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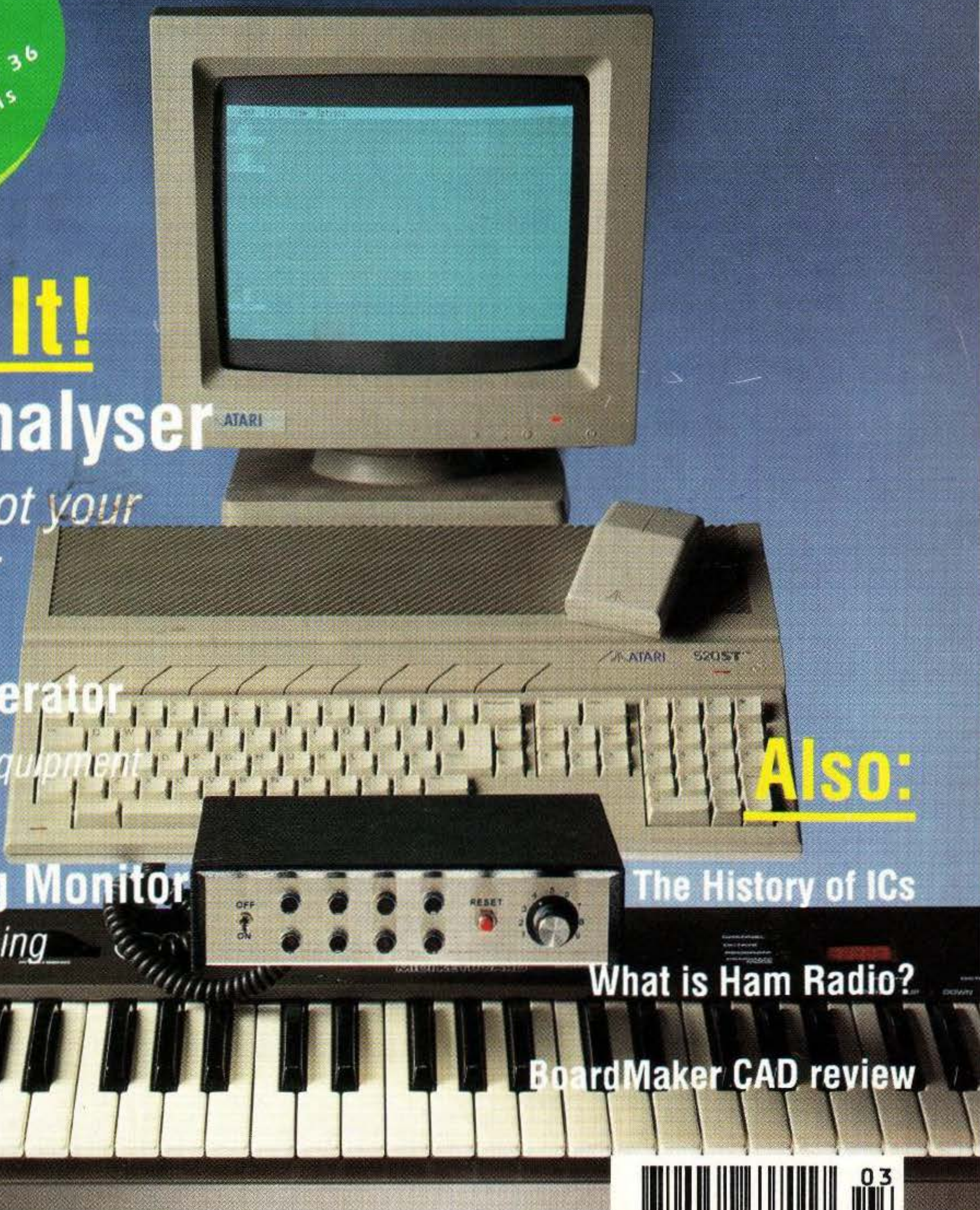

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March 1991

Volume [redacted] #[redacted]
27 3

Projects

Features

Regulars

Editorial

This month PE has both a new look and some new regular sections.Innovations replaces the news pages and Data Sheet provides an area to have an in depth look at both new and commonly used integrated circuits. With the end of Basic Electronics, the introduction of the Techniques section will allow readers to tap the brain of an electronics expert.

Kenn Garroch, Editor

Innovations

A look at what's new in the world of electronics, science and technology.

Philips Components recently announced a selection of new chips and modules. The QUART (Quad Universal Asynchronous Receiver Transmitter) SCC2694 features a specialised interrupt system that reduces the host processor workload. Five types of interrupt are accepted, receiver and transmitter FIFO (First In First Out) bytes, break detection and the change of state on two pins for each UART. The operating speed of each transmitter and receiver can be selected independently from one of 18 fixed baud rates. To minimise the amount of overrun and reduce the interrupt overhead, each receiver is buffered with eight character FIFOs and one shift register. There is also a power-down mode which stops the internal oscillators and stores the register contents.

The 27C010 and 27C240 add two new EPROMs to Philips' range of memories, providing one and four megabytes respectively. The first is set out as 131072 (128k) words of 8 bits and the second as 262144 (256k) words of 16 bits. Other features are CMOS circuitry for low power and good immunity to noise – power consumption is only 100µA in standby mode. Access times are 200ns and 150ns for the two versions offered.

To increase its range of LCD modules, Philips has announced three new devices. The LBN441R-30 provides four lines of 40 characters with the other two having 2 lines of 16 characters. The difference between them is that one (LBN211F-90) uses supertwist whereas the other (LTN211F-90) uses twisted nematic technology. All three modules incorporate their own control and drive circuitry.

To get things moving a little faster, a 30MHz version of the 80C51 microcontroller has been introduced. The PCB80C51BH-5-30 executes 60% of its instructions in 0.4µs with the rest at 0.8µs. Running at full speed the chip consumes 44mA at 5.5V supply voltage and 10.8mA and 50µA in power down and idle modes respectively. With two 16-bit timer/counters and various bit manipulation and BCD handling instructions, the 80C51 provides high performance at low cost.

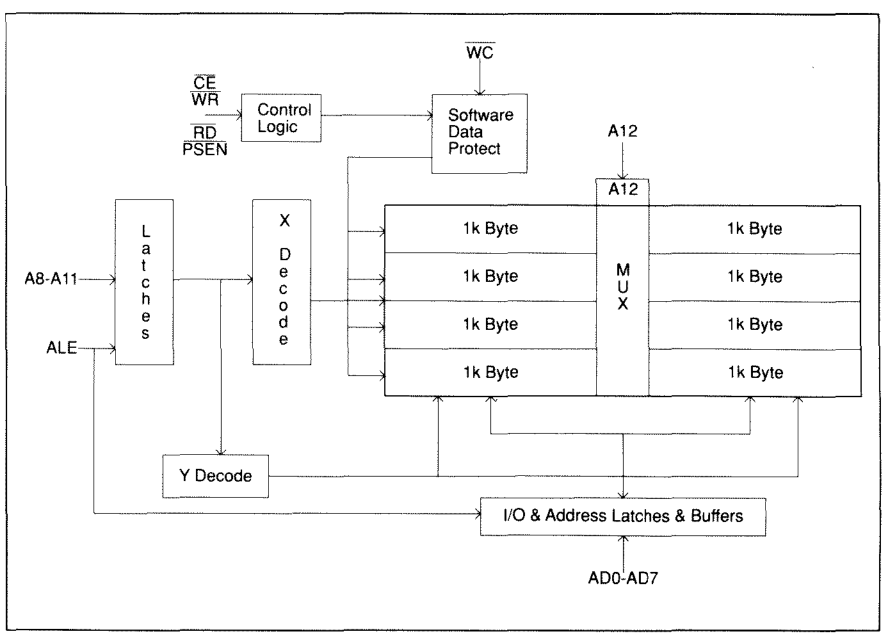
For those who don't want to go to the trouble of programming the thing in assembler, Philips can provide PL/M-51 and C language compilers.

