maximum or minimum and adjust R_{16} until the 555 output is low with no positive-going pulses. This can similarly be seen on a scope or logic probe, or the average voltage measured with a meter. With 12V applied and the motor connected the control can be adjusted "by ear" to give full speed. There should be a little play in the transmitter control whilst full speed is still obtained, i.e. a dead-band.

If for any reason a full stretch cannot be obtained, the value of R_6 may be changed. Note however that it is below its design value of about 1.6kohm, the remaining resistance being accounted for by the output resistance of the unbuffered c.m.o.s. gate. This effect could possibly be reduced if an emitter-follower were used in place of D_2.

The relative values of R_6 and R_7 control the width of the off dead-band, and the relative values of R_6 and R_8 + R_{16} control the pulse-stretching ratio. The value of C_3 is not critical, but should be in the range of 0.22 to 2.2 μF. Larger values make the system response more sluggish, and smaller values spoil the linearity of the pulse-stretching law. Transistors may also be substituted with any common-sense alternatives, although Tr_1 should be a high-gain device.

Encoder modifications

It is possible for the settings of other controls to affect the speed of the motor, although the off and forward/reverse changeover points are not affected. In applications where this variation is likely to be unacceptable



the following modifications are suggested, based on the Bessant design of encoder although equally applicable for similar encoders using c.m.o.s.

The modifications consist basically of inserting a dummy pulse into the frame, to equalize the length of the frame whatever the setting of all the controls. This dummy pulse has a minimum length of 1ms to avoid causing malfunction of the decoder, which is designed to accept pulses of less than 1ms as sync pulses. The modified pulse streams are shown in Fig. 5: in (a) with all the controls are at minimum, and in

Fig. 6. *Modifications to Bessant's of October 1973 issue give constant frame length by using existing counter and sacrificing one control channel (top), or by retaining nine-channel capability with count-to-eleven circuit (below). *74293 is recommended but has different pin connections than 7490.*

(b) at maximum. The dummy pulse is generated by the extra components in the Bessant encoder of Fig. 6 (a). This implementation sacrifices one channel, but if his is unacceptable then the variation in Fig. 6 (a) overcomes this problem by replacing the decade counter of the original circuit with a divide-by-eleven counter. When the counter reaches binary 1010 (decimal 10) the decoder produces no output. In Fig. 6 (a) the output for a count of decimal 9 is disconnected. In either case, when this end-state is reached the output of the multivibrator stays high until the monostable (555 timer) goes low, when the discharge terminal of the 555 grounds the common timing line. After a further 1ms the multivibrator goes low and the normal pulse sequence re-starts. The period of the monostable is set for just longer than the maximum normal frame length of the encoder. □

Go ahead for UOSAT

The University of Surrey's "AMSAT" team, in conjunction with the University's Department of Electronic Engineering and AMSAT (UK) has now embarked on the building of Britain's first Oscar amateur satellite spacecraft (see WoAR, September 1978). The project has been assured of financial support by British industry and a small full-time team (including a research officer, assistant, student and technician) is being recruited by the University's space studies group, under the direction of Martin Sweeting, G3YJO, who as research fellow will be project manager.

It is planned to have the spacecraft ready for launching into polar earth orbit in 19781-82. It will provide h.f. operators, for the first time, with a facility for gathering real-time information on prevailing ionospheric conditions. The project is also intended to stimulate a greater degree of interest in space sciences in schools, colleges and universities. Experimental modules are expected to include h.f. beacons, a magnetometer, radiation counters, earth-pointing slow-scan tv camera and synthesised voice telemetry system. A sum of about £85,000 has been raised and some 4000 solar cells, two nicad batteries and other key components promised. It is planned that several of the experimental modules will be built by amateur groups outside the university.

Microwave mixers

European interest in 10GHz operation, particularly in France, West Germany and Italy, remains at a high level although British activity seems slightly down on a year or two ago. An important aspect of the work is the link with the development of low-cost "front-ends" for future 12GHz domestic tv reception from satellites (January issue, pages 38-42). In both cases the prime requirement is to produce sensitive, low-noise receivers with a minimum of high-cost precision metalwork, as usually associated with microwave systems.

British 10GHz activities have in the past been facilitated by the availability of surplus waveguide and the bias has been towards the conventional approach of separate mixer and local oscillator stages. The alternative approach of using a self-oscillating mixer (a single Gunn diode, for example) has received less attention and encounters some discouragement from "old 10GHz hands", on the grounds that such front ends are excessively noisy (often 10dB above that obtainable with a separate diode mixer).

However, a recent article in the French amateur journal *Radio-REF* by J. Pauc, F3PJ, shows there is considerable interest in France, both among amateurs and commercial firms and organisations interested in direct broadcasting from satellites, in the techniques developed a few years ago at the University of Lancaster and described by Lazarus, Kycheung and Novak in *Microwave Journal* (March, 1977).

This work showed that the poor noise figure obtained with self-oscillating Gunn diode mixers is caused by the f.m. jitter of the oscillator and that by applying effective automatic frequency control it is possible to realise sensitive room-temperature receivers which are very stable and do not require expensive local oscillator noise cancellation. To quote the 1977 article: "they are competitive with, but require far less microwave hardware than the best conventional systems, and are strong candidates for practical system applications." Noise figures of 10dB and up to 15dB conversion gain have been achieved well above 10GHz. French work on these techniques seems to be yielding results although F3PJ indicates it is still at an experimental stage. The trick is to concentrate into the centre frequency of the i.f. the energy which would normally be distributed among the f.m. jitter sidebands.

Further impetus has been given to the use of anti-parallel harmonic diode mixers with Jim Dietrich, WA0RDX, reporting in *Ham Radio* a 1.3GHz mixer using half-wave lines and yielding a 6.4dB noise figure, nearly 40dB isolation between all ports, and low oscillator injection at half the usual frequency.

John Wood, G3YQC, in *CQ-TV* reports currently working on 10GHz equipment intended for fast scan television; other British amateurs interested in such work include G8EIM and GW6JGA/T.

Some 70 Italian amateurs are now using the 10GHz band and distances of over 200km have been achieved over sea paths and 350-400km over land paths between high sites. Most of the equipment uses 10mW Gunn diodes with separate diode mixers and 30MHz intermediate frequency.

WORLD OF AMATEUR RADIO

The successful series of open meetings of the R.S.G.B. Microwave Group continues with a further meeting at the IBA Engineering Centre, Crawley Court, near Winchester, on Sunday, April 1 (progress report and open forum).

Moonbounce "world first"?

Dave Price, GW4CQT, of South Wales is believed to have established a world record in becoming probably the first amateur to achieve "Worked All Continents" by using the earth-moon-earth path on 144MHz. His final contact, late January, was with South Australia; last year he made moonbounce contacts with Venezuela and a number of stations across the United States.

Although the e.m.e. path loss on 144MHz is rather less than 260dB, the difficulty of achieving the necessary high aerial gains has tended to concentrate most amateur e.m.e. working on the 432MHz band, although Douglas Parker, G4DZU at Leeds, with a 56-element array is one of the British stations equipped for listening on 144MHz.

Among those currently working on 432MHz moonbounce are the Oxford University Group with a 20ft dish (26dBi gain) and obtaining nearly 700 watts r.f. output from a pair of 4CX250B valves, and Chris Bartram, G4DGU, with a group of eight Yagi aerials each providing some 15dBi gain and a receiver using a Plessey GAT5 GaAs f.e.t. with a noise temperature of some 50-55° K.

In brief

The RSGB has published a new (2nd) edition of "Television Interference Manual" by Barry Priestley, formerly G3JGO. This 80-page booklet provides a concise account of the problems arising from the susceptibility of so much domestic electronic equipment to strong r.f. fields as well as offering much assistance in overcoming them (£1.56 including post & packing from RSGB, 35 Doughty Street, London WC1 2AE).

. The FCC has launched an enquiry to determine the extent to which r.f. interference impacts on consumer electronic products, medical products and public safety communications: one result may be further funding of work on the Texas Instruments high-performance tv receiver . . . . Increased sunspot activity has induced the American National Bureau of Standards to resume transmission of time and frequency information (WWV) on 20MHz . . . To mark its 60th year, Guildford & District Radio Society is issuing a special Diamond Jubilee award to those contacting four members of the society during the period March 1 to August 31 (h.f. or v.h.f.), details from L. Bright, G4BHQ, 4 Dagley Farm, Shelford, Guildford.

PAT HAWKER, G3VA

Functional logic symbols

Recommendations for a simplified method of representing complex digital circuits

by **G. M. Whittaker,** B.Sc. Ferranti Ltd, Edinburgh

The intelligibility of circuit diagrams can be greatly improved both by good overall layout and by concise, precise representation of the function performed by analogue and digital integrated circuits, for which a rigorously developed standard symbology is essential. Different categories of functional complexity of i.cs are defined, a variety of ways of representing i.cs is identified, and the preferred notation for each i.c. category is outlined. A unified system using these notations is outlined and examples of functional i.c. symbols are given.

TIME AND EFFORT could be saved, and errors of interpretation reduced, in the interpretation of digital circuit diagrams, if the symbol of each i.c. were to show as simply and precisely as possible the functional relationship between its inputs and outputs. It is this that IEC 117-15(1) and its direct derivatives including BS3939[2], should do. That they fail is demonstrated by the fact that PANAVIA, after initially specifying it in its entirety, have dropped the IEC notation for all i.cs more complex than logic gates.

Since IEC 117-15 and its derivatives are currently being revised to form a new standard, it is timely that engineers should examine the matter of functional i.c. symbols carefully to ensure that the new standard is fully developed to meet the needs of all categories of integrated circuits.

The purpose of the work reported here[3] is to develop the current IEC symbology as embodied in BS3939 to the point where it can be used for drawing precise functional circuit diagrams of all digital i.cs. There are similar arguments for the adoption of functional symbols for analogue i.cs.

Functional i.c. symbols

In contrast to the precise representation of simple logic gates and analogue operational amplifiers, the more complex i.cs are commonly represented on circuit diagrams as blank boxes with pin numbers, and in data books in a complex manner which may be difficult to interpret. Examination of i.c. data books shows that different manufacturers use diverse methods of presenting data about functionally similar i.cs. This diversity is increased in equipment manufacturers' circuit diagrams since a number of standards exist for graphical symbols for logic integrated circuits. Many problems have been caused by the publication of under-developed standards in the form of IEC 117-15 and its derivatives, which are unusable as they stand. They conflict with the JEDEC[4] symbols used widely in i.c. manufacturers' reference manuals, and employed by engineers and technicians throughout large sectors of industry. However, the JEDEC system cannot be used as the basis for functional symbols for i.cs more complex than logic gates and flip-flops.

The Approach

The report on functional logic symbols[3], while following BS3939 to the letter where possible, introduces a concise dependency notation representing multi-line addressing inputs and outputs, representation of tri-state logic clarified rules for logic polarity indicators, and appendices showing a variety of i.cs and giving guidance on the drawing of circuit diagrams. These rules have evolved in the light of experience in the documentation of a digital computer, and of comments on both the original draft of BS3939 and a preliminary edition of the report. They are currently being applied in the preparation of a UK Service publication.

It is thought that those who already understand and use digital logic could learn to read functional logic symbols and find their way round the revised standard in about a day using a properly structured course either of programmed learning or of formal instruction.

Though the interpretation of the functional logic symbols is relatively easily learned, the origination of the best possible symbol for a complex logic element from currently available data demands a knowledge of the rules. Thus, in the short term, the publication of a set of standard symbols for all available digital i.cs is necessary, leading eventually to the adoption of these symbols in manufacturers' data, so that the originators of circuit diagrams can quickly select the appropriate symbol of an i.c. for use in any application. Otherwise this system will continue to be unacceptable to industry.

Categories of i.c.

Digital i.cs are categorised in terms of hardware complexity, the unit being the gate or gate equivalent circuit.

— Small-scale integration (s.s.i.) contains no more than 11 gates per i.c.

— Medium-scale integration (m.s.i.) contains between 12 and 99 gates per i.c.

— Large-scale integration (l.s.i.) contains between 100 and 1000 gates per i.c.

TABLE 1 — Categorisation of digital ICs

Circuit Type	Single Function: Simple	Single Function: Complex	Multi-Function
digital simultaneous	**Gates** inverter buffer AND gate OR gate linear gate	**Simultaneous DICE** (Arrays of gates) decoder/demux function gen. full adder ROM shift network b.c.d.-to-7 seg decoder	**Simultaneous Multi-Function Digital** (arrays of DICE) a.l.u.
notation:	qualifying symbol or dependency	dependency	pin name arrays of DICE
digital sequential	**Multivibrators** SR, JK, T, D. Bistables monostable. astable.	**sequential DICE** (arrays of gates and bistables) latch counter frequency divider shift register RAM	**sequential** Multi-function **digital** (arrays of DICE) microprocessor p.i.a.
notation:	dependency	dependency	pin name arrays of DICE

TABLE 2 — Categorisation of Analogue i.cs

Circuit Type	Single Function: Simple	Single Function: Complex	Multi-Function
analogue simultaneous	**ACE** comparator op. amp. voltage ref. current ref. inverting amplifier normal amplifier	**ACE** multiplier function gen.	**Arrays of ACE** voltage regulator
notation:	shaped symbols	qualified symbols	arrays of ACE
analogue sequential	integrator differentiator	gated integrator track/hold.	
notation:	qualified symbols	qualified symbols	
converters		d.a.c.	a.d.c.
notation:		qualified symbols	qualified symbols

— Very-large-scale integration (v.l.s.i.) contains over 1000 gates per i.c.

However, the type of functional symbol used for an i.c. in ref. 3 depends on the functional complexity of the i.c. which may not correspond to hardware complexity. Functional complexity may be defined in terms of single-function and multi-function circuits, with the additional sub-divisions of simultaneous function and sequential function, as shown in tables 1 and 2.

Single-function circuits. Any circuit or i.c. which can be described by a single mathematical operation, logic function table (truth table) or logic state transition table is defined as a single function circuit.

Single-function digital circuits may be represented precisely and concisely using functional logic symbols and the dependency notation. Typical simple single-function logic elements are logic gates and flip flops. Complex single-function logic circuits composed of arrays of logic gates and flip-flops, such b.c.d. to decimal decoders, counters, shift registers and memory devices, are referred to in ref. 3 as digital computing elements (DICE). A single-function analogue circuit is one which can be fully described by a single block denoting a mathematical operation, referred to as an analogue computing element (ACE).

Multi-function circuits. Highly-complex i.cs may be represented in two ways: precisely, as a circuit composed of single-function computing elements showing the exact function, or more concisely as a block with signal names which act as aide-memoires and refer to the precise diagram. The choice of symbol for an i.c. depends on the space available, the complexity of the precise diagram, and the level of information one needs.

Dependency notation

The key to functional symbols for single-function digital computing elements is the use of a fully-developed dependency notation that allows the interaction between the control signals, data inputs and data outputs to be shown precisely.

One important benefit of the dependency notation is that symbols using it correctly are readily identifiable without further explanation and therefore the system is independent of language.

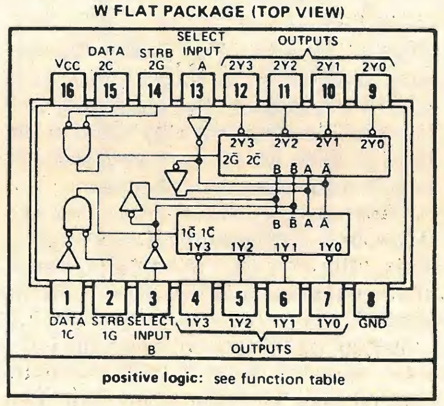


Fig. 1. *SN54155 digital integrated circuit as shown in the manufacturer's data.*

The dependency notation indicates the relationship between signals by means of both a letter placed adjacent to the affecting input which indicates the type of dependency, and an identifier which is both a suffix to the dependency indicator and is also placed adjacent to the affected signal. The following dependencies are defined: gating dependency; Gx gates the data on the signal labelled x: Activate dependency; Gx holds the output labelled x in its active state clocking dependency; Cx clocks the sequential elements inputs prefixed by x.

The clocking dependency is qualified by ⊣⊢, which is an edge trigger (1 negative-going) denoted in function tables by ↓, and by —|¬, a pulse trigger for master/slave flip-flops denoted in function tables by ⎍.