◆◆◆

The new Xicor X88C64 is a sophisticated EEPROM (Electrically Erasable Programmable Read Only Memory). It features a multiplexed address and data bus designed to interface directly to microcontrollers without the need for address latching and extra decoding logic. The advanced dual plane architecture sets out memory as two independant 4K x 8 memory areas. This allows non-volatile write operations to happen within one of the 4k blocks while simultaneously reading from the other 4k block. In addition there is a block protect option for individual 1k blocks which allows layers of security to be assigned to various sections of the memory. In the field, parameters can be pre-set in a protected portion of the memory and accessed only by service personnel.

The X88C64 gives 8k bytes of 5 volt EEPROM (or E^2PROM) that can be used either for program or data storage in systems based around the 80XX or 68XX architectures – also known as Harvard and Von Neumann respectively. Available in a 24-pin DIP, more information can be obtained from Micro Call, 17 Thame Park Road, Thame, Oxon, OX9 3XD, Tel. 0844 261939.

X88C64 EEPROM Operational Schematic. A12 selects between the memory blocks allowing reads and writes to take place at the same time.



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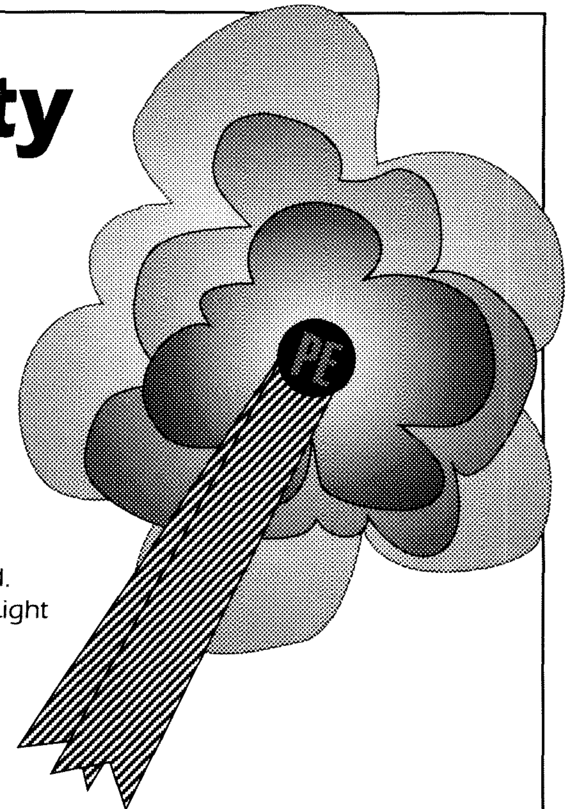

The top ten readers:

D. Brook of London has £118.16 refunded for trading with Number One Systems.

I. Radcliffe of Isle of Man receives £90.95 for buying goods from Greenweld Electronics.

D. Gladding of Manchester who bought £52.20 worth of goods from Greenweld Electronics.

D. E. Cossen of Bristol has the £45.54 he spent with Cirkit refunded.

I. J. McNair of Crewe traded with B. K. Electronics and has £39.99 refunded.

P. Eldridge of Dunstable gets back the £35.88 spent with Greenweld.

R. McConnell of Ratherland claims his £27.08 which he spent with Light Soldering Iron Developements.

D. Crome of Kent secures his £20.50 for purchasing goods from J. N. Bull Electrical.

J Kirby from London is reimbursed £19.95 for trading with T. K. Electronics.

A. G. Clark of Cheltenham has £12.50 repaid for his purchase from J. N. Bull Electrical.

See page 36 for more details!

Anyone building battery powered systems may be interested in the Maxim MAX406 precision operational amplifier (op amp). The device is specially designed for use in low power applications and can operate from single supplies ranging from 2.4V to 10V or from dual supplies up to +5V. It requires only a 1.2µA supply current enabling battery powered circuits to operate more than 15 times longer than those using other op amps. Able to source 2mA from a 9V supply, the MAX406 output voltage can swing from rail to rail (plus supply to minus supply) when the input voltage range extends down the negative supply rail.

When the chip is set for unity gain, the gain bandwidth product is typically 8kHz and the slew rate is 5V/ms. In its other operating mode, the MAX406 is stable with gains of two or more and the gain bandwidth product is typically 40kHz and slew rate of 20V/ms.

For more information contact Kudos Thame, 55 Suttons Park, London Road, Reading, Berks, RG6 1AZ, Tel. 0734 351010

◆◆◆

For those with a critical ear, Furukawa has introduced a new range of speaker cables featuring grain free, oxygen free, single crystal, 99.9999% pure copper conductors. The new process, known as Procc, ensures that there are no grain boundaries in the signal direction so that resistance is lowered. Normally, inclusions of hydrogen and oxygen create barriers to current flow and increase the resistance of the cable.

Known as the Evencap range, the cables are made up from strands of Procc conductor protected by polypropylene insulation. In the larger cables a non-magnetic cord is placed down the centre in order to reduce constant variations of electrostatic capacitance at the conductor's centre. This provides good overall linearity and clarity at low frequencies.

Prices start at £4.50 per metre for the FS2T14 with improved quality in the FS2T30F at £12 per metre and the even larger FS2T55F at £22.50 per metre.

For more information contact Quantum Audio Ltd. 22-26 Nelson Street, Kilmarnock, KA1 1BA - 0563 71122.

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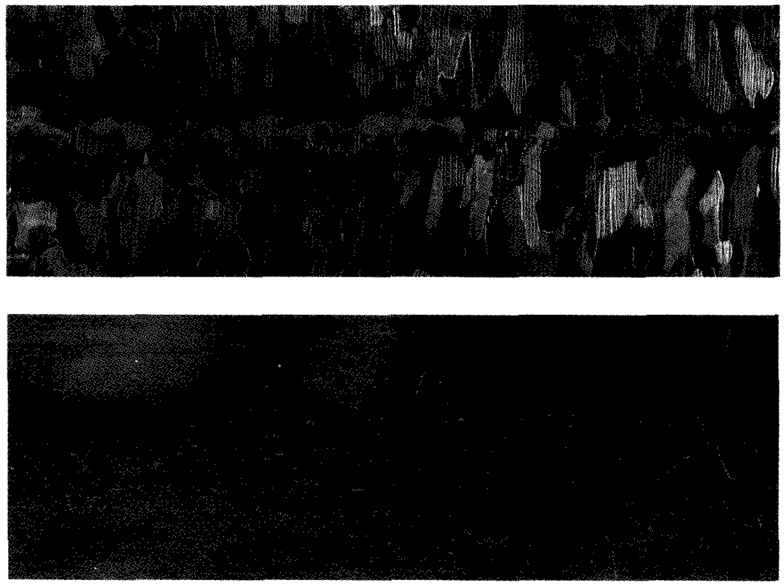

The upper photo shows the copper crystals produced by ta conventional process. The difference can clearly be seen when they are lined up with the new process.

Burr-Brown recently announced the launch of its new 12-bit digital to analog converter (DAC), the DAC667. It includes a 10V reference, double buffered latch, microcomputer interface and voltage output amplifier. The latter is able to swing ±10V on a ±12V supply. Offered as a direct replacement to the AD667, the device requires lower power and lower prices.

To assist interfacing to a variety of computer architectures, the DAC667's double buffered system is made up from four individually addressable latches. The first three of these each take four bits to be loaded into the main 12-bit latch when ready. This allows the device to be connected to four-eight-12-or 16-bit microprocessor buses. It also makes sure that no incorrect analogue voltages appear at the output due to unsynchronised bits.

On the output side, internal scaling resistors may be connected to produce bipolar output voltage ranges of ±10V, ±5V and ±2.5V or unipolar ranges of 0 to +5V and 0 to +10V.

For more information contact Burr-Brown, PO Box 11400, Tucson, AZ, USA.

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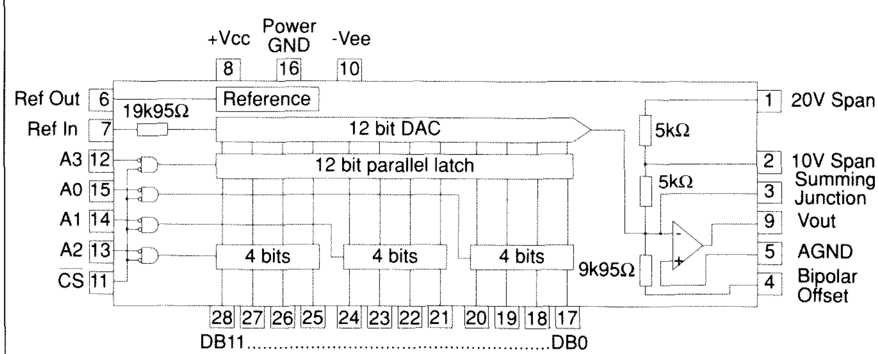
Operation and pin outs for the DAC667. The three 4-bit latches feed into the main 12 bit latch to allow interfacing to 4, 8, 12 and 16 bit data buses.



Techniques

Andrew Armstrong begins a new series of questions, answers and technical tips.

This is the first of a new series in which readers' questions will be answered and unusual technical tips presented. To start the ball rolling, here is a design for a simple ADC (Analogue to Digital Converter) for use where a dedicated ADC chip is not justified. In this example it is used in conjunction with a BCD to 7-segment display driver as a simple level indicator displaying readings of 0 to 9. However, it should find many other applications.

The analogue voltage is converted to a four-bit digital signal, so it digitises to 16 levels, counting zero. It uses only ordinary 2% resistors, one LM339 quad comparator, and one CMOS inverting buffer, so it is a little cheaper than a normal ADC chip.

The circuit is shown in Fig. 1. The complexity increases from left to right. The first comparator, IC1a, has its reference voltage set to half the total reference by R1 and R2, so that it switches when the analogue voltage crosses half the reference voltage. It is clear to see that this does what the most significant bit should do.

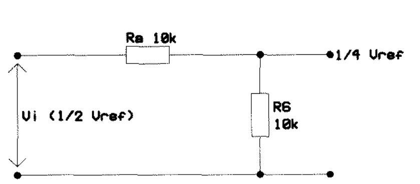


Fig. 2. Circuit Summary

The second comparator's comparison voltage is partly dependent upon the state of the first comparator. When the input voltage is below 50%, the output from the first comparator is at logic 1, and the output from the inverting buffer, IC2a, is at logic 0. This sets the comparison voltage to a quarter of the reference voltage, as is shown by the following reasoning: the network comprising R5, R6 and R7 may be re-drawn as shown in Fig. 2. The resistance Ra is the value of R5 and R7 in parallel, and the voltage V1 is the voltage that would appear on the junction of R5 and R7 if nothing else were connected. This is a completely exact-equivalent circuit, and it shows a potential divider dividing half Vref down by a half, to a quarter Vref.

The second comparator switches from 1 to 0 as the input voltage rises past a quarter of the reference voltage, but switches back to 1 when the first comparator switches at half of the reference voltage. This is exactly the function required of the second-most significant bit.

This reasoning extends to the third and fourth comparators, though by the fourth comparator it is less clear to see what is happening. The ideal resistor values would be in the ratio 1:2:4:8, but to digitise to 16 levels the values shown here are good enough.

With care, this technique could be expanded to five or six bits, but inaccuracies caused by the CMOS buffers not quite reaching its supply rails, and by the hysteresis applied to the comparators, would make it increasingly difficult to maintain monotonicity (meaning that, as the analogue input voltage is increased from zero to Vref, all the digital codes occur in the correct order).

The CMOS buffer must be powered by the reference supply, which may be in the range 3 volts to 12 volts, while the comparator should be powered from a supply at least 3 volts higher than that of the reference.

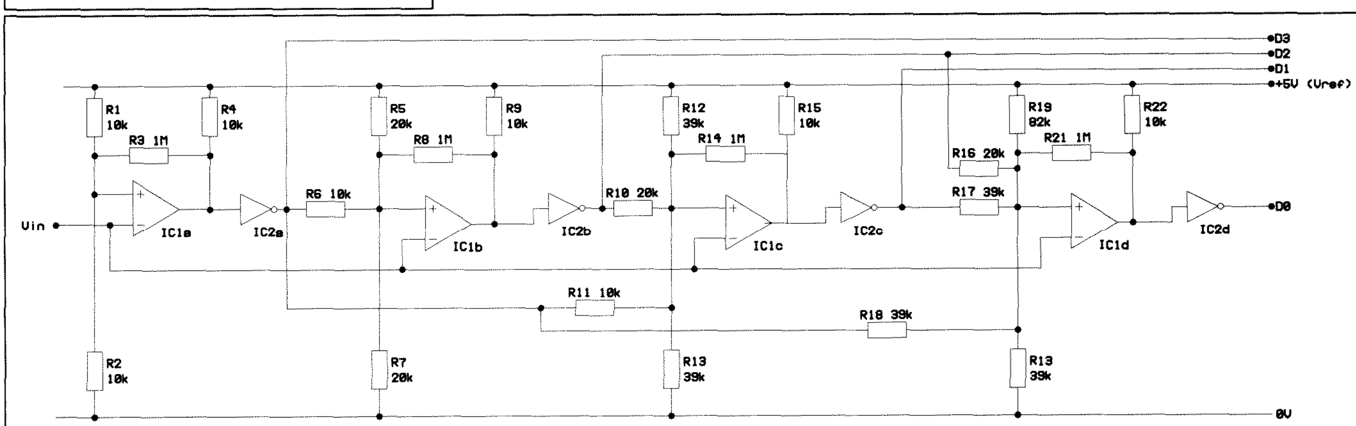


Fig. 1. ADC circuit diagram.

Undistorted,

Do you know of any type of design suitable for controlling volume in response to a control voltage without causing distortion?