Inhibit is indicated by—⊣ When an inhibit stands at its logic 1 state, it holds all outputs in that part of a digital two-state or linear element in the 0 state if normal or the 1 state of negated.

Isolate is shown by—⊞. When an isolate stands at its logic 1 state, it holds all outputs in that part of a digital tri-state or linear element in the open-circuit Z state.

Enable appears as—⊖| or—⊖⊞ and is more precisely referred to as negated inhibit or negated isolate, as appropriate.

Negation and polarity indicators. In IEC 117-15 and BS3939-21 a subtle differentiation is made between the logic negation indicator —⊖ which is used to annotate those signals which are active in the logic-0 state, and the polarity or active-low indicator ⊵ which is

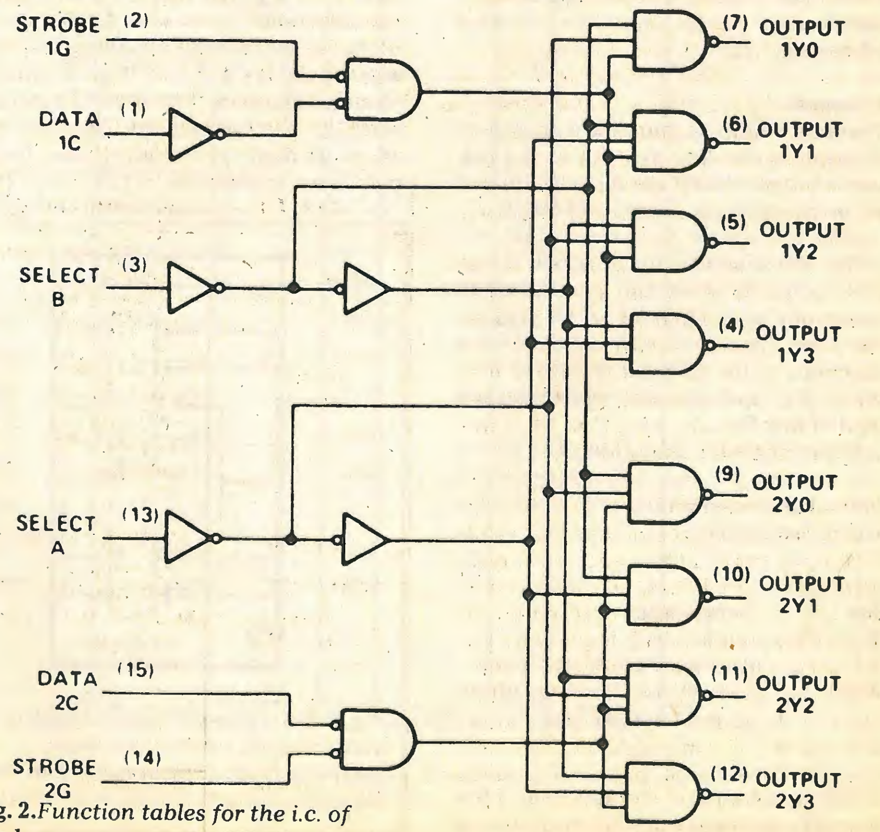


Fig. 2. *Function tables for the i.c. of Fig.1.*

FUNCTION TABLES
2-LINE-TO-4-LINE DECODER
OR 1-LINE-TO-4-LINE DEMULTIPLEXER

INPUTS				OUTPUTS			
SELECT		STROBE	DATA				
B	A	1G	1C	1Y0	1Y1	1Y2	1Y3
X	X	H	X	H	H	H	H
L	L	L	H	L	H	H	H
L	H	L	H	H	L	H	H
H	L	L	H	H	H	L	H
H	H	L	H	H	H	H	L
X	X	X	L	H	H	H	H

INPUTS				OUTPUTS			
SELECT		STROBE	DATA				
B	A	2G	2C	2Y0	2Y1	2Y2	2Y3
X	X	H	X	H	H	H	H
L	L	L	L	L	H	H	H
L	H	L	L	H	L	H	H
H	L	L	L	H	H	L	H
H	H	L	L	H	H	H	L
X	X	X	H	H	H	H	H

FUNCTION TABLE
3-LINE-TO-8-LINE DECODER
OR 1-LINE-TO-8-LINE DEMULTIPLEXER

INPUTS				OUTPUTS							
SELECT			STROBE OR DATA	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
C†	B	A	G‡	2Y0	2Y1	2Y2	2Y3	1Y0	1Y1	1Y2	1Y3
X	X	X	H	H	H	H	H	H	H	H	H
L	L	L	L	L	H	H	H	H	H	H	H
L	L	H	L	H	L	H	H	H	H	H	H
L	H	L	L	H	H	L	H	H	H	H	H
L	H	H	L	H	H	H	L	H	H	H	H
H	L	L	L	H	H	H	H	L	H	H	H
H	L	H	L	H	H	H	H	H	L	H	H
H	H	L	L	H	H	H	H	H	H	L	H
H	H	H	L	H	H	H	H	H	H	H	L

†C = inputs 1C and 2C connected together
‡G = inputs 1G and 2G connected together
H = high level, L = low level, X = irrelevant

used to annotate signals which are' active in the low-voltage state. In this paper, reference is made to the negative logic indicator, and logic-0 or 1 states are referred to in the text. However, the Dutch have understandably decided to drop the concept of logic states and use only the active-low indicator, referring to low or high-voltage states — a measure which other countries may well adopt, with resulting simplification of their standards.

Pin name notation. For use in multi-function i.cs, pin name abbreviations or initials must be short but memorable and preferably standardized. Manufacturers' pin names, where they already exist in data sheets, should be followed where practical.

Examples
Various practical circuits are shown to illustrate some key aspects of the advanced dependency notation as applied to functional logic symbols of DICE.

Manufacturer's diagrams of an SN 54155[4] are shown in Fig. 1, applications of which are shown in the function tables of Fig. 2. Three of these applications are illustrated in functional logic diagrams of the element in Figs. 3 to 5, while Fig. 6 shows the negative-logic dual of Fig. 5.

Figure 3 shows the 54155 dual 2-to-4-line encoder in its basic form in positive logic. The manufacturers pin names are shown bracketed.

Pin	Dependency
2, 14, 15	inhibit
1	enable (negated inhibit)
3, 13	binary-coded address inputs (activate dependency)

The A (activate) dependency indicates that enabled outputs are activated when a ddressed. Ther inhibit dependency de-activates all outputs from that part of the symbol. The outputs are all negated, meaning that they stand at the logic-0 state when activated and the logic 1 state when de-activated.

Figure 4 shows the i.c. connected as a 3-to-8-line encoder with positive logic in force. The BIN/OCT block is optional, the function being self evident from the symbol.

In Fig. 5 is the symbol when the i.c. is used as a 1-to-8-line demultiplexer in positive logic. Here the addressing input gates data onto the addressed output. The G dependency is therefore applicable. The outputs are shown negated since they are high (logic-1 state) when not addressed.

The negative-logic dual of the i.c., when used as a 1-to-8-line demultiplexer, is shown in Fig. 6. Note that the labels on the outputs are changed because 'all high' on the addressing input pins now represents octal zero. The negative-logic form is the simplest form of the symbol, and illustrates the point that most logic systems are more conveniently represented in terms of negative logic than positive logic.

Part of an array of eight 1K × 1 bit r.a.ms is shown in Fig. 7. The information in one symbol need not be repeated in the others, saving drawing time and space. The precise operation of the circuit is readily discernible from this diagram, whereas prolonged study of the data sheet was necessary to find out precisely how it works — an exercise which illustrates the importance of publishing such symbols for all originators of diagrams to copy.

Timing diagrams
Precise signal flow through digital circuits, including details of clock pulse edges or levels which cause certain actions, can be presented by means of timing diagrams, as shown by Fig. 8, in which the step by step execution of a

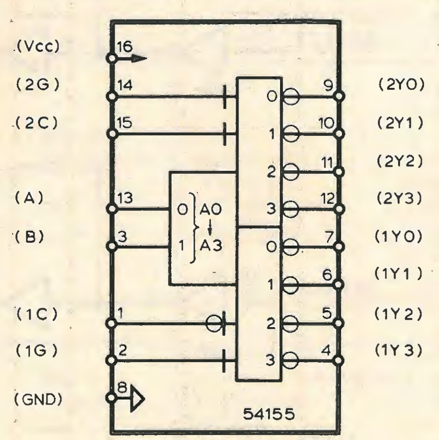


Fig. 3. *Dual 2-to-4 decoder. Much of the maker's data, needing package diagrams and function table, can be incorporated into this form of notation.*

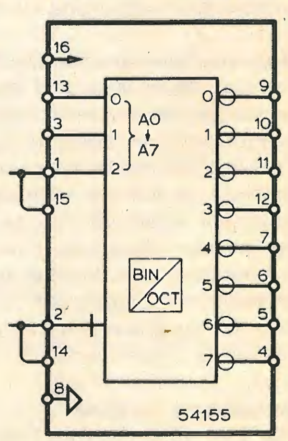


Fig. 4. *SN54155 used for 3-to-8 decoding.*

program instruction by a mini-computer can be seen. The operation of the circuit at each step is described by the text blocks at the top of the diagram.

The page is usually divided by vertical dotted lines, which represent clock-pulse edges. The circuit and signals contained between these lines shows the circuit configuration, signal values, etc, during that clock pulse. Sequential elements that are triggered by the clock-pulse edge are represented with the line passing through them, the clocking signal being positioned on the dashed line. The state after the clock edge is written to the right. A signal line that crosses a clock edge is not affected by that edge.

The same techniques have been used to draw the block diagram of the computer's control and display panel, showing the computer as a single block, and illustrating the sequence of operation of that peripheral in a much more helpful manner than a plain block diagram giving no sequential information.

The combination of functional symbols with timing diagrams forms a powerful technique, which can even be used for documenting the clock-pulse by clock-pulse operation of minicomputer or microprocessor based systems, the interpretation of these diagrams being easily learned. However, the originators of such drawings must be trained in the techniques.

There is a real danger that the revised IEC standard system of functional logic symbols for digital computing elements will become even more complex than the existing standard. It is vital that rules that are difficult to understand are simplified or replaced, rather than expanded, but for political reasons it is easier to add new rules than to amend or simplify existing rules.

Argument about the shape of AND/OR/INVERT gates is unimportant compared with the vital issue of producing intelligible blocks for digital computing elements, for which purpose rectangular gates seem preferable as in Fig. 7, and have advantages for computer graphics. While recognising slight advantages of shaped gates in some circumstances, it must be accepted that they are a lost cause as far as the IEC standard is concerned.

There is a real danger that the new IEC standard for logic symbols will continue to express simple concepts in a complex and long-winded manner, similar to the current standards.

It is essential that experienced users of digital circuit diagrams, all of whom will sooner or later be affected by the new standard, interest themselves in and contribute constructively to the development and simplification, if

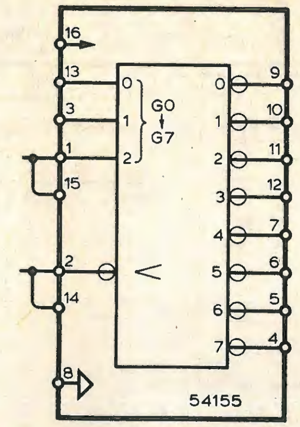


Fig. 5. *Example of 54155 used as 1-to-8 multiplexer.*

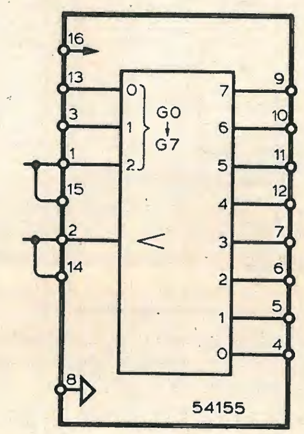


Fig. 6.*Multiplexing 1 to 8, using negative logic.*

Control signals.

Ax = activate dependency affecting x
Cx = clocking dependency affecting x
Gx = gating dependency affecting x

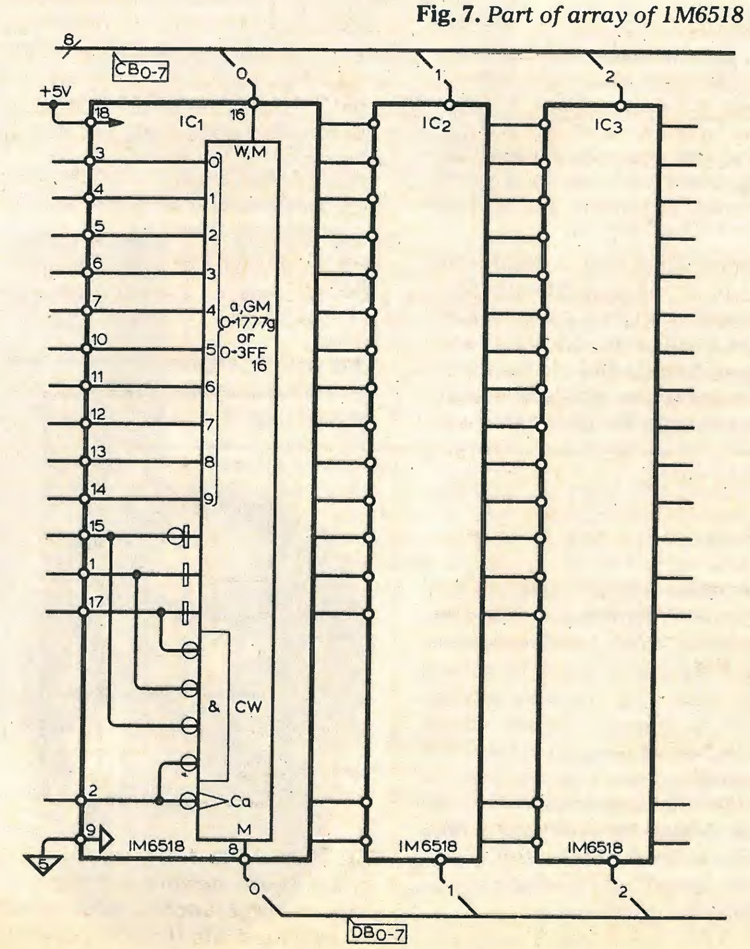
Identifiers. x is replaced by numbers of lower case letters to represent normal dependency. The following identifiers have defined meanings.

M = Memory location
r = Read dependency
w = Write dependency
, = AND relationship between identifiers
+ = increment counter by 1

Symbols.

xD = data input of D bistable or data latch affected by x
Q = data output of sequential element
& = AND dependency

Fig. 7. *Part of array of 1M6518 r.a.ms.*



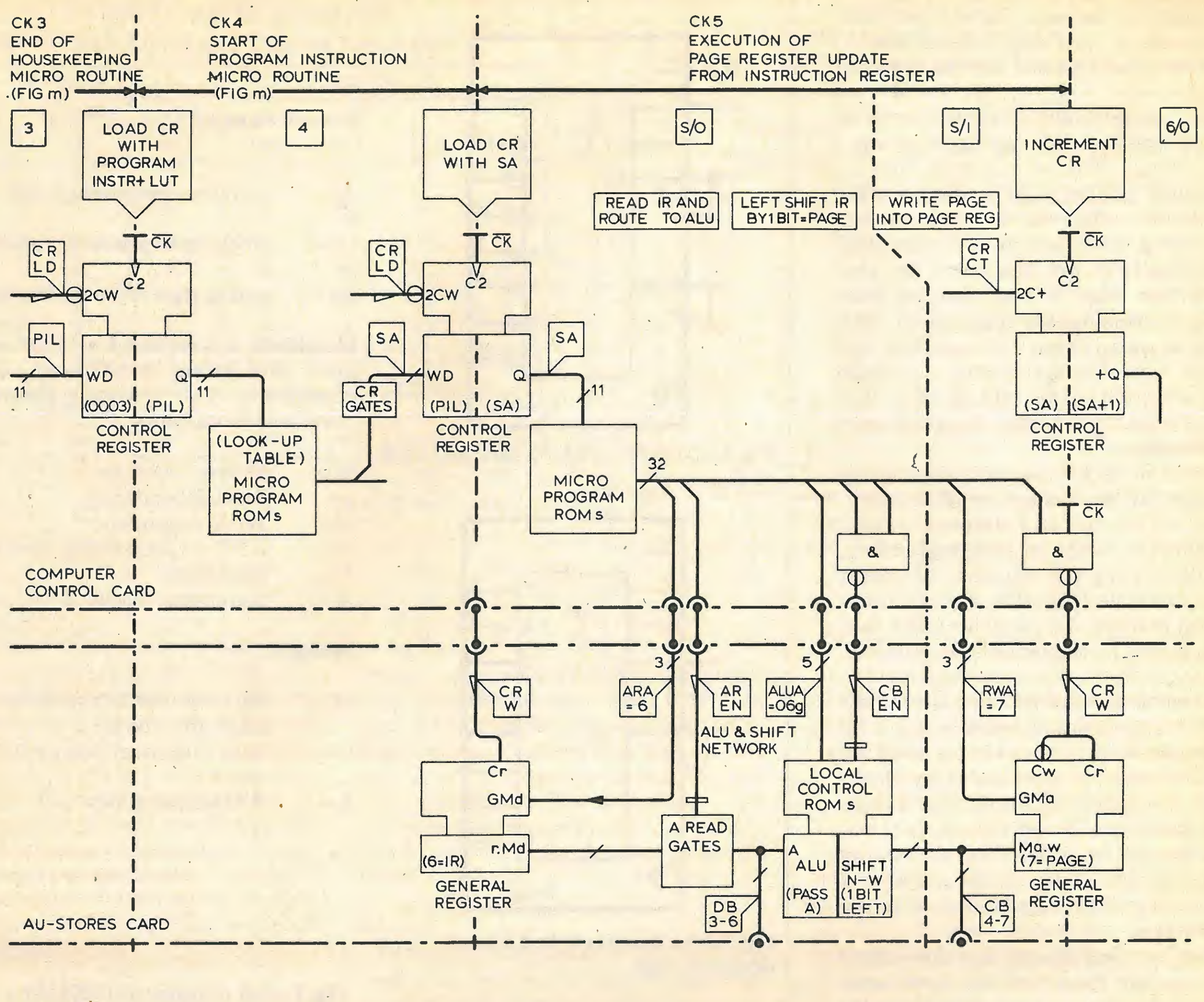


Fig. 8. *The method suggested in the article to show the execution of an instruction by a minicomputer.*

necessary, of the new standard within the existing framework, as soon as its draft becomes available for public comment.