J R Gibbs
Swindon

There is more than one approach to this problem. A possible answer would be to use a proper analogue multiplier, which tends to give much less distortion than low-cost gain control ICs. Unfortunately, analogue multipliers good enough

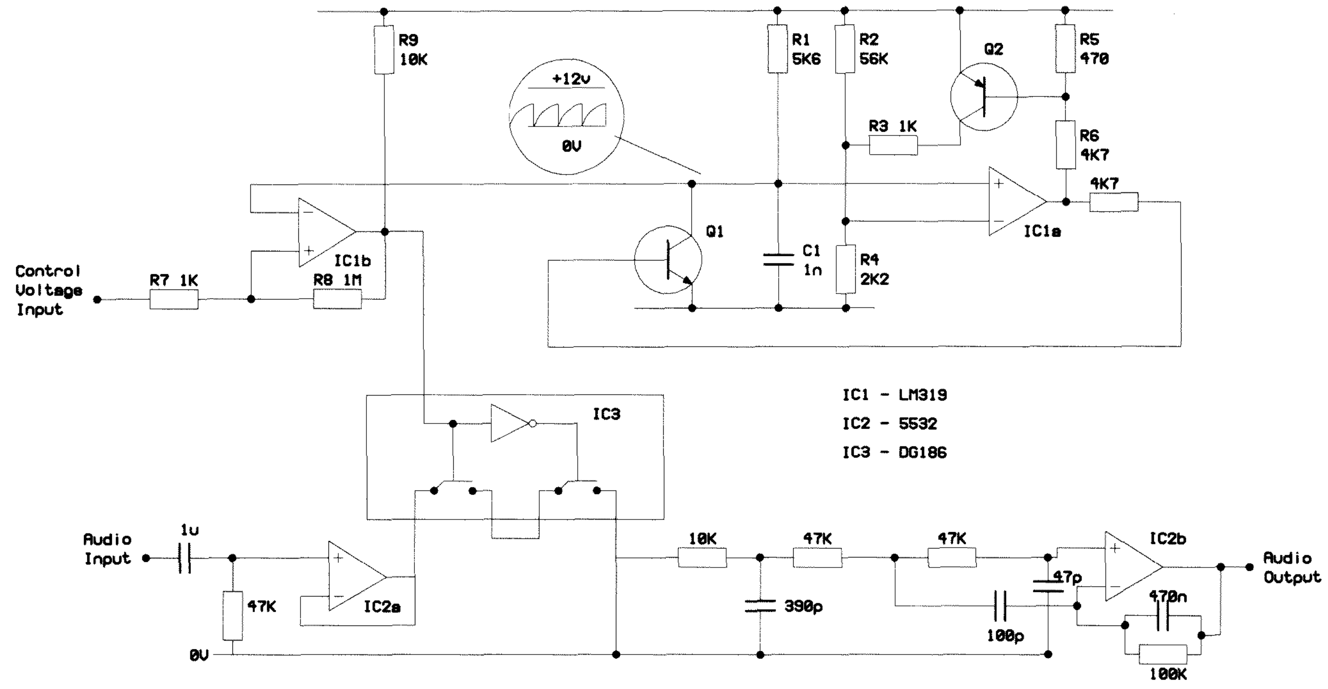


Fig. 3. Volume control.

to be worth considering for the purpose are very costly.

The circuit I have chosen does not rely on any analogue characteristic to control the gain, so distortion that would normally arise due to analogue non-linearities is largely eliminated.

The design employs a fast analogue switch to switch the output rapidly between signal input and ground. The output is filtered to average the signal voltage, and the switching frequency is well outside the audio range. The net effect is that the output signal consists of the input signal multiplied by the mark:space ratio of the switching.

The circuit can be divided into two main parts. There is the variable mark:space waveform generator, which generates a sawtooth waveform and compares this with the control voltage to generate the switching waveform, and the audio chain consisting of input buffer, switch and filter.

The sawtooth generator works by charging and discharging a capacitor between two well-defined voltages. The capacitor is charged via a resistor rather than, as might have seemed possible, a constant current source, so that the waveform will be exponential in shape. This means that the mark:space ratio of the switching responds approximately as would a logarithmic potentiometer to a linear variation of control voltage, just the volume control law that one needs.

While the capacitor is charging towards the threshold voltage, the output of IC1a is at 0V and transistor Q2 is switched on while Q1 is switched off. This sets the switching threshold at approximately 8.25V. As soon as the capacitor voltage crosses this threshold, IC1a switches so that Q2 switches off and Q1 switches on. C1 rapidly discharges via Q1, until its voltage falls below the voltage set by the potential divider formed by R4 and R2, approximately 450 mV. The output of IC1a switches back to 0V and the process repeats itself. IC1b compares the sawtooth waveform with the control voltage input to provide the switching signal for the analogue switch ic. Note that IC1 is a fast comparator, and that slower devices are unlikely to work properly in this circuit.

The sawtooth generator operates at a frequency of approximately 150kHz. This may be calculated as follows: the capacitor charges to 69% of the power supply voltage each cycle, and because the discharge is very rapid, it is the charging time which largely determines the frequency. Starting with the standard capacitor charging equation:

$V = 1 - \exp(-t/T)$

where V is the instantaneous voltage at time t, and T is the time constant of the resistor and capacitor, we can arrive at the equation:

$t/T = -\ln(1 - V)$

Using the value of V above, 0.69, we find that the charging time is 1.17 times the RC time constant.

The analogue switch ic is chosen primarily for its ability to switch rapidly. The DG186 can switch in 150ns, and has the added advantage of a nominal 15 ohms on-resistance. The on-resistance matters, because it can be affected by the instantaneous value of the signal voltage, and thus cause non-linearity. If the on-resistance is insignificant compared with the load resistance on the output of the analogue switch, then small changes in this resistance will add an insignificant amount of distortion to the signal.

The audio input buffer uses a standard low noise, low distortion opamp, the 5532. The other half of this opamp is used for the filter on the output. The second-order active filter on the output (with a turnover frequency of 49kHz) is preceded by a passive RC filter, at a frequency of 40kHz so as to avoid placing too much demand upon the slew rate of the opamp. ■

You *Can* Stop The Music

Robert Penfold's in-line MIDI Analyser allows rapid analysis of many common electronic music faults.

There can be no doubt that the MIDI (Musical Instrument Digital Interface) standard has revolutionised musical electronics. Modern digital electronics provided us with instruments of great power and versatility. MIDI provides the means of connecting them all together, with or without a computer controller, into an integrated system in which one instrument can act as a 'master player' for a number of others, and the control codes can be stored on disk for use later if desired.

Although MIDI is an extremely good system which has been able to accommodate a wide range of electronic musical instruments and recording equipment, it is not totally without problems. One of these is simply that, in order to make the system sufficiently versatile to be really useful, it has become somewhat complex and daunting in appearance. Even so, it is not too difficult to grasp a basic understanding of the MIDI codes and facilities that are available, but a little concentrated study is required.

What is probably a more major problem is that MIDI is often implemented on individual instruments in a rather convoluted fashion. Modern instruments, and those a few years old, come to that, achieve compactness and low cost by using a minimum of controls. The familiar push-button switches and multi-digit led or lcd displays usually enable any desired parameter to be adjusted and displayed, but it can be slow and cumbersome finding the right combination of key presses to reach the desired function.

Grabbing a byte

For some instruments it is possible, at extra cost, to use an external controller to simplify adjustments and reduce the risk of errors when setting up. For most of us, though, it is a matter of muddling through with the front panel controls until we become familiar with the instrument. This can take time, and can naturally bring problems when something in the system fails to work. Is the problem due to a faulty lead, is the controller set up sending the wrong data, or is the receiving device set up wrongly?

Without the aid of test equipment it can be very difficult to track down the problem quickly. In fact, without some means of checking the MIDI data being transmitted it can sometimes begin to seem impossible to locate the problem at all.

There are various types of MIDI tester, ranging from simple units that merely indicate whether or not there is a signal at the end of the cable, through to complex computer-based systems which can store and display large amounts of data. The most popular MIDI testers fall somewhere between these two extremes, and one popular type which works quite well has a simple decoder and led display which shows the types of message being received (note on, note off, system exclusive, and so on), plus the channel number. Although a unit of this type is very useful for much testing, it sometimes fails to provide sufficient detail. For instance, it will not usually give any indication of such things as note values and velocity values.

This led to the development of the MIDI analyser featured in this article, which is quite straightforward and inexpensive to build, but provides reasonably detailed information on the received MIDI signals. In essence it is very simple, as it merely grabs a MIDI byte and displays the binary pattern on a row of eight leds. The prototype simply displayed the first byte received after switch-on, or after the reset button had been activated. This was useful, but would only show the header byte of a MIDI message. The header reveals the message type and the channel number, but does not give any idea as to what follows in the data bytes.

The final unit as described here has the additional feature of a counter so that anything from the first byte received through to the ninth byte received can be displayed. This is much more versatile, and by selecting the second or third bytes, and then playing a note on the instrument, the note or velocity values (respectively) will be displayed. If a note is played and immediately released, a six-byte sequence should be produced by the instrument. The fourth byte will be the note-off message, while the fifth and sixth ones will again be the note and velocity values. These can all be checked using this MIDI analyser.

You are not restricted to testing note-on and note-off messages. With a velocity sensitive keyboard you could check that it is functioning properly by holding down a note. The first three bytes will then be the note-on message, and the fourth byte will be the velocity message header byte. The fifth byte will be the data byte for this message. The unit will obviously respond to program-change messages, or any other MIDI messages produced by changing controls on a MIDI device. Always read the first byte to check the message type and channel, and the second and third bytes (where appropriate) to check the data values. By using this method to check message types, channel numbers, and data values, you can take most of the guesswork out of MIDI system troubleshooting. You will know whether data is reaching its intended destination and, in most cases, exactly what data is being sent. This makes it obvious whether the problem is due to wrong data, a faulty cable, or the receiving device being incorrectly set up (or faulty).

Of course, unlike a complex computer-based analyser, you can not use the unit to read a number of bytes at once. To check (say) a pair of three-byte messages you must repeat the message six times, checking a different byte each time the message is transmitted. This is obviously less convenient, but greatly simplifies the unit and makes it relatively cheap.

The system

The block diagram (Fig.1) shows the general make-up of the MIDI analyser. It is built around a UART (universal asynchronous receiver/transmitter). A MIDI signal is a form of serial signal, and is in many respects the same as a conventional RS232C type. It uses a word format of one start bit, eight data bits, one stop bit, and no parity. This can be handled by virtually all serial devices, and is probably the most common word format these days. MIDI differs from the RS232C standard in that it has the non-standard and relatively high baud rate of 31250 baud (or 31.25k baud if you prefer). Although higher than the maximum RS232C standard of 19200 baud, it is still within the capabilities of most serial interface chips. Another way in which MIDI deviates from the RS232C standard is that it does not use signal levels of (nominally) plus and minus 12 volts. Instead, it uses a current loop system with opto-isolated inputs and a loop current of 5mA.

The unit therefore has an opto-isolator at the input. This drives the serial input of the UART, and also drives an output socket, or THRU socket, as it is called in the MIDI standard. This enables the unit to be connected in-line, so that the data can be checked, but still fed through to the appropriate receiving device. The basic clock signal is generated by a 4MHz crystal-controlled oscillator. The UART requires a clock frequency that is sixteen times the required baud rate, which in this case works out at 500kHz (31.25x16 = 500). The 4MHz signal is therefore fed through a three-stage binary counter in order to give a divide-by-eight action and the required 500kHz clock signal. Note that in this application the transmitter section of the UART is not required, and is just ignored.

The UART decodes the serial input signal, and as soon as each byte has been received and decoded, the appropriate binary pattern is placed on the eight parallel outputs. This data is fed to an eight bit latch which in turn drives the led display. A pulse must be fed to the clock input of the latch in order to latch the appropriate byte of data. There is a status flag output on the UART which goes high when a fresh byte of data has been received and decoded, plus an input which is taken low in order to reset this flag. An inverter connected between these two terminals results in the data received flag resetting itself almost instantly every time it is set, generating a brief pulse in the process. This pulse is fed to a divide-by-N counter which can be set to count from one to nine pulses, and then inhibit itself. When the appropriate number of pulses have been counted it activates a monostable which generates a short pulse that stores the current byte of data in the latch.

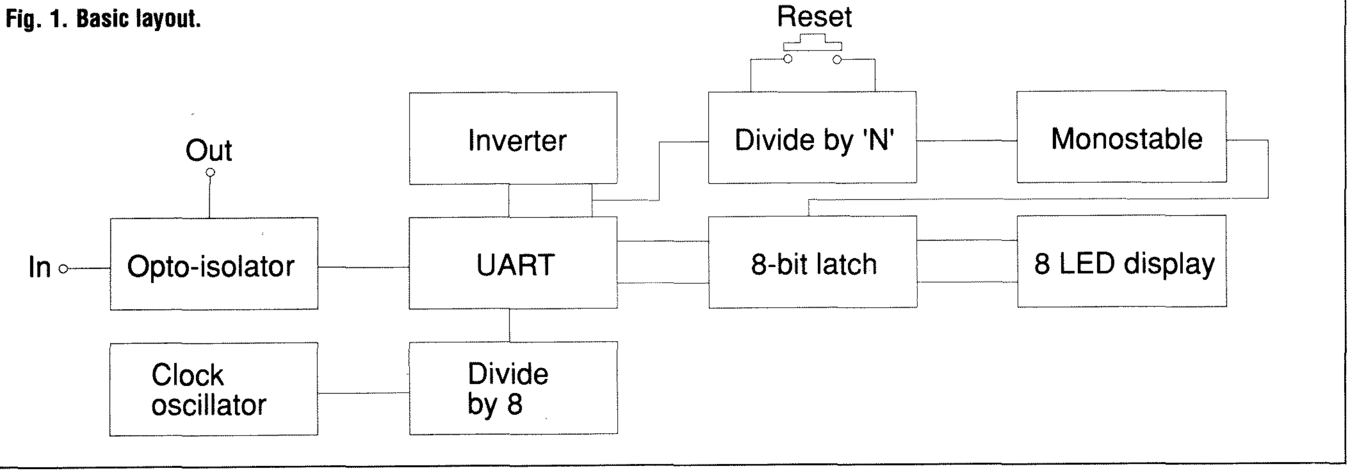
Once the counter has deactivated itself, further bytes of MIDI data will have no effect on the main circuit, and the display is "frozen". However, data will still flow through to the output socket. Operating the reset button resets the counter and the latch, switching off all the leds in the display. The Nth byte of data received thereafter will then be latched onto the display again.

Circuit operation

Fig.2 shows the full circuit diagram of the MIDI analyser project. The UART (IC3) is an AY-3-1015D. The industry standard 6402 type is also suitable (but generally a bit more expensive). IC3 can handle any standard word format, and it is programmed for the required format via pins 34 to 39. In this case they are simply hard-wired for the required format of eight data bits, one stop bit, and no parity.

TR1 generates the 4MHz clock signal, and operates in a standard

Fig. 1. Basic layout.