It is recommended that a team with experience of modern digital techniques, documentation and programmed learning be formed to draw up and publish the standard symbols for available logic elements; to validate, amend and where possible simplify the rules and definitions so that they are no more complex than necessary to describe the available i.cs; and to devise a course of programmed learning for use in industry, further education and the Services.

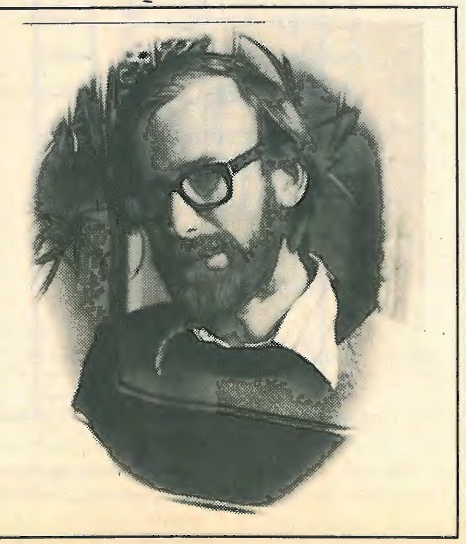
Notes

This article expresses the opinions of the author only and does not necessarily represent the policy of the BS Logic Symbols sub-committee to which he was appointed after it was written.

Some symbols used in this article are additional to BS3939, where this has been found necessary for the sake of accuracy and clarity. While they are not necessarily identical to the symbols that will be incorporated in the forthcoming draft of the IEC standard, they illustrate the lines along which it must develop in order to document existing i.cs.

The author

Giles Whittaker was educated at Cranbrook School in Kent and shortly after leaving school took a commission in the Royal Signals, in which he served for three years. After his army service, he went to Aberdeen University, where he took an honours degree in electrical engineering and went immediately to Ferranti, in Edinburgh to join a team of technical writers. Mr Whittaker is now project leader of the team, and is currently concerned with avionics equipment using microprocessors.



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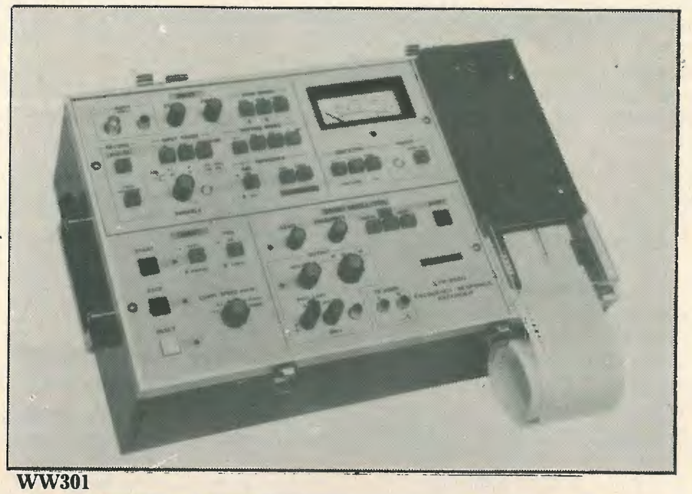
1. IEC, 1975, Graphical symbols for binary logic elements, IEC Publication 117-15.
2. BSI, 1977, Graphical symbols for binary logic elements, BS3939, Section 21, Issue 2.
3. Whittaker, G.M., 1978, Functional Logic Symbols, Ferranti Ltd., Edinburgh, Report No. EIS 840.
4. TI, 1975, TTL Data Book for design engineers, first edition, Texas Instruments.
5. Panavia, 1977, SP-P-0004/A Section 6, Graphics Symbols and reference designators, Part 4, Electronic Symbols, Nato unclassified. □

NEW PRODUCTS

Professional readers are invited to enter codes on the reply-paid card bound in at pages 112/3

Frequency-response recorder

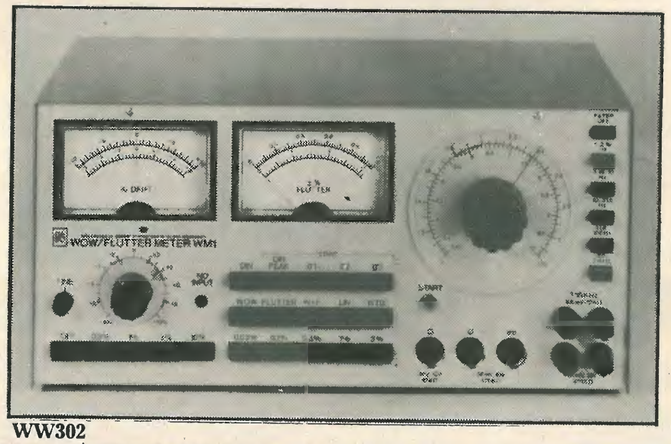
A measurement "tool" designed to analyse the performance of audio equipment, which can provide plots of frequency response on either log or linear scales, has recently been produced by Martron Ltd. This frequency-response recorder consists of an audio sweep oscillator and pen recorder, which is linked to a three-way meter, indicating frequency, sweep oscillator output and a.c. input. The LFR-5600 also has display oscilloscope outputs, and automatic start circuitry is included for use with tape recorders. A built-in recorder plots d.c. levels, enabling wow and flutter, drift, and other characteristics to be recorded. Martron Ltd, 20 Park Street, Princes Risborough, Bucks.
WW301



WW301

Wow and flutter meter

A feature of the Bang & Olufsen wow and flutter meter WM1 is a built-in frequency analyser for wow and flutter spectra, covering 1Hz to 316Hz in five ranges. The instrument has two pointer indicators, one for drift measurement from ± 0.316% to ± 10%; and one for wow/flutter from ±0.03% to ±3.16%. It has separate filters for wow and flutter measurements, and the f.s.d. of 0.03% in the most sensitive position makes it suitable for work on professional audio equipment. It offers sigma and quasi peak measurements based on 5s or 30s periods in addition to normal peak periods. Input voltage is 3mV to 10mV and there is automatic indication of too low input. Analogue output (to c.r.o. etc) is 1V. Optional extras are t.t.l.-compatible remote control and a crystal controlled reference oscillator. Bang & Olufsen Nederland, Koninginneweg 54, 1241 Kortenhoef, Netherlands.
WW302



WW302

Pocket radiotelephone

Cleartone Electronics have just announced their latest handportable unit, the Ranger CH800, which operates in the 148-174 MHz band with either 2 or 4 watts output. Cleartone say the equipment is "pocket-sized" (which presumably depends on the size of your pocket), the precise measurements being 151mm × 45mm × 62mm. In addition to its availability in 4 or 6 channel versions, it is housed in a rugged Lexan outer case for protection in harsh environments, and will operate for up to eight hours from its re-chargeable ni-cad batteries. Servicing is apparently easy, with all circuits on one side of a p.c. board, and access to several test points permits unprecedented ease in circuit trouble-shooting. Tone options and accessories are also available, and Cleartone point out that sales and service is available, nationwide. List price is £325. Marketing Dept, Cleartone Electronics Ltd, Abercarn, Gwent, South Wales.
WW303

WW303

Automatic component bridge

Using a microprocessor as the central calculator, Wayne Kerr's B605 Automatic Component Bridge, which permits the user to "plug in and read," is a further development of some of the company's earlier measuring packages, such as the B424 Component Meter. The intention, according to the manufacturer, has been to extend typical facilities to achieve a high level of accuracy while maintaining simplicity of operation. The traditional transformer/ratio-arm solution to the bridge problem has given way here to a technique involving an extension of the analogue bridge method. The phase-comparison of two signals results in numerical material which feeds a bridge circuit and a d.v.m. The signals are synthesized by a 32MHz crystal-controlled clock and a divide-by-16 counter, the microprocessor carrying out the final arithmetic. A common measuring chain is used to check the voltage across the "unkown" component and an internal "standard" component, with a guard amplifier ensuring that the parallel voltages are proportional to the magnitude of the unknown impedance. The clock generates 100Hz, 1kHz or 10kHz signals as selected by the operator's front panel settings, and the signal level is adjusted by attenuator to suit the integrator's dynamic range, before being passed to the phase-sensitive detector. The 20 bit resolution of the d.v.m. helps to avoid truncation error problems during the microprocessor's solution of the transformation equations, and the numbers are stored in r.a.m. until all measurements are made and the calculations effected. Briefly, the process can be summarized as a situation where Fourier analysis of each signal using a separately derived phase reference permits measurement of in-phase and quadrature components of the signals, the fifth offset correction then being made and the terms being enumerated in the dual-slope integrating d.v.m. Display is thereafter automatic, given that the correct numerical range has been selected. Resolution is claimed to be an "impressive" 0.0001pF on the C range, and accuracy 0.1% guaranteed across the whole (1 ohm to 1 Megohm) impedance range. Power supplies can be either mains or battery, and the display is liquid crystal rather than l.e.d. in view of the battery option. Price is in the range £1,000 to £1,200. Wayne Kerr, Wilmot Breedon Electronics Ltd, Durban Road, Bognor Regis, West Sussex PO22 9RL.
WW304

Temperature controller chip

Featuring an on-chip power-failure detector, the new General Instruments AY-3-1270 provides control facilities for home heating, cooling, and air conditioning systems. The controller is designed for digital thermometer applications and, in addition to accepting inputs direct from a thermistor temperature sensor, it will drive the display devices without the need for interface circuitry, according to the manufacturer. In the event of power being removed for longer than a specified time, or when

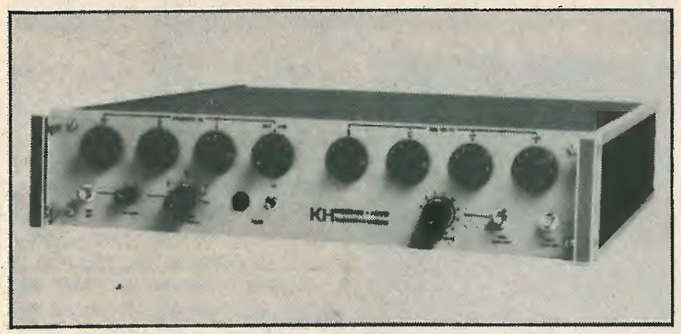
temperatures vary outside normal levels, warning is provided by flashing the display on and off until manually re-set. Temperature sensing error is ±1°C and hysteresis can be set to 0, 0.2, 0.4, 0.8, 2, 4 or 8°C. Power requirements are claimed to be non-critical, 9V at 40mA being all that is required, and typical applications are air conditioning systems, automobile engine temperature measurement, and heater control in addition to boiler and freezer control. The package is a 40 pin dual-in-line type, suitable for use in ambient temperatures from −25°C to +70°C. General Instrument Microelectronics Ltd, Regency House, 1-4 Warwick Street, London W1R 5WB.
WW305

Intelligent primary multiplex analyser

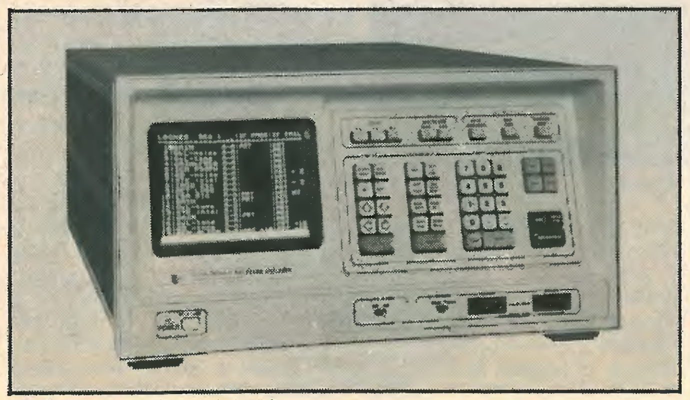
A compact, easy to use microprocessor-based instrument intended for automated voice channel measurements has been developed by Hewlett Packard in their South Queensferry, Scotland plant. Increased speed in circuit checking of multiplexed telephone equipment is one of the claimed advantages of the new unit, and the integrated system, which represents a new concept in automated measurement of voice-channel apparatus, has taken more than five years to develop. Comparable in size with a laboratory oscilloscope, the analyser can sequence through an exhaustive series of tests before calculating and displaying the results automatically. As well as characterising the analogue-to-analogue performance of pulse-code-modulated channel banks, separate tests of analogue to digital and digital to analogue performance can be made, and the unit can be used to check out frequency-division multiplexed terminals and time-division multiplexed switching equipment, including single channel p.c.m. codecs. Standard CCITT measurement masks are stored in r.o.m. and facilities are provided to allow an operator to store alternative masks in non-volatile memory. In order to cover world requirements, two models are being produced. Model HP3779A provides voice channel measurements to CEPT (Conference of European Postal and Telecommunications administrations) recommendations and with a digital option will test p.c.m. equipment conforming to CCITT recommendations G.711 and G.732. This represents 30 voice channels in 32 time slots encoded using the A-law and time division multiplexed into a 2048 k.bit digital stream. The B version is intended for Bell system users, and similarly it may be used to test p.c.m. equipment to CCITT recommendations G.711 and G.733, in other words, 24 voice channels in 24 time slots encoded using the mu-law and time division multiplexed into a 1544 k.bit digital stream. Measurement capability of both versions is available on request. Hewlett Packard Ltd, King St Lane, Winnersh, Wokingham, Berkshire.
WW306

Ultra-low distortion oscillator

An ultra-low distortion oscillator intended for critical audio laboratory applications, the 4024A presents typical distortion of less than 0.005% through the entire audio range. Tuning error is 0.5% with re-settability of 0.1%, and the tuning range, selected by three "digit" rotary switches, is 0.001Hz to 100kHz. The main sine wave output is controlled by a four-digit attenuator, providing 1mV resolution and a maximum output of 10V r.m.s. Amplitude stability is better than ±0.1% for a period not exceeding one hour, and in addition to these features, the unit provides a quadrature sine wave output and square pulse output. Amplitude is variable to 10V r.m.s. on "quadrature sine wave," while square wave and pulse output is variable to 5V peak to peak with pulse width variable from .1µs to 100µs. Keithley Instruments Ltd., 1 Boulton Road, Reading, Berks RG2 0NL.
WW307



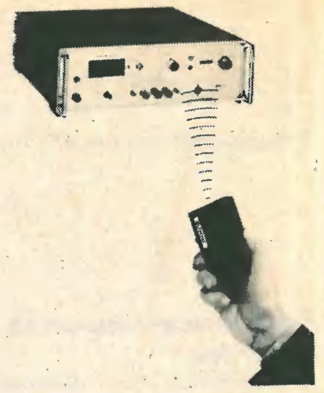
WW307



WW306

Remotely controlled power supply

Control of equipment by remote means, mainly using ultrasonics, has become an accepted "stunt" in the domestic tv field. The technique fulfils an industrial function in the remotely controlled power supply from Oltronix of Switzerland, who have recently announced the introduction of their RACPAC DPM. The system differs from the conventional form in that signals are at infra-red level and consist of bi-phase coded, 6-bit pulse sequences, in charge of a digital output panel indicating output ranges of 0 to 32V and 0 to 60V at claimed power outputs of 300, 600 and 900W. Functions controlled are on/off, pre-set output voltage



and current (limit) plus several alternative features which can be built in to order by the manufacturer, although we have no information on just what these options might be. The controller is hand-held, battery-operated, and has an operational range of 25 metres; furthermore it seems to be the first unit of its kind to appear, and may well be of interest to laboratory and industrial users. Final price depends upon the range of options selected. UK agents: Wessex Electronics Ltd, 114-116 North Street, Downend, Bristol BS16 5SE.
WW308

Production optical fibre

An operationally-proven optical fibre for the domestic and industrial market is available on a four-to-six week delivery basis. Specified as a six-fibre multi-channel cable for high bandwidth applications, the cable is said to save valuable installation time, since it can be laid and spliced in a fraction of the time required for twisted-wire paired cables. The makers, the US Valtec Corporation, say it can be installed with conventional coaxial cable pulling equipment, and each colour-coded sub-channel includes a dielectric strength member which imparts its strength to commercially-available, single-channel connectors. The entire cable is protected in corrugated aluminium sheathing to prevent crushing and the access of moisture. This cable is coded TC-MG-06 and the manufacturer claims a signal-carrying capacity equivalent to 2,100-pair copper wire cable, even though the fibre-optic cable's diameter is only 16.5mm, thereby achieving great savings in duct and storage space as well as transportation costs. Further options include steel sheathing as protection against rodents and copper conductors for electrical transmission. Communications Fibreoptics Division, Valtec Corporation, West Boylston, Ma. 01583, USA.
WW309

NRDC-AMBISONIC UHJ

SURROUND SOUND DECODER

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The unit is designed to decode not only UHJ but virtually all other 'quadrophonic' systems (Not CD4), including the new BBC HJ 10 input selections
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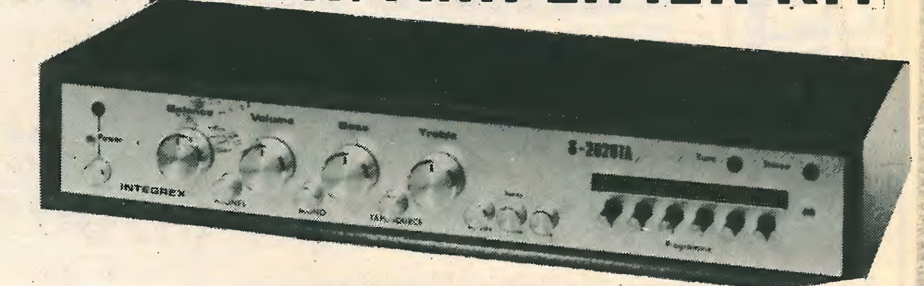


A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.

Brief Spec. Amplifier Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc.), THD less than 0.1% at 20W into 8 ohms. Power on/off FET transient protection. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses 3302 FET module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.2μV. THD 0.3%. Pre-decoder 'birdy' filter. **PRICE: £59.95** + VAT
Nelson-Jones Mk. 2 Stereo FM Tuner Kit. Price: **£69.95** + VAT.

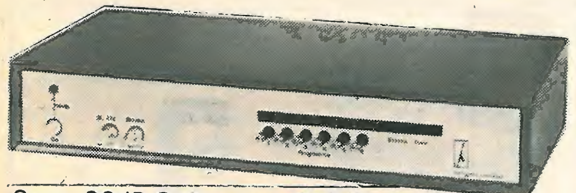
NELSON-JONES MK. I STEREO FM TUNER KIT

A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.

Brief Spec. Tuning range 88—104MHz. 20dB mono quieting @ 0.75μV. Image rejection — 70dB. IF rejection — 85dB. THD typically 0.4%.
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.
Compare this spec. with tuners costing twice the price.

Mono £36.40 + VAT
With ICPL Decoder £40.67 + VAT
With Portus-Haywood Decoder £44.20 + VAT

STEREO MODULE TUNER KIT

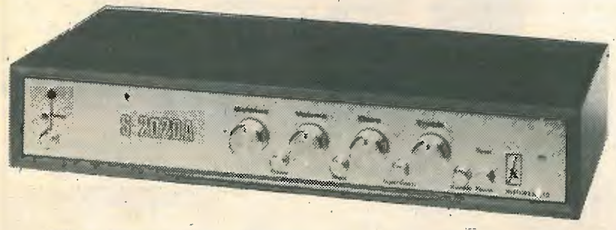


A low-cost Stereo Tuner based on the 3302 FET RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC Variable INTERSTATION MUTE. PLL stereo decoder IC. Pre-decoder 'birdy' filter Push-button tuning

Sens. 30dB S/N mono @ 1.2μV
THD typically 0.3%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

PRICE: Stereo £33.95 + VAT

S-2020A AMPLIFIER KIT



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Typ Spec. 24+24W r.m.s. into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

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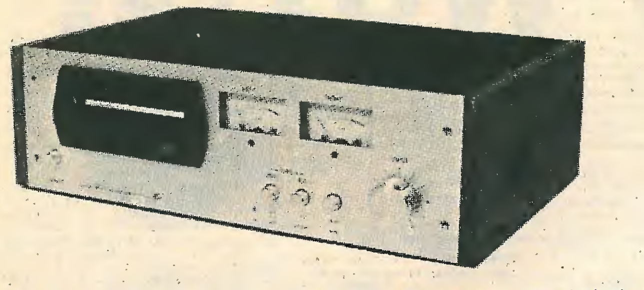

We are the Designer Approved suppliers of kits for this excellent design. The Author's reputation tells all you need to know about the circuitry and Hart expertise and experience guarantees the engineering design of the kit. Advanced features include: High quality separate VU meters with excellent ballistics. Controls, switches and sockets mounted on PCB to eliminate difficult wiring. Proper moulded escutcheon for cassette aperture improves appearance and removes the need for the cassette transport to be set back behind a narrow finger trapping slot. Easy to use, robust Lenco mechanism. Switched bias and equalisation for different tape formulations. All wiring is terminated with plugs and sockets for easy assembly and test. Sophisticated modular PCB system gives a spacious, easily built and tested layout. All these features added to the high quality metalwork make this a most satisfying kit to build. Also included at no extra cost is our new HS15 Sendust Alloy record/play head, available separately at **£7.60** plus VAT, but included FREE as part of the complete kit at **£81.50** plus VAT.

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Typical enclosure size 355 x 246 x 222 mm.
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Kit comprises: Two 8" base drive units, two 2-way crossover units, two tweeters. Assorted hardware. Instruction manual and template.
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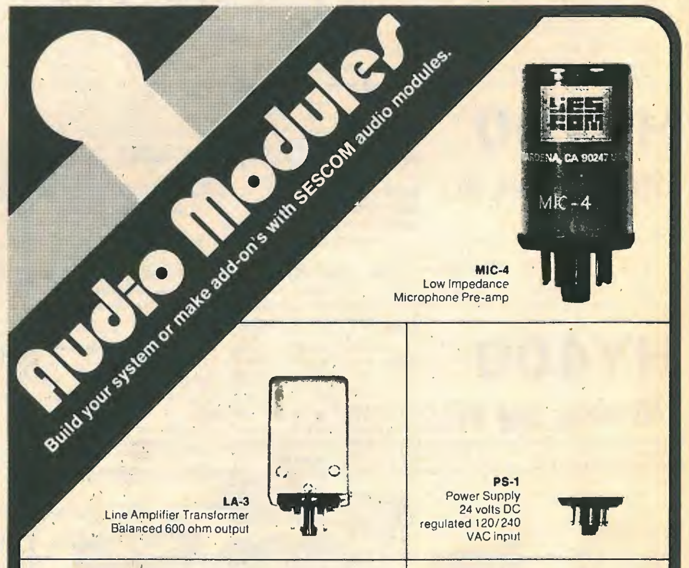

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EBF80	0.50	GZ32	0.65	U191	0.75	6AM5	1.60	6Y6G	0.95	50C5	0.70
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ECC82	0.50	KT88	5.75	UAF42	0.75	6AS6	0.80	9D2	0.60	78	0.75
ECC83	1.15	MH4	1.00	UBF80	0.55	6AT6	0.75	9D6	0.75	80	0.75
ECC84	0.45	ML6	1.00	UBF89	0.50	6AU6	0.40	10C2	0.60	85A2	2.20
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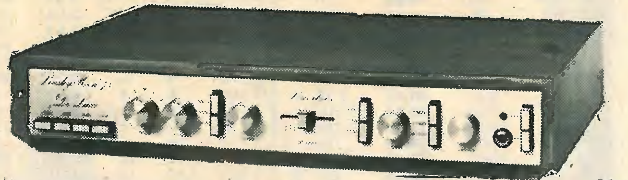

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14. Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£8.20
15. Handbook	£0.30
16. High Quality Teak Veneer cabinet 18.3" x 12.7" x 3.1"	£10.70

2 each of packs 1-7, 1 each of packs 8-16 inclusive are required for complete stereo amplifier. Total cost of individually purchased packs £92.80

PACK PRICES FOR STANDARD KIT

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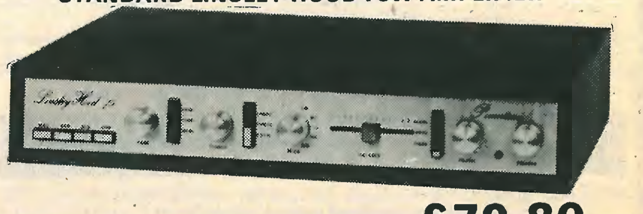
SPECIAL PRICE FOR COMPLETE KIT £99.30 + VAT

The standard model of our kit for Mr. Linsley-Hood's 75 watt design has for a long time offered exceptional performance at a very modest cost with high quality high power ready-built units of comparable quality generally being over three times the price.

Features of the amplifier include very low distortion (less than 0.01%), 75W rms per channel power output, rumble filter, variable slope scratch filter, variable transition frequency tone controls, tape monitoring facilities and individually adjustable inputs. This model is based on 5 circuit boards which not having the controls mounted on them can, if desired, be effectively used separately in high performance audio systems not based on our metalwork.

Our new De Luxe model uses 14 boards which interconnect with gold plated contacts and are designed to have the potentiometers and switches mounted upon them. This system almost eliminates internal wiring, making installation, after their assembly, delightfully straightforward, and as each board can be easily removed in seconds from the chassis, checking and maintenance is so simple that even newcomers to electronics will be able to cope competently with the kit. Additional features of our new model are inclusion of the latest circuit improvements, generously sized heat sinks for heavy duty use, even in tropical climates, and metal oxide resistors throughout for long-term stability and reliability.

STANDARD LINSLEY-HOOD 75W AMPLIFIER



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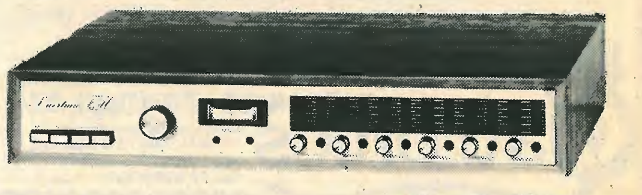
WIRELESS WORLD FM TUNER



Designed in response to demand for a tuner to complement the world-wide acclaimed Linsley-Hood 75W Amplifier, this kit provides the perfect match. The Wireless World (Skingley and Thompson) published original circuit has been developed further for inclusion into this outstanding slimline unit and features a pre-aligned front end module, excellent a.m. rejection and temperature compensated varicap tuning, which may be controlled either continuously or by push-button pre-selection. Frequencies are indicated by a frequency meter and sliding LED indicators, attached to each channel selector pre-set. The PLL stereo decoder incorporates active filters for "birdy" suppression and power is supplied via a toroidal transformer and integrated regulator. For long term stability metal oxide resistors are used throughout.

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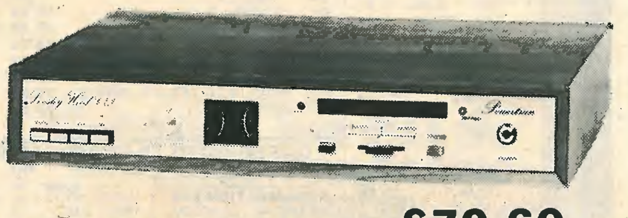
LINSLEY-HOOD CASSETTE DECK



SPECIAL PRICE FOR COMPLETE KIT £79.60 + VAT

Pack	Price
1. Stereo PCB (accommodates 2 rep. amps. 2 meter. amps, bias/erase osc. relay)	£3.35
2. Stereo set of capacitors, M.D. resistors, potentiometers for above	£7.95
3. Stereo set of semiconductors for above	£8.50
4. Miniature relay with socket	£2.90
5. PCB, all components for solenoid, speed control circuits	£3.80
6. Goldring-Lenco mechanism as specified	£18.50
7. Function switch, knobs	£1.90
8. Dual VU meter with illuminating lamp	£6.95
9. Toroidal transformer with E.S. screen prim. 0-117V, 234V. Sec. 15V	£4.90
10 Set of capacitors, rectifiers, I.C. voltage regulator P.C.B. for power supply (Powertran design)	£2.80
11. Set of miscellaneous parts, including sockets, fuse holder, fuses, interconnecting wire, etc	£3.40
12. Set of metalwork including silk screened fascia panel, internal screen, fixing parts, etc	£7.10
13. Construction notes	£0.25
14. High Quality Teak Veneer cabinet 18.3" x 12.7" x 3.1"	£10.70

One each of packs 1-14 inclusive are required for complete stereo cassette deck. Total cost of individually purchased packs £83.00

Matsushita WY 436 AZ head (optional extra) . £4.50 (free with compete kit)

Published in Wireless World (May, June, August 1976) by Mr. Linsley-Hood, this design, although straightforward and relatively low cost, nevertheless provides a very high standard of performance. To permit circuit optimization separate record and replay amplifiers are used, the latter using a discrete component front-end designed such that the noise level is below that of the tape background. Pushbutton switches are used to provide a choice of equalization time constants, a choice of bias levels and also an option of using an additional pre-amplifier for microphone use. The mechanism used is the Goldring-Lenco CRV, a unit distinguished in its robustness and ease of operation. Speed control and automatic cassette ejection are both implemented by electronic circuitry. This unit which is powered by a toroidal transformer and uses metal oxide resistors throughout offers an excellent match for the Wireless World Tuner and the Linsley-Hood 75 Watt Amplifier. Circuit changes as published in February, 1978, follow-up article are included in the kit AT NO EXTRA COST! A higher performance head (Matsushita WY 436 AZ head as recommended in the follow-up article) is offered as an optional extra but this will be automatically supplied FREE OF CHARGE with all orders for complete kits!

T20+20 AND T30+30 20W, 30W AMPLIFIERS

Designed by Texas engineers and described in Practical Wireless, the Texan was an immediate success. Now developed further in our laboratories to include a Toroidal transformer and additional improvements, the slimline T20+20 delivers 20W rms per channel of true Hi-Fi at exceptionally low cost. The **easy to build** design is based on a single F/Glass PCB and features all the normal facilities found on quality amplifiers including scratch and rumble filters, adaptable input selector and headphones socket. In a follow-up article in Practical Wireless further modifications were suggested and these have been incorporated into the T30+30. These include RF interference filters and a tape monitor facility. Power output of this model is 30W rms per channel.