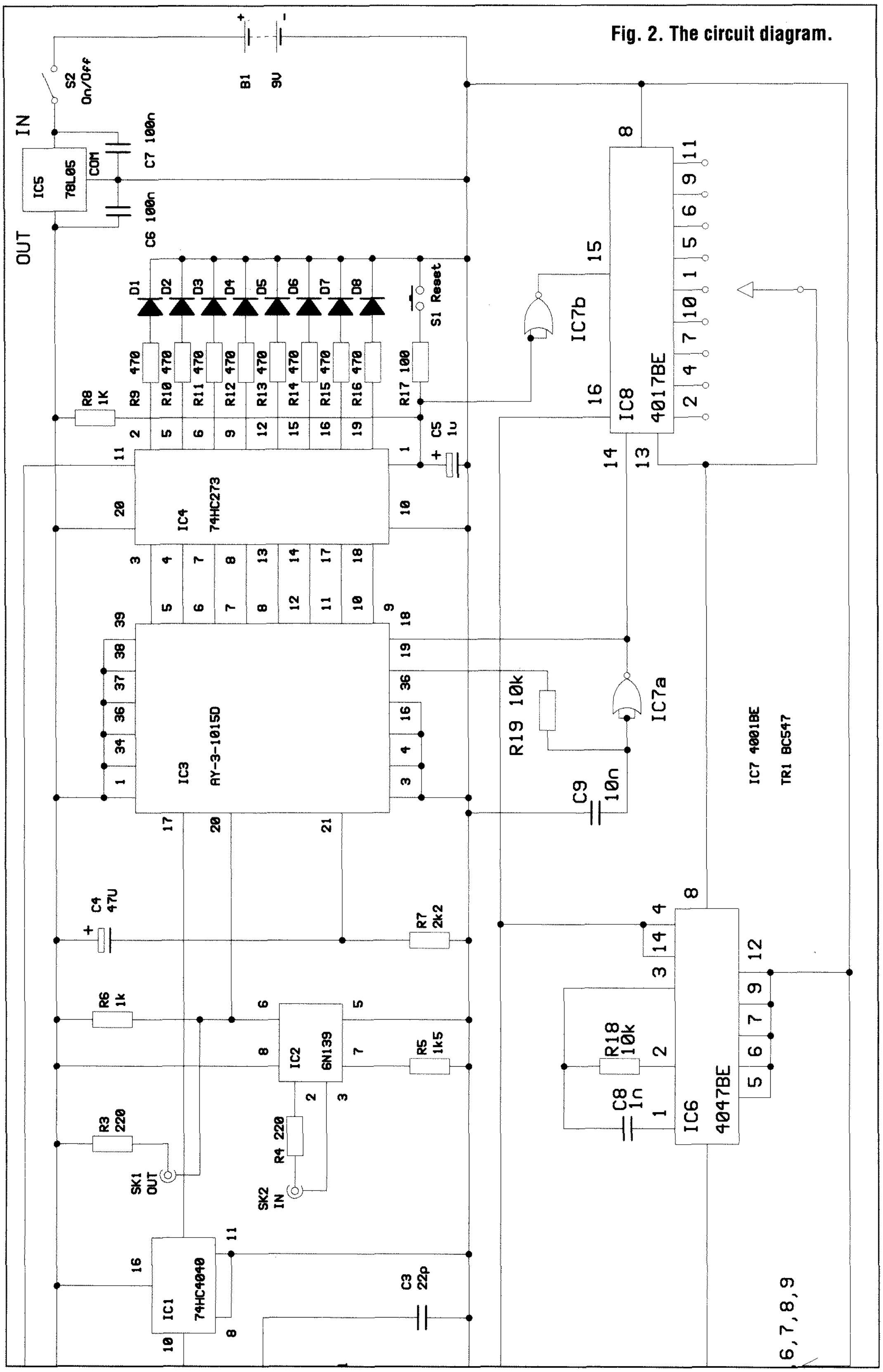


Fig. 2. The circuit diagram.

configuration. IC1 is a 12-stage binary divider, but in this circuit only the first three stages are used, giving the required divide-by-eight action. Note that IC1 must be the 74HC version of the 4040 counter in order to guarantee that it will be fast enough to cope with a 4MHz input using a 5 volt supply.

Opto-isolation is provided by IC2. This is a high quality device which on has a photo-diode driving an emitter follower on the receiving side, and a common emitter switch at the output. This gives the combination of high efficiency and high operating speed that is demanded by MIDI applications. Its efficiency is easily high enough to permit it to drive both IC3 and output socket SK1.

IC7a is a two input NOR gate, but in this circuit it is simply wired as an inverter. This is used to reset the data-received flag, with C9 and R19 providing a short delay so as to lengthen the pulses generated. This ensures that IC7a will drive the counter circuit (IC8) reliably. The latter is a CMOS 4017BE one of ten decoder. This has ten outputs (0 to 9) which go high in sequence for one clock cycle each. At switch-on the counter is reset to zero by the pulse produced by R8 and C5. This pulse is a negative type which is designed to reset the latch (IC4), but an inversion through IC7b gives a positive pulse which resets IC8. Operating S1 permits the latch and counter to be manually reset.

IC8 has an 'inhibit' input that blocks the clock signal if it is taken high. S3 is used to connect this input to one of the decoded outputs. If, for example, output 2 is used, this will go high after two clock cycles, and block the counter. The clock cycles are derived from the data-ready flag of IC3, and the counter will therefore block itself when the second byte of MIDI data is received. The selected output, as it goes high, triggers IC6, which is a 4047BE astable/monostable, used here in the positive edge-triggered monostable mode. Its not-Q output produces a negative pulse that is used to latch the current byte of MIDI data into IC4. This device is actually an octal D-type flipflop, but it works as an eight bit data latch if the latching pulse is fed to its clock