SPECIAL PRICES FOR COMPLETE KITS

T20+20 KIT PRICE £33.10 + VAT

T30+30 KIT PRICE £38.40 + VAT

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WWII TUNER

SPECIAL PRICE FOR COMPLETE KIT £47.70 + VAT

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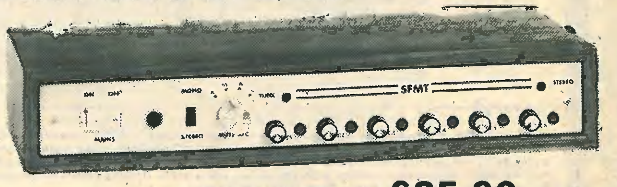
Following the success of our **Wireless World FM Tuner Kit** this cost reduced model was designed to complement the **T20+20** and **T30+30** amplifiers and the cabinet size, front panel format and electrical characteristics make this tuner compatible with either.

POWERTRAN SFMT TUNER



PRICE FOR COMPLETE KIT £35.90 + VAT

AVAILABLE AS COMPLETE KIT ONLY

This is a simple, low cost design which can be constructed easily without special alignment equipment but which still gives a first-class output suitable for feeding any of our very popular amplifiers or any other high quality audio equipment. A phase-locked-loop is used for stereo decoding and controls include switchable afc, switchable muting and push-button channel selection (adjustable by controls on the front panel). This unit matches well with the **T20+20** and **T30+30** amplifiers.

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- ★ Ultra low feedback (an incredible low 14dB overall!), super high slewing rate (20V/μs), 200W rms continuous to 4 ohm from EACH channel, input sensitivity 0.775V (0dB).
- ★ Professional quality components, sturdy 19" rack mounting chassis complete with sleeve and feet for free standing work too.
- ★ Easy to build — plenty of working space with ready access to all components, minimal wiring, extensive instruction suitable for both experienced constructors and newcomers to electronics.
- ★ Value for money — quality and performance comparable with ready-built amplifiers costing over £600!

PSI 4002 STUDIO MODEL

Cabinet size 17.2" x 6.7"

COMPLETE KIT ONLY £196.90+VAT

READ THE REVIEW IN SOUND INTERNATIONAL DEC 78!

TRANSCENDENT 2000 SINGLE BOARD SYNTHESIZER

As featured in Electronics Today International

The kit includes fully finished metalwork, fully assembled solid teak cabinet, filter sweep pedal, professional quality components (all resistors either 2% metal oxide or ½% metal film!) and it really is complete — right down to the last nut and bolt and last piece of wire! There is even a 13A plug in the kit — you need buy absolutely no more parts before plugging in and making great music! Virtually all the components are on the one professional quality fibre glass PCB printed with component locations. All the controls mount directly on the main board, all connections to the board are made with connector plugs and construction is so simple it can be built easily in a few evenings by almost anyone capable of neat soldering! When finished you will possess a synthesizer comparable in performance and quality with ready built units selling for between £500 and £700!

COMPLETE KIT ONLY £172.00 + VAT!

Comprehensive handbook supplied with all complete kits! This fully describes construction and tells you how to set up your synthesizer with nothing more than a multi-meter and a pair of ears!

CHROMATHEQUE 5000 5-CHANNEL LIGHTING EFFECTS SYSTEM

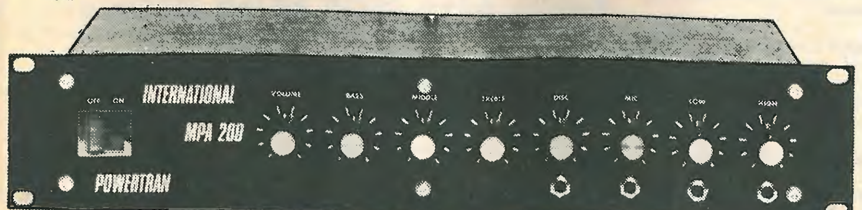
This versatile system featured as a constructional article in ELECTRONICS TODAY INTERNATIONAL has 5 frequency channels with individual level controls on each channel. Control of the lights is comprehensive to say the least. You can run the unit as a straightforward sound-to-light or have it strobe all the lights at a speed dependent upon music level or front panel control setting or use the internal digital circuitry which produces some superb random and sequencing effects. Each channel handles up to 500W and as the kit is a single board design wiring is minimal and construction very straightforward.

Kit includes fully finished metalwork, fibreglass PCB, controls, wire, etc. — Complete right down to the last nut and bolt!

COMPLETE KIT ONLY £49.50 + VAT

MPA200 100W MIXER/AMPLIFIER

Featured as a constructional article in Electronics Today International the MPA 200 is an exceptionally low-priced but professionally finished general purpose, rugged, high-power amplifier which has an adaptable range of inputs such as disc, microphone, guitar, etc. There are 3 wide range tone controls and a master volume control. Mechanically the design is simplicity in the extreme with minimal wiring making construction very straightforward. Kit includes fully finished metalwork, fibreglass PCB's, controls, wire, etc. — Complete right down to the last nut and bolt!



COMPLETE KIT ONLY £49.90 + VAT

All kits also available as separate packs (e.g. P.C.B. component sets, hardware sets, etc.). Prices in FREE CATALOGUE.

EXPORT A SPECIALITY!

Our Export Department can readily despatch orders of any size to any country in the world. Some of the countries to which we sent kits last year are shown in this advertisement. To assist in estimating postal costs our catalogue gives the weights of all packs and kits. This will be sent free on request, by airmail, together with our "Export Postal Guide" which gives current postage prices. There is no minimum order charge. Prices same as for U.K. customers but no Value Added Tax charged. Postage charged at actual cost plus 50p documentation and handling. Please send payment with order by Bank Draft, Postal Order, International Money Order or cheque drawn on an account in the U.K. Alternatively for orders over £500 we will accept Irrevocable Letter of Credit payable at sight in London.

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SECURICOR DELIVERY: For this optional service (U.K. mainland only) add £2.50 (VAT inclusive) per kit.

SALES COUNTER: If you prefer to collect your kit from the factory, call at Sales Counter (at rear of factory). Open 9 a.m.-4.30 p.m. Monday-Thursday.

QUALITY: All components are brand new first grade full specification guaranteed devices. All resistors (except where stated as metal oxide) are low noise carbon film types. All printed circuit boards are fibreglass, drilled roller tinned and supplied with circuit diagrams and construction layouts.

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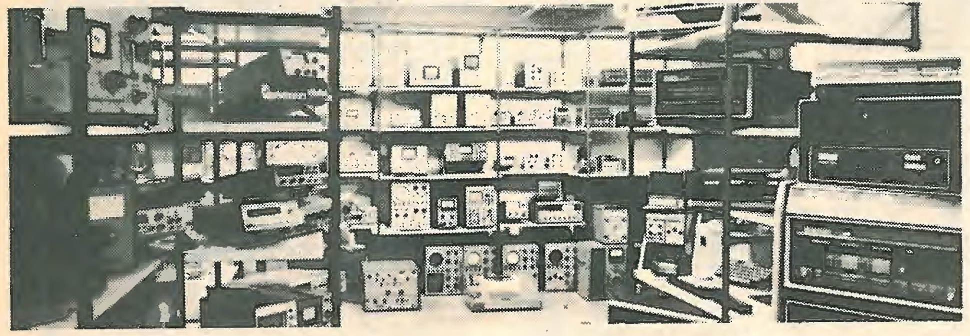
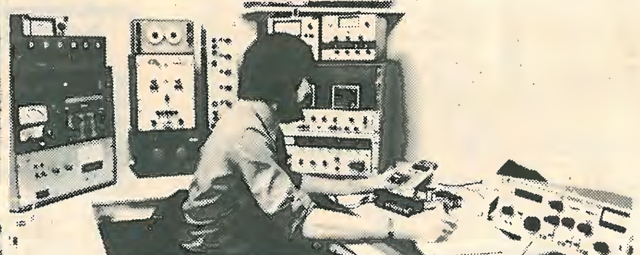


Back up

To support our growth we have a skilled team. This includes trained sales staff, whose role is not only to sell, but provide a helpful information service to our many customers. Backing this team is our own service laboratory where technicians monitor each item of equipment we sell. Our maxim is *service*, and those who have dealt with us will know that we endeavour to always live up to our reputation. Equipment can be configured to customer's exact requirement, and a number of options can be made available — almost like custom-tailoring.



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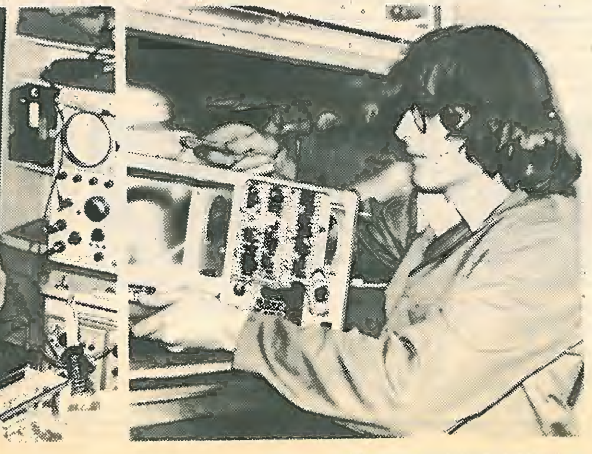
Our own service laboratory checks each item that arrives at our Pancras Road headquarters. Electronic test equipment is then thoroughly cleaned and a schedule prepared for any work which needs to be carried out to meet customer's requirements. Whether it is new test equipment or used, all items pass through the service laboratory where they are given final tests to ensure they meet manufacturers' specifications, before delivery to the customer.



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DC-35 MHz at 2nV/cm.
Trigger holdoff. Bright CRT Display.
Lightweight.
SUPERB CONDITION — QUANTITIES AVAILABLE
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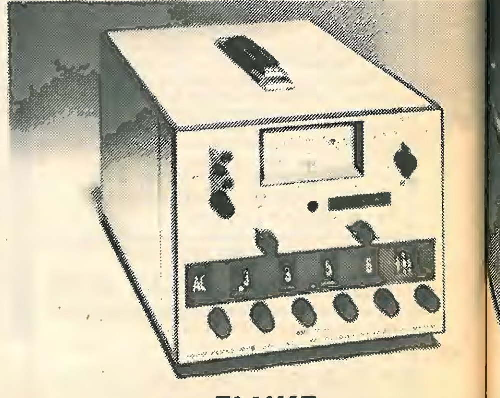

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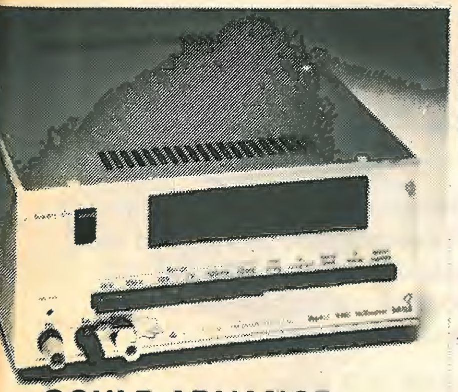

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DC coupled.
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cy 0.1% ± 1 digit
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UNUSED CONDITION.
QUANTITIES AVAILABLE.
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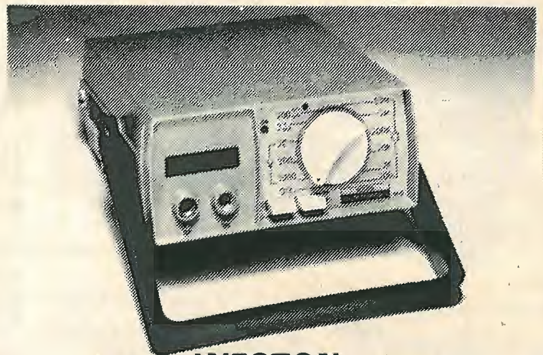

WESTON
DIGITAL MULTIMETER TYPE 4449

3½ digit. Scale length 1999.
AC-DC Volts 100mV-1kV.
100µV resolution.
AC-DC current 100µA-1mA.
100nA resolution.
Resistance 100Ω-10mΩ.
100mΩ resolution.
UNUSED CONDITION — QUANTITIES AVAILABLE.
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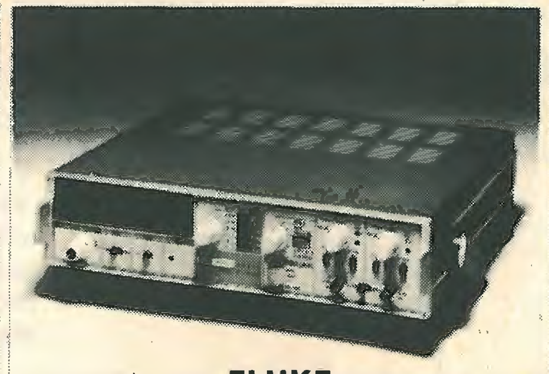

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Options 15 & 16

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Variable trigger level.
IEEE interface, rear inputs.
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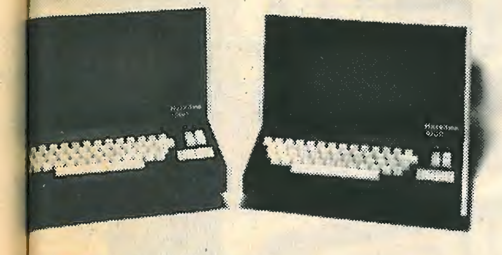

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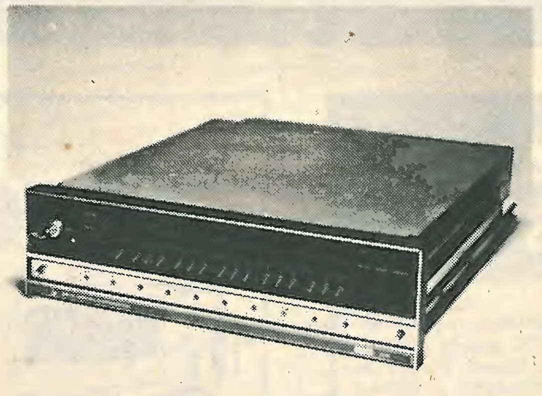

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Special Purchase of these popular 16-bit minis.
Prices from: **£995.00** (4K 1200 series CPU) to **£3,500.00** (32K 800 series CPU with 2.5 Meg disc).

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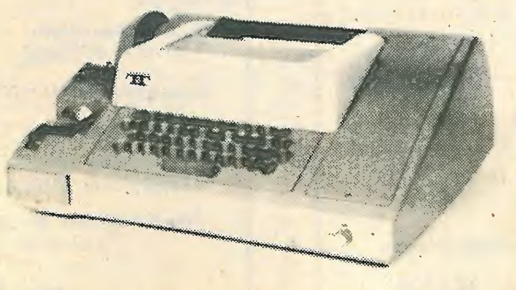

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Single line panel display with 16 or 18 5 x 7 dot matrix positions and a repertoire of 64 characters. Input requirements: a six-bit (binary) code must be present at the data input terminal during the first five clock pulses of each character position. Power requirements: Positive logic supply 4.75-5.25V, 160mA. Negative logic supply —11.4 - —12.6V —50mA. Display power supply 237.5-262.5V 30mA. Supplied with full technical data.
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18 keys including numerals 0-9, decimal point, C K + — × + = Push button "make-or-break" keys. Overall dimensions 5⅞" x 4⅝" x 1½". Mounted on PCB with output from each key + common.
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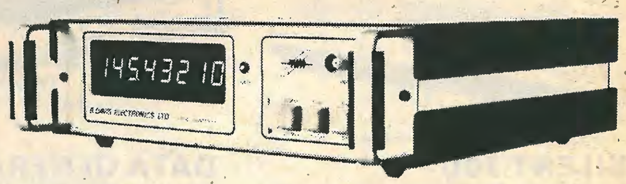

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The following have also agreed to contribute

Prof. Colin
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Tony Davies
Founder of Membrain Ltd.
M.D. of Schlumberger UK and Solartron Ltd

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GZ34†	1.52*
GZ37	4.00*
KT61	3.50*
KT66	5.00*
KT88	6.25*
KTW61	1.75*
KTW62	1.75*
KTW63	1.75*
M8079	9.04
M8080	6.37
M8081	6.78
M8082	5.58
M8083	5.86
M8091	7.85
M8096	3.75
M8097	3.56
M8098	3.40
M8099	5.20
M8100	6.39
M8136	6.60
M8137	6.80
M8140	4.50
M8141	4.85
M8142	4.75
M8144	3.75
M8149	5.10
M8161	6.12
M8162	5.87
M8163	4.50
M8190	4.60
M8195	3.70
M8196	6.50
M8204	5.72
M8212	4.66
M8223	2.30
M8224	2.90
M8225	2.60
M8248	7.95
MU14	1.00*
MX119	24.75
MX123	45.00
MX145	33.75
MX151	13.50
MX152	80.00
MX161	80.00
MX163	14.55
MX164	14.45
MX166	18.00
MX168	22.25
N78	9.00*
OA2†	0.55
OA3	1.10
OA4	1.10
OB2†	1.00
OB3	0.75
OC2	0.75
OC3	0.75
OD3†	0.75
OZ4	1.50
PC86†	0.85*
PC88†	0.85*
PC95	0.70*
PC97	1.08*
PC900†	1.00*
PCC84†	0.50*
PCC85	0.60*
PCC88	0.65*
PCC89†	1.05*
PCC189†	1.00*
PCC805†	0.95*
PCC806†	0.95*
PCE82†	1.72*
PCF80	0.96*
PCF82†	0.50*
PCF86†	0.75*
PCF87	1.10*
PCF200†	1.15*
PCF201†	1.10*
PCF801†	0.60*
PCF802†	0.88*
PCF805	1.44*
PCF806	1.44*
PCF808	1.44*
PCL82†	0.80*
PCL83†	1.58*
PCL84†	0.75*
PCL85†	0.96*
PCL86†	0.85*
PCL805/85†	0.96*
PD500	3.60*
PE06-40N	27.30
PFL200	1.12*
PL36†	1.12*
PL81	1.12*
PL81A†	1.12*
PL82	0.60*
PL83†	0.55*
PL84†	0.75*
PL504/505†	1.20*
PL508†	1.60*
PL509†	2.72*
PL519†	3.60*
PL801	1.10*
PL802†	3.46*
PY33	1.10*
PY81†	0.92*
PY82	0.90*
PY83	0.75*
PY88†	1.16*
PY500A†	1.60*
PY800	0.92*
PY801	0.92*
QQV02-6	9.96
QQV03-10†	2.00*
QQV03-20A	13.00
QQV06-40A	13.00
QQV07-50	40.37
QQZ03-20A	27.50
QQZ06-40A	45.20
QU37	11.00
QV03-12	8.50
QV04-7	2.50
QV08-100	89.30
QY3-65	44.50
QY3-125†	12.00
QY4-250	55.14
QY4-400	62.67
QY5-500	132.00
QY5-3000A	228.00
QZ06-20	20.60
R10	5.00
R17	1.65
R18	3.95
R19	1.00
R20	1.44
RG3-250	21.51
RG3-250A	23.28
RG3-1250	22.20
RG4-1250	27.50
RG4-3000	56.65
RR3-250	34.77
RR3-1250	62.37
S11E12	22.36
S130	2.00
S130P	2.50
STV80-40	10.00
STV280-80	20.00
SU41	2.50
SU42	3.00
TD03-10	21.50
TD03-10E	22.75
TD03-10F	24.00
TT15	22.00
TT21	9.63
TT22	9.63
TT100	60.00
TY2-125	49.50
TY4-400	59.30
TY4-500	76.82
TY5-500	160.00
TY6-800	145.00
TY6-5000A	217.85
TY6-5000B	206.00
TY6-5000W	195.80
TY7-6000A	237.60
TY7-6000W	192.50
TZ40	15.00
U18-20	2.50*
U19	9.15
U25	1.16*
U26	1.44*
U37	11.00
UABC80†	0.58*
UAF42	1.25*
UB41	1.25*
UBC41	1.00*
UBF89	0.60*
UCC84	1.10*
UCC85†	0.55*
UCF80	1.15*
UCH42	1.20*
UCH81†	0.65*
UCL82†	0.75*
UCL83	1.44*
UF41	1.00*
UF42	1.25*
UF80†	0.50*
UF85†	0.65*
UF89†	0.55*
UL41	1.60*
UL84†	0.85*
UM80	1.00*
UY41†	0.75*
UY85†	0.65*
VLS631	8.22
XG1-2500	25.25
XG2-6400	72.30
XG5-500	16.80
XGQ2-6400	78.60
XR1-1600A	21.40
XR1-3200	104.54
XR1-3200A	57.25
XR1-6400	65.80
XR1-6400A	122.34
YD1120	206.00
YD1240	206.00
Z759	9.60
Z803U	7.90
ZM1000	4.60
ZM1001	5.38
ZM1020	8.55
ZM1021	7.96
ZM1022	8.23
ZM1023	7.66
ZM1040	11.57
ZM1041	9.67
ZM1042	11.08
ZX1051	87.60
IB3GT†	0.65
IB24	10.00
IB35A	17.00
IB63	45.00
IR5†	0.55*
IS5†	0.40*
IT4†	0.40*
2AS15	10.00
2C39A†	9.00
2C43	18.00
2D21†	0.80
2E26	5.00
2J42	60.00
2J55	175.00
2J70A	235.00
2J70B	250.00
2K25†	10.00
3-400Z	35.00
3-500Z	35.00
3A5	1.35
3B24	5.00
3B28†	4.50
3B29	10.00
3B-240M	15.00
3B241M	15.00
3C23	10.00
3C45†	8.50
3CX100A5	20.00
3E29†	8.50
3S4†	0.75*
3V4†	1.00*
4.65A	23.35
4-125A†	12.00
4-250A	36.00
4-400A	37.00
4B32	25.36
4C35	40.00
4CX250B	17.50
4CX350A	31.35
4CX150A	21.00
4X150D	25.00
5B-254M	13.98
5B-255M	13.98
5C22	40.00
5J-180E	614.79
5R4GY†	1.10*
5U4G	1.52*
5U4GB	2.26*
5V4G†	0.65*
5Y3GT	0.85*
5Z3	1.50*
5Z4G	1.12*
5Z4GT	1.00*
6-30L2	1.56*
6AB4	0.75*
6AB7	0.75*
6AC7	0.75*
6AF4A†	0.70*
6AG7	0.75*
6AH6†	0.95*
6AK5†	0.50*
6AK6	0.95*
6AL5†	0.40*
6AM4	2.30*
6AM5	3.85
6AM6†	0.70*
6AN5	2.50*
6AN8A†	0.70*
6AQ5†	0.85*
6AR5	0.70*
6AS6†	0.80*
6AS7G†	1.50*
6AT6†	0.75*
6AU5GT	4.26*
6AU6†	0.65*
6AV5GT	3.74*
6AV6†	0.75*
6AX5GT	1.60*
6B7	0.75
6B8	0.75
6BA6†	0.50
6BA7	5.12
6BA8A	3.75
6BC4	3.71
6BE6†	0.46*
6BH6†	1.20*
6BJ6†	1.20*
6BK4	4.21*
6BL6	85.00
6BL7GT	3.96*
6BM6	85.00
6BN6	0.80*
6BQ7A	1.25*
6BR7	4.00*
6BR8†	1.50*
6BS7	4.00*
6BW6	3.75*
6BW7	1.40*
6BX7GT	4.96*
6BZ6	1.78*
6C4†	0.55*
6CB6A†	0.55*
6CD6GA	4.90*
6CG7	1.72*
6CH6	4.42*
6CL6†	0.75*
6CW4	7.24*
6D2†	0.40*
6DK6	2.49*
6DQ6B	3.90*
6EA8	2.21*
6EB8	2.12*
6EW6	1.50*
6F6	1.75*
6F23	1.60*
6F28	1.16*
6F33	13.35
6H1	11.75
6H2N	1.05*
6H3N	1.05*
6H6	1.50*
6J4†	1.20*
6J6†	0.55
6J7	0.80*
6K4N	1.25*
6K6GT	1.30*
6K7	1.50*
6K8	1.75*
6KD6	4.79*
6L6G	2.50*
6L6GA	1.50*
6L6GT	0.85*
6L6GC	1.95*
6L7	2.00*
6N2P	1.05*
6N3P	1.05*
6N7	1.05*
6P25	3.60*
6Q7	2.20*
6R7	1.80*
6SA7	1.45*
6SC7	1.45*
6SF7	1.60*
6SH7	1.50*
6SJ7	1.00*
6SK7	1.30*
6SL7GT	0.70*
6SN7GT†	0.70*
6SQ7	1.30*
6SR7	1.50*
6SS7	1.80*
6U8	1.00*
6US†	0.55*
6V6GT†	0.65*
6X4†	0.60*
6X5GT†	0.60*
7B7	1.70*
7C5	1.75*
7C6	1.25*
7H7	2.00*
7R7	1.50*
7S7	2.25*
7Y4	1.60*
7Z4	1.85*
11E3	42.89
12AT6	1.20*
12AT7†	0.50*
12AU6	0.65*
12AU7†	0.47*
12AV6	0.85*
12AV7	3.46*
12AX7†	0.55*
12AY7†	0.85*
12B4A†	1.00*
12BA6	0.65*
12BE6	1.60*
12BH7†	0.65*
12BY7†	0.80*
12E1	7.10
12E14	24.59
12E11TT	54.09
13E1	43.55
19H4	20.96
19H5	22.50
24B9	30.50
30C15	1.56*
30C17	1.56*
30C18	1.44*
30F5	1.60*
30FL1/2	1.12*
30FL12	1.72*
30FL14	1.44*
30L1	0.84*
30L15	1.72*
30L17	1.72*
30P4	0.92*
30P19	1.12*
30PL1	1.32*
30PL13	1.72*
30PL14	1.68*
30PL15	1.72*
35W4	0.60*
50C5	0.70*
75B1	3.30
75C1	1.70
85A1	7.50
85A2	1.65
90AG	7.96
90AV	7.96
90CG	[illegible]
90C1	1.70
90CV	13.68
92AG	7.26
92AV	7.16
95A1	4.60
150B2	2.15
150B3	3.90
150C2	1.50
150C4	2.20
211	3.00
723AB†	8.00
803	10.00
805	20.00
807†	1.20
811A†	8.00
812A	8.35
813	17.00
833A	30.00
866A	8.85
872A	13.75
922	4.36
931A	12.24
1624	2.25
1625	1.70
2050	2.50
4212E	118.95
4212H	147.74
5544	54.00
5545	59.00
5551A	69.75
5552A	94.30
5553A	225.30
5642	5.26*
5654	3.61*
5651	180*
5670	2.86*
5675	9.09*
5687	4.30*
5696	1.94*
5718	6.40*
5725	3.40*
5726	3.52
5727	4.80
5749	4.90*
5751	4.66*
5763	3.12*
5814A	2.60*
5840	4.40*
5842	6.90*
5876A	9.38*
5879	4.84*
5886	10.50
5963	1.87*
5965	2.36*
6005	3.65*
6021	4.46
6057	6.23
6058	9.04
6059	4.00
6061	4.25
6062	3.75
6063	3.65
6064	5.86
6067	6.60
6072	5.62
6080	6.85*
6097A×B×C	40.00
6146A	5.12*
6146B	5.58*
6159	6.00
6189	6.08
6201	5.12
6442	15.00
6883B	5.92
6973	3.32*
7025†	1.20*
7551	5.94
7586	11.38*
7587	19.60*
7609	31.50
7868	3.94*
7895	12.90*
8005	30.00
8068	5.50
8122	42.00
8136	2.68*
8417	5.34
18042	5.43
18045	6.17

BASES

Type	Price
B7G unskirted	0.15
B7G skirted	0.30
B9A unskirted	0.15
B9A skirted	0.30
Int Octal	0.20
Loctal	0.25
Nuvistor base	0.55
8 pin DIL	0.15
14 pin DIL	0.15
16 pin DIL	0.17
Valve screening cans all sizes	0.30

CRTs

Type	Price
2AP1*	8.50
2BP1*	9.00
3BP1	8.00
3DP1*	5.00
3EG1*	7.50
3FP7*	6.00
3GP1	8.00
3JP1*	8.00
3JP2*	8.00
3JP7*	10.00
3KP1*	15.00
3RP1*	35.00
5ADP1	35.00
5BP1*	10.00
5CP1*	5.00
5CP1A	40.00
5FP15A	15.00
5UP7*	14.00
DG7-5	25.00
DG7-32	36.00
DH3-91	31.00
DH7-11	68.00
VCR97*	5.00
VCR138*	10.00
VCR138A*	12.50
VCR139A*	8.00
VCR517A*	10.00
VCR517B*	6.00
VCR517C	6.00

Tube Bases 0.75
* = Surplus
VAT 8%

INTEGRATED CIRCUITS

Type	Price
7400	0.16
7401	0.16
7402	0.16
7403	0.16
7404	0.16
7405	0.16
7406	0.40
7407	0.40
7408	0.20
7409	0.20
7410	0.16
7411	0.26
7412	0.26
7413	0.32
7414	0.36
7416	0.32
7417	0.32
7420	0.17
7422	0.20
7423	0.32
7425	0.30
7427	0.30
7428	0.43
7430	0.17
7432	0.30
7433	0.36
7437	0.32
7438	0.32
7440	0.18
7441	0.85
7442	0.72
7443	0.90
7447AN	0.90
7450	0.18
7451	0.16
7453	0.18
7454	0.18
7460	0.18
7470	0.35
7472	0.33
7473	0.36
7474	0.36
7475	0.54
7476	0.40
7480	0.55
7481	1.00
7482	0.75
7483	0.90
7484	1.00
7485	1.25
7486	0.35
7489	2.50
7490	0.52
7491	0.80
7492	0.60
7493	0.60
7494	0.80
7495	0.72
7496	0.80
7497	3.00
74100	1.00
74107	0.45
74109	0.70
74110	0.50
74111	0.70
74116	1.75
74118	1.00
74119	1.50
74120	0.83
74121	0.40
74122	0.60
74123	1.00
74125	0.55
74126	0.55
74128	0.60
74132	0.70
74136	0.55
74141	0.80
74142	2.30
74143	2.50
74144	2.50
74145	0.90
74147	2.00
74148	1.75
74150	1.60
74151	0.85
74153	0.85
74154	1.75
74155	0.85
74156	0.85
74157	0.75
74159	2.10
74170	2.30
74172	4.40
74173	1.40
74174	1.50
74175	0.90
74176	1.10
74178	1.25
74179	1.25
74180	1.15
74190	1.50
74191	1.50
74192	1.35
74193	1.35
74194	1.25
74195	1.00
74196	1.20
74197	1.10
74198	2.25
74199	2.25
76013N	1.75*
TAA570	2.30*
TAA630S	3.50*
TAA700	3.91
TBA480Q	1.84*
TBA520Q	2.30*
TBA530	1.98*
TBA540Q	2.30*
TBA550Q	3.22*
TBA560CQ	3.22*
TBA673	2.19*
TBA700	1.52*
TBA720Q	2.30*
TBA750Q	2.07*
TBA800	1.20
TBA920	2.90
TBA920Q	2.99
TBA990Q	2.99*
TCA270Q	2.99*
TCA760A	1.38*

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(8508)

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(9024)

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(9033)

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AVIATION DIVISION
Bishops Cleeve, Cheltenham, Glos. GL52 4SF.
or use our ANSAFONE facility:– (0242-67-5359)

(9020)

Broadcasting Engineer

enjoy the benefits of working at the fore of broadcasting technology

We require an Engineer, male or female, qualified to HNC or equivalent level, with at least three years' experience in a broadcasting discipline to maintain the advanced electronic equipment at our main transmitting stations and relay stations bringing Independent Television and Independent Local Radio into millions of homes.
The successful applicant will become a member of a team based at our Black Mountain Transmitting Station, Hannahstown, Dunmurry, Northern Ireland and will be required to travel throughout Northern Ireland. A current driving licence is required. The post will involve some week-end working. Equipment familiarisation training will be provided.
The salary will be on a scale up to £5,688 per annum, with provision for movement on to a higher scale rising to £6,399 per annum. These rates are inclusive of a productivity supplement.
Relocation expenses will be paid where applicable.

IBA INDEPENDENT BROADCASTING AUTHORITY

Act now! Write or telephone for an application form quoting Ref. No. WW/35ER to:– Mr. M. Wright, Personnel Officer – Engineering Regions, Independent Broadcasting Authority, Crawley Court, WINCHESTER, Hants. SO21 2QA.
Telephone No: Winchester 822574.

Electronics Technician

£4017-£4917 pa inc.

to provide technical assistance to staff and students in the Polytechnic's projects laboratory, based at Enfield.

Major responsibilities will include the development of the Microprocessor Unit, the design and construction of matching circuits for transducers and data logging equipment, and construction of working systems incoprorating microprocessors.

Knowledge of workshop practice is essential, together with a good electronics qualification or sound industrial and manufacturing experience in allied fields.