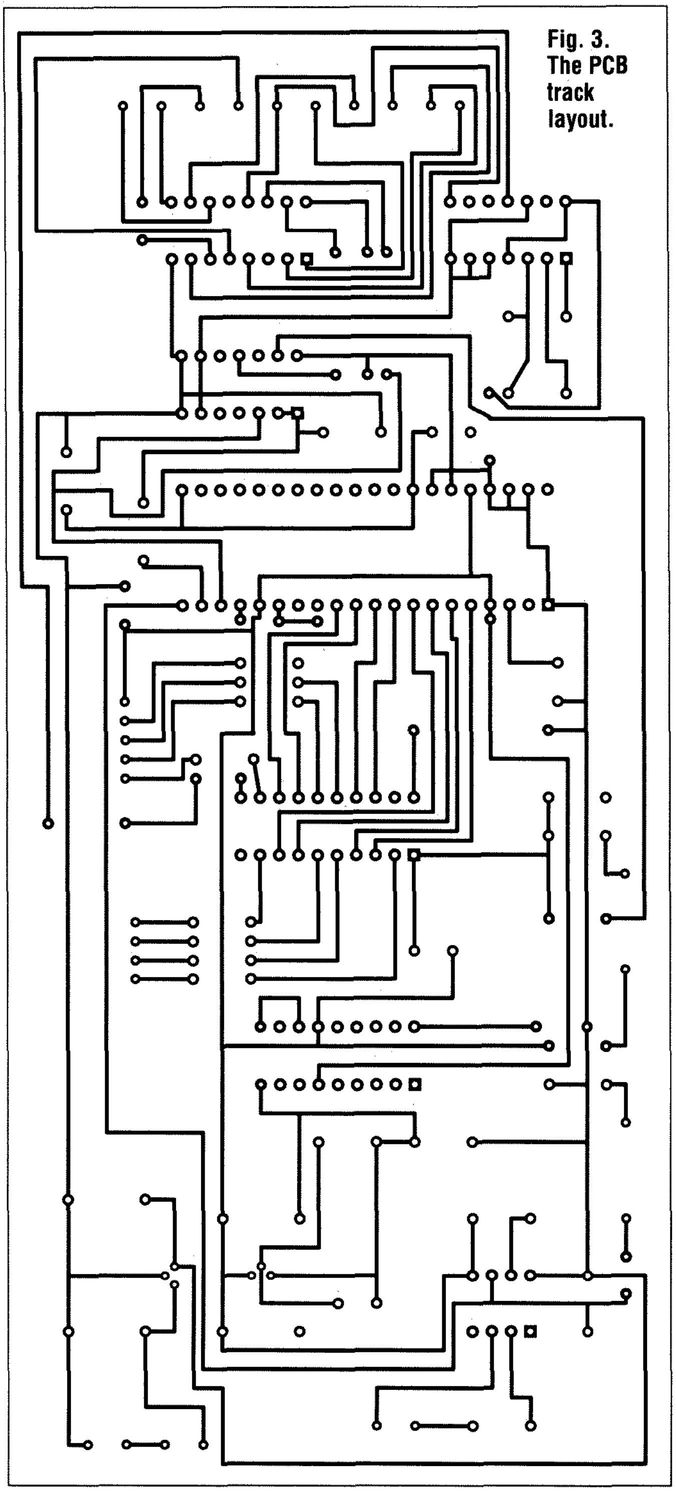


Fig. 3. The PCB track layout.

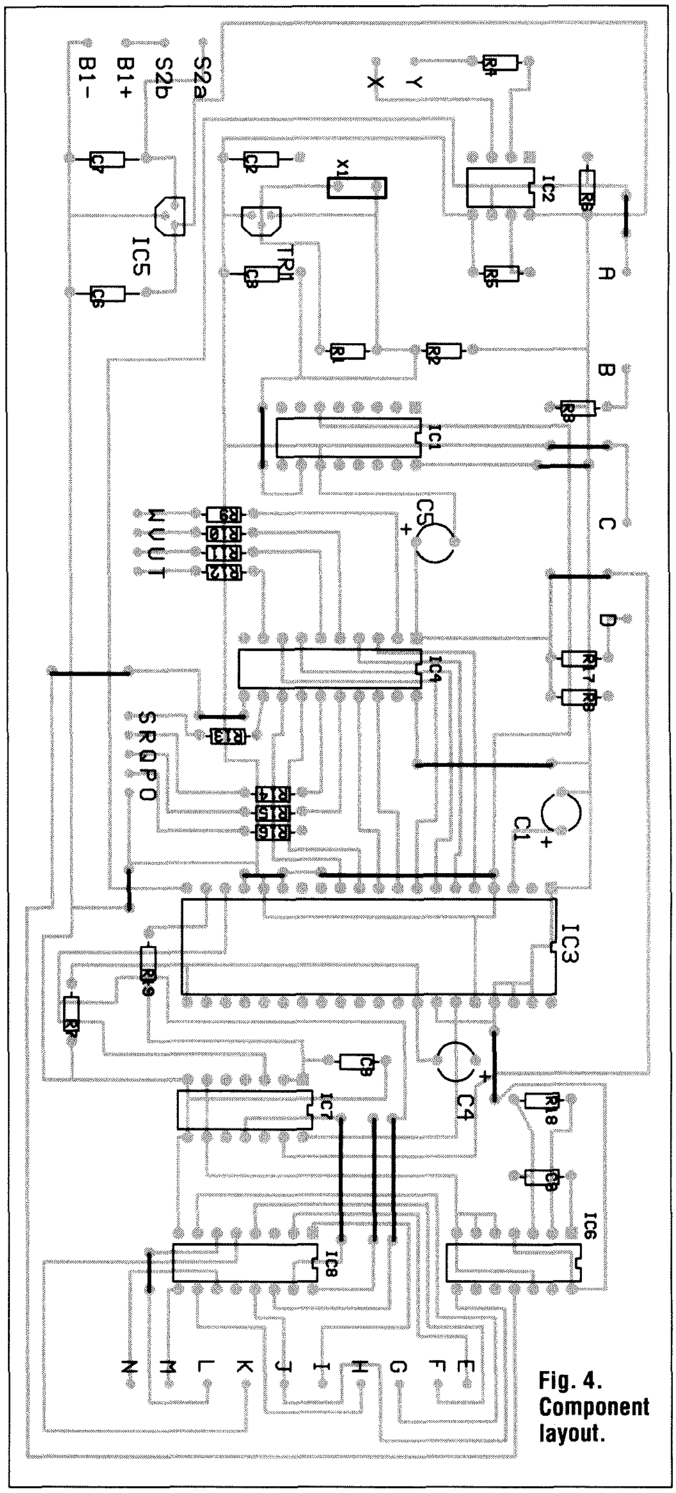


Fig. 4. Component layout.

input. The eight outputs of IC4 drive individual panel leds via current limiting resistors R9 to R15. The HC version of the 74273 has been specified for IC4 since, with the intermittent operation involved in this application, it gives a much lower current consumption. However, the ordinary 74LS273 seems to work perfectly well.

Although IC8 is a one of ten decoder, only bytes one to nine (not ten) can be latched into IC4. This is simply because output 0 of IC8 goes high at reset, making it unusable. Using it would simply block the operation of the unit.

Power is obtained from a 9 volt battery, but IC5 is used to give a 5 volt stabilised supply from this. The current consumption of the circuit is approximately 7mA under standby conditions, but the led currents must be added to this once a byte of data has been latched into the unit. The led current is about 6mA per device, giving a total current consumption of over 50mA with all eight leds switched on. The unit could be powered from a high power PP3-size battery, but if it is likely to receive a lot of use a higher capacity type, such as six HP7 cells in a holder, would be a better choice.

Note that IC7 is a CMOS quad two-input NOR gate, but in this circuit only two sections of the device are actually used. The inputs of the other two gates are connected to the negative supply rail to prevent spurious operation and

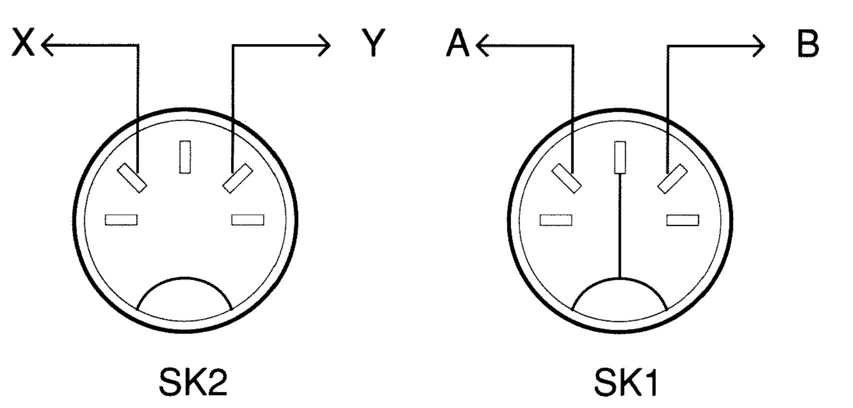


Fig. 5. MIDI In/Out sockets.

possible damage due to static charges. Apart from this these two gates are just ignored.

Construction

Details of the printed circuit board are provided in Fig. 3. Construction of the board is largely straightforward, but bear in mind that, with the exception of opto-isolator IC2, all the dil integrated circuits are static-sensitive types. The usual anti-static handling precautions should therefore be observed when dealing with these devices. Although IC2 is not a mos device, it is not particularly cheap, and I would recommend that a holder should be used for this component as well.