Write quoting ref 4.16D for further details and an application form, posting first-class to: Appointments Officer, Middlesex Polytechnic, Bounds Green Road, London N11 2NQ. Closing date 2 April.

(9057)

Middlesex Polytechnic

UNIVERSITY OF LEICESTER

Electronics Technician

There is a vacancy in the Electronics Workshop of the Joint Biological Sciences Medical Sciences Workshops for a Technician to work on the design, development, construction and repair of scientitic electronic equipment used in teaching and research. Fault-finding and repair work will form a significant part of the job and experience in this type of work would be useful. Applicants must be qualified to ONC standard or equivalent. The post carries good conditions of service, including four weeks' annual holiday. Salary on an incremental scale for Technicians Grade 5 £3186 to £3720 p.a. (under review).
Applications in writing should be forwarded to the Administrative Officer, School of Biological Sciences, University of Liecester, University Road, Leicester LE1 7RH.

(9025)

MAINTENANCE ENGINEER

A Maintenance Engineer is required for the repair and testing of a range of professional audio and lighting control equipment.

Applicants should have sound knowledge of modern analogue and digital techniques and, ideally, possess a current driving licence. Salary will be negotiable around £4,000 p.a.

Apply with full details of qualifications to Box No. 8956 (London area).

(8956)

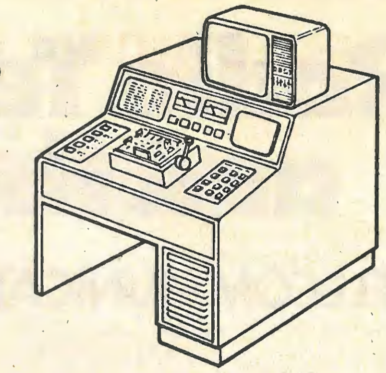
UNIVERSITY OF LONDON
KING'S COLLEGE

ELECTRONICS TECHNICIAN GRADE 5

Required for the Department of Chemistry. In addition to the construction of specialised equipment the applicant would be expected to assist in the maintenance of laboratory instruments, a knowledge of which is desirable. Salary on scale £3651 per annum, rising to £4,185 per annum inclusive (under review). Good conditions, four weeks' annual holiday. Contributory pension scheme. Apply in writing with full details to: **The Head Clerk (Ref. 210235/WW), King's College, London, Strand WC2R 2LS.**

(9026)

TEST EQUIPMENT ENGINEERS



Come and join Rediffusion and help us design a brand new range of test equipment for production testing our future colour receivers. Our present equipment is a combination of sophisticated manual and automatic test consoles employing both analogue and digital circuitry. We are currently looking at the application of microprocessors to the testing of television modules and are confident that our future equipment will take advantage of these latest techniques.

Applications are invited from well qualified and experienced test equipment engineers to join our energetic young team at Chessington, Surrey, working in a congenial and stimulating environment. We have vacancies at both senior and intermediate levels, offering excellent salaries and opportunities for career advancement in this exciting field.

Since engineers are expected to see their projects through to completion, some travelling to our factories in the North East is expected to assist on installation and commissioning and to give back-up service where necessary.

Additionally, an intermediate engineer is required to be based at Bishop Auckland in our Engineering Department on the main factory site. This position involves some design and development work interspaced with the planned maintenance of complex production test equipment.

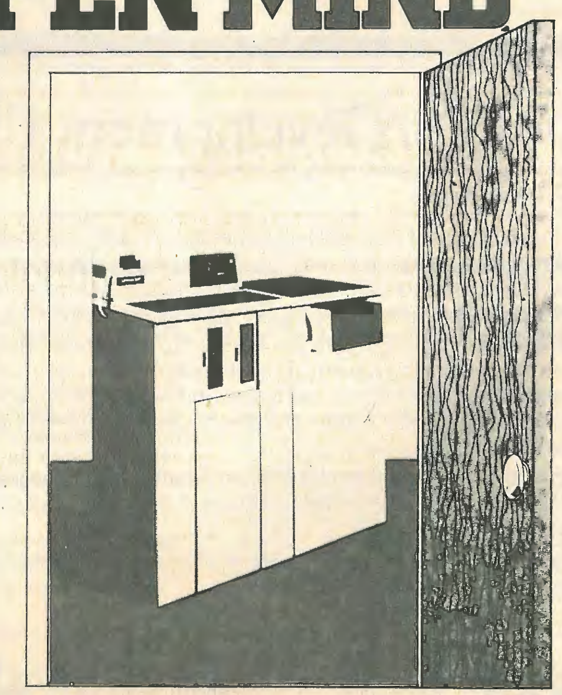
If you are interested in these challenging positions and would like more details or wish to discuss the matter in depth, please write to or telephone:

REDIFFUSION

Mr H. Brearley,
Rediffusion Consumer Electronics Limited.
Fullers Way Sth., Chessington, Surrey KT9 1HJ
Telephone: 01-397 5411

WE HAVE AN OPEN DOOR FOR AN OPEN MIND

Test Engineers



Open minds and creative thinking have made Linotype-Paul the market leader in the field of sophisticated phototypesetting equipment for the world's graphics industries.

We are leaders not by accident but by design and in order to maintain our position and our record growth pattern we now have excellent openings for electronics engineers at all levels.

If you have an electronic engineering background coupled with at least 2 years practical experience and/or a formal qualification we'd like to meet you.

Anyone with experience in the following, would also be welcome. Prototype Wirers, A.T.E. Engineers, Electronic and Mechanical Inspectors, Skilled Fitters, P.C.B. Draughtsmen/women, Programmers, Electronic and Mechanical Development Engineers.

Ring Cheltenham 41441, reversing charges, or write to
Patrick Cooper, Personnel Officer,
Linotype-Paul Ltd., Chelham House,
Bath Road, Cheltenham.

Linotype-Paul 1974

Radio Technology and the Future

TELECOMMUNICATIONS OPPORTUNITIES

In the Home Office Directorate of Radio Technology you will be responsible for the study of radio propagation matters over the whole of the radio frequency spectrum above 10 kHz and for the forward planning, management and regulation of frequency bands allocated to the broadcasting, fixed, maritime and land mobile, and space services.

The work will also involve preparing specifications and giving type-approval of equipment for fixed and mobile services, applying computer techniques to frequency assignment problems, developing equipment for the location and suppression of radio interference, and giving technical advice on all aspects of licensing radio services and in connection with the international radio monitoring service.

The vacancies are in Central London and Stanmore, Middlesex.

Candidates (aged at least 25) must have ONC in Engineering (with a pass in Electrical Engineering 'A') or in Applied Physics, **or** hold an equivalent qualification. In addition, they must have had at least 7 years' experience of skilled work on radio, radar or other electronic work.

Salary in London starts at £5230 and rises to £5710; £250 less at Stanmore. Good promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 5 April, 1979) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). **Please quote ref: T/5096/4.**

HOME OFFICE

(9075)

Design/Development Engineers

c£6,000 p.a. **Croydon**

Aeronautical and General Instruments Ltd. is an expanding public company well respected internationally for the design, development and manufacture of aerial reconnaissance equipment, marine instrumentation and telecommunications.

Two Electronics Engineers are needed to spearhead design and development work on an exciting new product area in the telecommunications field. They would be involved in both software and hardware aspects of microprocessor design and in data transmission technology. Some foreign travel would be involved.

Applicants should have at least two years design experience, preferably in logic design. They could therefore be in their 20's, and should be qualified to HNC or degree level.

These are key appointments providing both an interesting challenge and excellent career opportunities.

Please send brief career details to:

Roger Hindle Limited
34 Queens Gate Place Mews London SW7 5BQ.

(9038)

THE OPEN UNIVERSITY

Faculties of Science and Technology

Electronics Designer

Science and Technolgy Electronics Common Facilities have a vacancy for an Electronics Designer The successful applicant will fill the post as the main electronics designer in a small team backing up both science and technology based research and home experiment kit development

The work is varied and covers virtually the whole range of electronics Design experience is essential as is an innovative nature

The salary range (which is under review) is £4 245-£4 782 Terms and conditions are good Housing is readily available within the city of Milton Keynes set in the north Buckinghamshire countryside

Application forms and further particulars are available from the Recruitment Office (MH494 2). The Open University, P O Box 75, Walton Hall Milton Keynes MK7 6AL or telephone Milton Keynes 63405. there is a 24 hour answering service on 63868

Closing date for applications 26th March

(9021)

UNIVERSITY OF LONDON
GOLDSMITH' COLLEGE
New Cross, London SE14 6NW

TECHNICIAN

Required in the Psychology Laboratory to start as soon as possible. Applicants should have qualifications and / or experience in one of the following:—

(a) Maintenance of electronic equipment (e.g. CC TV. and general audio-visual equipment).

(b) Construction and maintenance of general laboratory equipment involving general workshop procedures.

The appointment will be on either Grade 3, 4 or 5 depending upon qualifications and experience, with salary on one of the following scales:—

Grade 3 — £2,697 x 5 increments to £3,084 per annum
Grade 4 — £2,976 x 5 increments to £3,426 per annum
Grade 5 — £3,210 x 5 increments to £3,747 per annum
plus £465 London Allowance

Write for further particulars, to the Personnel Officer, to whom applications should be sent by 30th April, 1979.

(9059)

MARINE ELECTRONICS

We need an engineer familiar with Radar, MF/HF synthesised SSB/VHF Autopilots, etc. to service and install anywhere, but must be based in London.

If you are able to be your own boss apply giving details of experience salary required.

We are also prepared to offer an engineering partnership arrangement, if you are the right man.

TELESONIC MARINE LTD.
243 Euston Road
London N.W.1.

(8959)

Engineers

- DESIGN / DEV
- TEST
- FIELD SERVICE

High Salaries – Most Areas
Phone 01 - 731 4353

(8995)

Apex Personnel

Senior Engineer

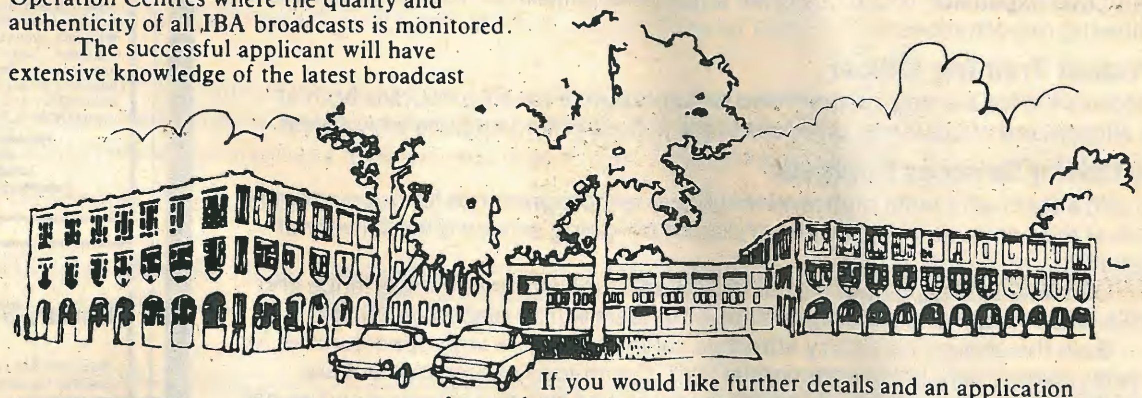
Service Continuity Section

An unusual vacancy exists for an engineer to lead a small multi-disciplinary team researching into operational procedures which will enhance continuity and security of the radio and television services transmitted by the Authority.

The increasing incidence over recent years of electronic hijacking of broadcast transmitters has led to the decision to form a special group to analyse past events and postulate theories explaining the modus operandi of the miscreants. The team will also be expected to formulate appropriate alterations in the design of transmitting stations and the 42 new Regional Operation Centres where the quality and authenticity of all IBA broadcasts is monitored.

The successful applicant will have extensive knowledge of the latest broadcast technology and the ability to appreciate the bizarre nature of the problem. He or she may have been involved in the planning or execution of a past event and will be familiar with satellite and digital systems, though experience of teletext techniques would be considered.

Working conditions are second to none in our well equipped laboratories and the group will be given the opportunity to take over as much working space as required. The fresh approach which the post entails necessarily confines applications to those not already in the employ of the Authority in any technical capacity.



IBA INDEPENDENT BROADCASTING AUTHORITY

If you would like further details and an application form, please write or telephone, quoting reference KS/AT to:

Senior Personnel Officer,
Independent Broadcasting Authority, Crawley Court, Winchester, Hampshire, SO21 2QA. Telephone: Winchester 822270.

(9080)

WYE COLLEGE
(University of London)

WORKSHOP TECHNICIAN (ELECTRONICS)

Applications are invited for the above post in the Department of Agriculture Engineering Workshop in which electronic instrumentation is widely used. Applicants should probably have an ONC/OND in Technology or Engineering with some practical experience of analogue to digital converters. Applicants with City and Guilds Certificate 231 will also be considered. Salary scales: Grade 1 £2,193-£2,499 p.a.; Grade 2 £2,364-£2,880 p.a.; Grade 3 £2,688-£3,060 p.a. (all under review) according to age and qualifications. Application forms and further particulars available from **Personnel Officer, Wye College, Ashford, Kent. Tel. No. 812401, Ext. 228.** Applications should be received as soon as possible.

(9027)

Senior Electronics Service Engineer

A SENIOR MAINTENANCE ENGINEER IS REQUIRED FOR THE REPAIR AND CALIBRATION OF PROFESSIONAL EQUIPMENT USED IN THE EXECUTION OF RESEARCH PROGRAMMES AT THE LABORATORY.

This involves the maintenance of oscilloscopes, pulse generators, counters, digital voltmeter, precision high power magnet controller and analysers of various kinds. Experience in fault finding on some of the equipment is necessary.

It is hoped to gradually extend the maintenance capability to include microprocessors, computers and associated peripherals.

Please send for an application form to M. L. Malpass, Personnel Manager, Philips Research Laboratories, Cross Oak Lane, Redhill, Surrey, quoting reference 113.

PHILIPS Research Laboratories

PHILIPS

(9090)

ATE
A closely guarded secret?

It's no secret that automatic test and inspection is revolutionizing the electronics industry.

Our Autotest systems, with an international reputation for both versatility and reliability, are used for varied applications, from testing television PCB's to fault location on avionic systems. At the sharp end of our Autotest business the continued expansion of our customer support facilities in St. Albans offers the following opportunities:-

Product Training Officer

Responsible for the arrangement and presentation of training courses both at St. Albans and at customer premises in the programming and use of Autotest.

Customer Services Engineer

To join a team who write high level language user programmes for our customers both at the commissioning stages and as an on-going service after delivery of systems.

Candidates should have digital, analogue or measurement experience and whilst qualifications may be significant, emphasis will be placed on ability.

Both the above posts carry attractive salaries together with opportunities for greater involvement in the commercial field. Conditions of employment are excellent including productivity bonus, pension and sick pay schemes and we can offer generous relocation expenses where appropriate.

For further information of these opportunities, perhaps others that may interest you, please telephone John Prodger. or write to the

Recruitment Manager,
Marconi Instruments Ltd.,
Freepost.
St Albans, Herts.
Telephone St Albans 59292

Marconi Instruments

A G.E.C. MARCONI ELECTRONICS COMPANY (9041)

APPOINTMENTS IN ELECTRONICS
£5 – £10,000

Take your pick of the permanent posts in:

MISSILES — MEDICAL
COMPUTERS
RADAR — COMMS
MICROPROCESSOR
HARDWARE — SOFTWARE

For free expert advice and immediate action on salary and career improvement, 'phone or write to, Mike Gernat BSc.

Technomark
Engineering and Technical Recruitment
11 Westbourne Grove
London W2. 01-229 9239 (8423)

Cyclotron Unit
Medical Research Council
requires a

Junior Technician B

Preferably under 23 years for the servicing and maintenance of electronic equipment and to act as standby cyclotron operator, involving occasional shift duties. An ONC or equivalent qualifications in a relevant subject required. Some servicing experience preferable. Salary according to age and experience in the range of £2523 to £3369 (inclusive of London Weighting). Day release facilities available. Also a

Junior Technician A

Aged 16 and over, to assist in electronics team. Experience not essential. Day release facilities available. Four GCE 'O' levels required. Salary according to age and experience in the range £2259 to £3258 (inclusive of London Weighting). For further information and application form, please contact Miss A. Pires at the Cyclotron Unit.

Hammersmith Hospital
Ducane Road
London W12 0HS
Telephone No. 01-743 4594
Ext. 103 (9101)

Radar/Radio Engineer

required for maintenance of Airport ground radars 10 cm. and 3 cm., navigational aids and communications equipment. Technical qualifications desirable and it is essential that applicants have considerable experience and are capable of working without close supervision. Salary, including shift pay, weekend enhancement and pay supplement, approx. £4050 to £5142, plus some overtime. Written applications, giving age, experience and qualifications, to the Airport. Director, Southend Airport, Southend-on-Sea, Essex.

(9067)

UNIVERSITY OF LIVERPOOL
DEPARTMENT OF PHYSICS

ELECTRONICS TECHNICIAN

to assist with developing and constructing digital and analogue electronic equipment. Applicants must possess ONC, C & G or equivalent qualification and have some experience. Good opportunity to learn about micro-processors. Salary within a range up to £3720 p.a. (under review).

Application forms may be obtained from The Registrar, The University, P.O. BOX 147, Liverpool, L69 3BX. Quote Ref: RV/508/WW. (9069)

READY, STEADY, GROW!

Join a firm that's doubled its profits for each of the last three years and grow with Rofin. High interest jobs for:

ELECTRONICS SERVICE ENGINEER
ELECTRONICS TEST ENGINEER
ELECTRONICS TEST TECHNICIAN
INSTRUMENT TECHNICIAN
WITH PRECISION, MECHANICAL AND OPTICAL EXPERIENCE

Telephone or write to Bill Harmsworth, Rofin Ltd., Winslade House, Egham Hill, Egham, Surrey. Tel. Egham 7541. (9097)

CHELSEA COLLEGE
University of London

ELECTRONICS TECHNICIAN ENGINEERS/TECHNICIANS

required for interesting work in Electronics Workshop serving Electronics and Physics research and teaching. Work includes prototype instrument design, development and construction, and the servicing of electronic equipment. We have two vacancies, one at grade 5, salary £3651 to £4185 per annum, and the other at grade 3, salary £3153 to £3525 per annum. Both salaries are inclusive but are under review. Generous holidays.

Day release for further study may be arranged at grade 3. Details and application form from Mr. M. E. Cane (3/5EW), Department of Electronics, Chelsea College, Pulton Place, London, SW6 5PR.

(9070)

PIONEER®

An extensive expansion programme to diversify our after sales service activity has created additional vacancies at our service centre in Iver.

BENCH SERVICE TECHNICIANS

We require service personnel to join a friendly team of Technicians in our modern well equipped service department and laboratory to assist in repair and maintenance of sophisticated Audio and In-Car stereo equipment of our world renowned brand.

Applicants should hold C & G Radio and TV, Electronics Technician or equivalent certificate with a minimum of two years' experience in the Audio field. Alternatively five years' of relevant experience with sound knowledge of Electronics is acceptable.

Salary in the area of £3,500 to £4,500 per annum, according to experience.

If you think that you can help us in our expansion programme then contact us now and find out more about our generous staff benefits. We offer excellent working conditions, training programmes and day release to advance your career and knowledge in the field of high fidelity.

Luncheon Vouchers. Pension Scheme.

Apply in writing to: **Mr. A. H. K. Littlemore, Pioneer High Fidelity (G.B.) Ltd., The Ridgeway, Iver, Bucks., or telephone Iver (0753) 652222/7.**

(9030)

SYSTEMS ENGINEERS

Simulators are today's most advanced training systems and by incorporating tomorrow's technology into an already highly sophisticated product we have created an exciting and challenging environment.

To meet this challenge we would like to hear from men and women who are qualified to HND/degree level and have relevant experience in Systems Simulation or Systems engineering, utilising Assembler language — a knowledge of high level languages would be useful.

Should you believe your experience or qualifications are in line with our requirements and would like additional information please contact: John Perry on Crawley 28811 up to 5.30 p.m. or Crawley 35279 after 5.30 and listen to our Ansafone message.

PROJECTION ENGINEER

Required to service our projection and sound equipment. Applicants should either be qualified projectionists or have a basic knowledge of this type of equipment. Male and female applicants please contact the Personnel Manager.

Rank Film Laboratories
North Orbital Road
Denham
Uxbridge
Tel. Denham 2323

(9043)

Celestion
Loudspeakers for the Perfectionist

Situated in a pleasant part of East Anglia, are in the forefront of loudspeaker design and manufacture. Expansion policies have created the following opportunities for self-motivated people prepared to join an established team:

SENIOR JIG & TOOL DESIGN DRAUGHTSMAN/WOMAN

to design press tools, jigs, fixtures and special purpose machines. We require several years' experience in jig and tool design, plus an ONC or equivalent qualification. A knowledge of pneumatics would be an advantage.

PLANNING ENGINEER

to contribute to planning in new products from development through to final manufacture, detailing processes, specifying equipment and tooling requirements, and assisting with factory layout. Applicants would be expected to have experience in engineering and assembly methods in medium batch production, and be qualified to at least ONC standard. Experience of CPA rechniques would be helpful.

DRAUGHTSMAN/WOMAN

to join Design and Development team, initially to carry out routine drawings and modifications, but with capability to progress to design work. Applicants should be in their early 20's, and have a minimum of two years' experience in light or electro mechanical engineering, and hold a City and Guilds Technician's Certificate or equivalent qualification.

The Company offers competitive salaries, a contributory pension scheme with free life assurance, and appropriate re-location expenses.

For an application form please apply to:—**The Personnel Officer, Rola Celestion Ltd., Ditton Works, Foxhall Road, Ipswich, Suffolk IP3 8JP. Telephone No. Ipswich 73131.**

(9066)

Brompton Hospital

Junior Medical Electronics Technician

Required to undertake work involving maintaining, installing and developing Medical Electronics equipment. Applicants should have a good general knowledge of electronics and be qualified to ONC (Electrical and electronic engineering standard or equivalent). Previous hospital experience not essential.

Salary will be on scale £3423-£4498.

Further information available from the Physicist in Charge Mr. R. B. Logan-Sinclair, Tel: 01-352 8121 Ext. 4252.

Application form and job description from Miss J. A. Jenks, Personnel Manager, Brompton Hospital, Fulham Road, London SW3 6HP. Telephone as above Ext. 4357.

(9042)

SERVICE ENGINEER

required for the repair and maintenance of electro-mechanical coin machines. Basic knowledge of wiring diagrams and small mechanical parts helpful but training will be given. Must have a clean driving licence. Salary around £70 per week.

J.C.W. (AUTOMATICS) LTD.
83 Lavender Hill
Battersea, S.W.11
Tel: 228 4359 (9079)

TEST ENGINEER

Up to £6000 p.a.

We are one of the world's leading producers of sophisticated environmental test equipment, with over twenty years' experience in high performance electro-hydraulic test machines and vibration systems.

Excellent career opportunities exist for engineers with HNC or equivalent in Electronics or Radio and TV and an interest in mechanics, to undertake bench testing of printed circuit assemblies, with subsequent involvement in the testing of complete systems. Applicants should have experience in fault-finding to component level.

Apply in writing, or telephone
Servotest Ltd.
Sarsfield Road
Greenford
Middx UB6 7AA
Tel: 01-998 1552 (Mrs. T. Malin)

SERVOTEST

(9056)

Sony Broadcast Limited

are engaged in marketing SONY professional broadcast equipment throughout Europe, Africa and the Middle East.
We have now an opening for a

Senior Lecturer

to assist the Technical Training Manager in providing expertise and support for our products, with a special emphasis on conducting training courses for customers and participating in the planning of further expansion of this important function.
Candidates should have a wide experience in video tape recording, in the theoretical analysis of digital circuitry and analogue/digital signal processing, and a sound knowledge of the broadcasting industry in its most modern applications. They must have the ability to present ideas clearly to a wide range of students and answer the most difficult questions.
The above senior position is permanent at the Company's modern offices in Basingstoke's new business area. A certain amount of travel through the whole marketing area and to the Headquarters of Sony Corporation could be involved.
We will provide whatever additional training is necessary to familiarise the successful candidate with our modern and sophisticated equipment.
A highly competitive and attractive salary is offered to the right person, together with the usual benefits of a large multi-national Company.
Please write in confidence, giving career history and essential details to:

Personnel Manager

SONY Broadcast

Sony Broadcast Ltd.
City Wall House
Basing View, Basingstoke
Hampshire UK RG21 2LA

(9034)

GRANADA TELEVISION LIMITED

YOUNG ELECTRONIC ENGINEERS

(Male or female)

We are looking for Electronic Engineers to fill a number of interesting jobs in the technical operations department at our Manchester studios.

The duties cover the operation and maintenance of all our electronic equipment including TV cameras, video recorders, film scanners and distribution and display equipment. The kind of people we need will probably hold a formal qualification in electronics engineering, but more important, will have a good understanding of basic electronics including digital techniques and the engineering principle of colour television. They must be fit with normal colour vision and prepared to work irregular hours including weekends. People with no previous broadcasting experience will be appointed at £3,775 per annum on a scale rising to £5,939 by annual increments.

Experienced staff will be appointed at the appropriate point of this scale. Four weeks' annual leave plus pension and free life assurance.

Write with full details of education, qualifications and experience, stating age to:

Robert Connell
Granada Television Limited
Quay Street
MANCHESTER M60 9EA

(9035)

BRUKER

ENGINEERS/ SCIENTISTS

Our United Kingdom subsidiary is expanding and we need engineers/scientists to join our back-up team.

The high-technology scientific instruments which form our product range are at the forefront of their design and require a first-class understanding of state-of-the-art electronic techniques, coupled with a high degree of initiative in tackling unusual problems.

The job requires the ability to trouble-shoot on site down to component level; after an initial period, to carry out full system installation, commissioning and operator training; and to liaise at a professional level with both the scientific user and the system designer.

The ideal applicant will be self-motivated and well presented, as befits the Company's professional image. A keen interest in all aspects of electronics, a preparedness to travel extensively in the United Kingdom (foreign travel also possible) and the capability of working away from base without supervision are also essential. A minimum qualification of HNC (electronics) is required and some design experience would obviously be an advantage. Some knowledge of the German language, although not essential, would help.

This is a challenging opportunity for those prepared to work hard, and will be rewarded by way of basic salary plus incentive.

Interested? Then please write giving full details of qualifications, career to date, personal data, etc., to:

R. F. Ladbury
BRUKER SPECTROSPIN LIMITED
Unit 3, 209 Torrington Avenue, Coventry CV4 9HN

(9036)

LABORATORY TECHNICIANS

Vacancies exist within the BBC's Equipment Department based at Chiswick for both **Senior Laboratory Technicians** and **Laboratory Technicians.**
Duties include the testing of newly manufactured broadcasting equipment and the work is interesting and varied, covering techniques in sound, television and radio frequency engineering.
For the Senior Laboratory Technician posts applicants should possess 3 years' relevant experience together with HNC and City and Guilds F.T.C. in either Telecommunications or Electronics. The current salary range is £4195 to £5715 but this is under review.
For the Laboratory Technician posts applicants should have 1 year's relevant experience together with ONC and Final City and Guilds in either Telecommunications or Electronics. The current salary range is £3805 to £4605 but this is under review.
Accessibility is reasonable due to the proximity of the M4 and Gunnersbury station. Staff restaurant facilities are available and conditions of service are competitive.
Requests for application forms to **Engineering Recruitment Officer, BBC, Broadcasting House, London W1A 1AA,** quoting reference no. 79.E.4017/WW.

BBC

(9017)

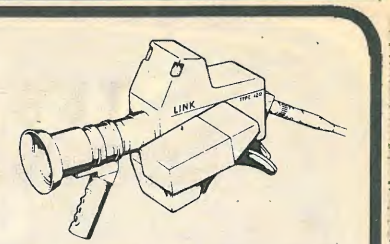
★£8,000★ FOR YOUR SONY U-MATIC EXPERIENCE.....

And that's not all – this could be the offer you just can't refuse!
Joining this leading international company, you would be responsible for the service and repair of Sony U-matic VTR and television equipment – incorporating NTSC and PAL colour systems – plus Convergence Editing Units and professional audio systems. In addition, the opportunity may arise to work on advanced cameras and there is the possibility of some overseas travel.
Based in West London close to road and rail links, working conditions are excellent with sophisticated modern workshop facilities and pleasant surroundings.
In addition to the attractive salary, there is an excellent BUPA membership scheme.
For further details please contact Mike Gernat quoting ref: MB2.

Technomark
Engineering and Technical Recruitment
5-11 Westbourne Grove, London W2
Telephone 01-229 9239

(9023)

LINK



TELEVISION

WE ARE Link Electronics Ltd., a successful expanding company with room for individual ability to make itself felt.

WE MAKE A full range of TV studio broadcast equipment, including colour cameras.

WE NEED DEVELOPMENT ENGINEERS at senior and junior levels, to put good theoretical knowledge into practice in circuit design of all types of broadcast equipment, employing the latest techniques. You must have 2-3 years' relevant experience in industry, preferably obtained in a TV or similar environment.

SENIOR TEST ENGINEER to undertake test and commission of advanced and complex TV cameras and associated equipment. This appointment is at a senior level and so direct experience of similar equipment is a must.

WE OFFER:

SALARY Above average, according to ability and not a rigid grade structure.

BENEFITS Generous holidays, free life and health insurance, pension scheme, staff restaurant, relocation expenses.

LOCATION A modern factory in a very pleasant part of Hampshire with no traffic problems and easy access to London, the South Coast and many major towns.

HOUSING A wide choice. Prices from about £15K upwards if you want to buy.

TO APPLY: Either phone Jean Smith at Andover (0264) 61345 and ask for an application form or write with enough information to make form unnecessary.

LINK ELECTRONICS
North Way, Andover
Hampshire, England
Telephone Andover (0264) 61345

(9022)

Section Chiefs
c.£6,000
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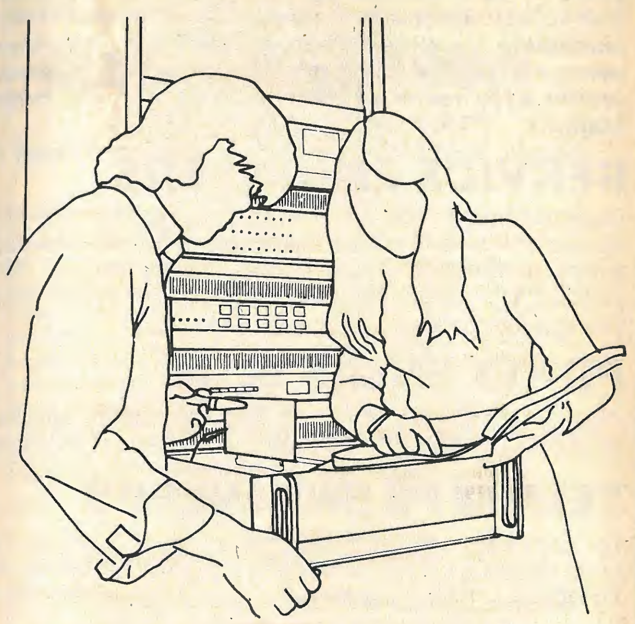

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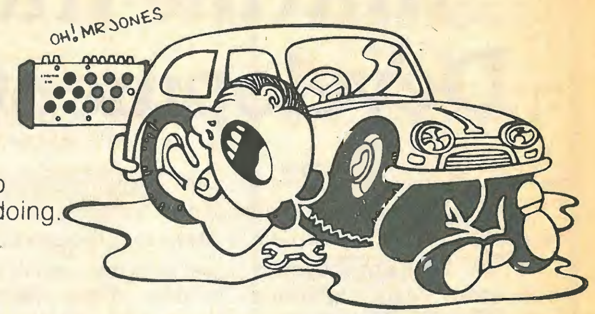

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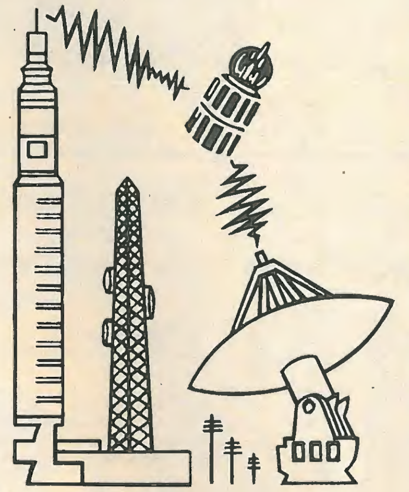

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