There are several link wires, and these can be made from about 22 swg tinned copper wire. Alternatively, trimmings from resistor and capacitor leadout wires may well suffice. For crystal X1 to fit onto the board properly it must be a miniature wire-ended (HC-49/U or similar) type. Most 4MHz crystals currently available would seem to be of this type. The capacitors must also be miniature printed circuit mounting types if they are to fit into the layout properly (7.5mm lead spacing types in the case of polyester components). Fit single-sided pins to the board at the points where the connections to the off-board components will be made.

An instrument case measuring about 200x130x50mm makes an excellent housing for this project. The exact layout of the unit is not critical, but try to use a sensible layout that avoids too many long wires. It might be difficult to find sufficient front panel space to accommodate the eight display leds comfortably in a single row. To avoid cramming the leds very close together I opted for the alternative of using two rows of four leds. As many MIDI bytes are effectively two four-bit messages, this gives what is in many ways an equally clear display.

The wiring is fairly simple and is detailed in Fig. 6. You will probably not be able to obtain a nine-way switch for use in the S3 position, but twelve-way rotary types with an adjustable end stop are readily available. It has been assumed in Fig. 4 that S3 is a switch of this type. To conform strictly to the MIDI standard the middle pin of SK1 should be connected to the chassis of the MIDI analyser (which helps to minimise the radiation of radio frequency interference from a cable connected to the THRU socket). Most DIN sockets have a chassis tag, or this connection can be made via a soldertag fitted to the case.

Getting it across

When initially testing the unit it is advisable to feed it from the OUT socket of a synthesiser or other MIDI keyboard instrument. The unit has standard (for MIDI) five-way 180 degree DIN connectors, and so it can be wired into the system using ordinary MIDI leads. Set the instrument so that it is not sending any MIDI data such as active sensing of MIDI clock signals (most instruments will by default fail to send any messages such as these). At switch-on all eight leds should fail to light up. Switch off at once and recheck all the wiring if any of the leds should switch on.

Set S3 to the 1 position, and then play any note on the instrument. The unit should then display the header byte, which for all MIDI channel messages is split into two nibbles (the upper and lower sets of four bits). The most significant nibble shows the message type, while the least significant one shows the channel number. The binary code for a note-on message is 1001, and this should be shown on the four left hand leds. The channel number is the appropriate binary value, but there is a minor complication here in that the convention is for MIDI channels to be numbered from 1 to 16. The binary value in the least significant nibble is, of course, in the range 0 (0000 in binary) to 15 (1111 in binary). Therefore, the value displayed will be one less than the MIDI channel number used. Table 1 shows the binary pattern for each MIDI channel number.

As an example, if channel 4 is used, the full binary number on the eight leds will be 10010011 (with leds being switched on for a 1, and off for a 0).

If you reset the unit by pressing S1, set S3 to the 2 position, and then

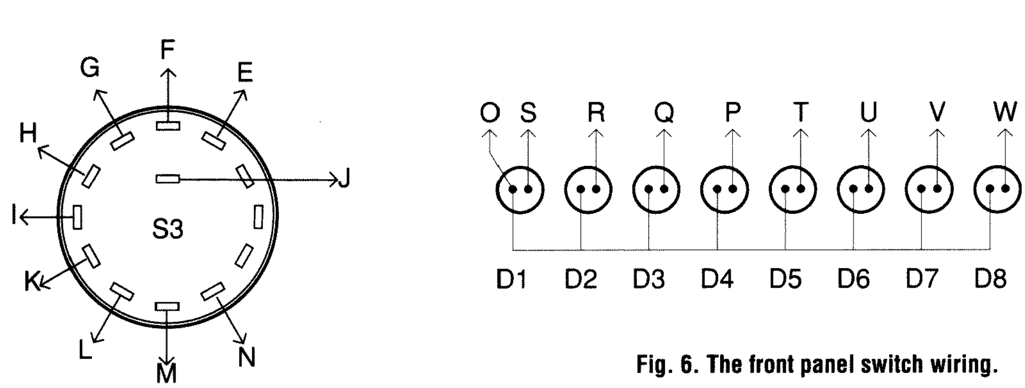


Fig. 6. The front panel switch wiring.

Table 1

Binary code	MIDI channel number
0000	1
0001	2
0010	3
0011	4
0100	5
0101	6
0110	7
0111	8
1000	9
1001	10
1010	11
1011	12
1100	13
1101	14
1110	15
1111	16

COMPONENTS

RESISTORS

R1	470k
R2,R6,R8	lk (3 off)
R3,R4	220R (2 off)
R5	lkS
R7	2k2
R9 - R16	470 (8 off)
R17	100
R18,R19	10k (2 off)

CAPACITORS

C1	100µ 10V radial elect
C2,C3	22p ceramic plate (2 off)
C4	47µ 10V radial elect
C5	lµ 63V radial elect
C6,C7	100n ceramic (2 off)
C8	ln polyester
C91	On polyester

SEMICONDUCTORS

IC1	74HC4040
IC2	6N139 opto-isolator
IC3	AY-3-1015D (or 6402)
IC4	74HC273
IC5	uA78L05
IC6	4047BE
IC7	4001BE
IC8	4017BE
TR1	BC547
D1 - D8	Panel LED (8 off)

MISCELLANEOUS

B1	6 x HP7 size cells in plastic holder
S1	Push to make - release to break
S2	s.p.s.t. sub-min toggle
S3	12 way 1 pole with adjustable end-stop
SK1,SK	25 way (180 degree) DIN socket (2 off)
X1	4MHz miniature wire-ended crystal

Case about 200 x 130 x l50mm
control knob
battery connector
DIL IC holders; 8 pin, 14 pin (2 off), 16 pin (2 off) 20 pin, and 40 pin
printed circuit board
wire, solder, pins, fixings, and so on.

play another note. The note value should be displayed. Data values will, of course, be shown on the display as seven-bit binary patterns (the most significant bit is always set to 0 for data bytes), rather than as decimal numbers from 0 to 127. It is not too difficult to do a quick conversion where necessary, but in most cases you can simply test data bytes under different conditions to check that the data is changing in basically the right way. With note values, for instance, try checking a low note first, and then a high one. This should give an obvious increase in the binary value displayed. A similar approach could be used when testing the third byte in a note-on message, which is the velocity value. Playing a note gently should give a low value, playing one hard should give a high value.

Often when checking systems using this unit you will only be interested in the basic note-on and note-off messages, or in the channel number contained in the least significant nibble of a message. However, you may occasionally need to identify other channel message types, in which case Table 2 should help

If 1111 is the most significant nibble of the header byte, then the message is a system type such as a system exclusive message, or a MIDI clock type. In this case, the least significant nibble does not indicate the channel number, but instead shows the type of message (such as 0000 for a system exclusive type). ■

Most sig. nibble	Message type	Data bytes
1000	note-off	2
1001	note-on	2
1010	poly key pressure	2
1011	control change	2
1100	program change	1
1101	channel key pressure	1
1110	pitch wheel change	2

Converting Ideas Into Cash

Ever thought of patenting your invention? Barbara Cookson explains how it is done and points out the pitfalls.

Many people toy with the idea of converting an electronics project into a business proposition. A clever design for a new electronic gadget looks good but how is it possible to get it manufactured by an existing company, and wouldn't the idea be stolen? Such paranoia means that many good ideas never see the light of day commercially and their inventors never see any profit. There is not much satisfaction in saying to your grandchildren, "Of course, I thought of personal phones or 3D TV before they did but I was afraid to make a go of it".

Protection

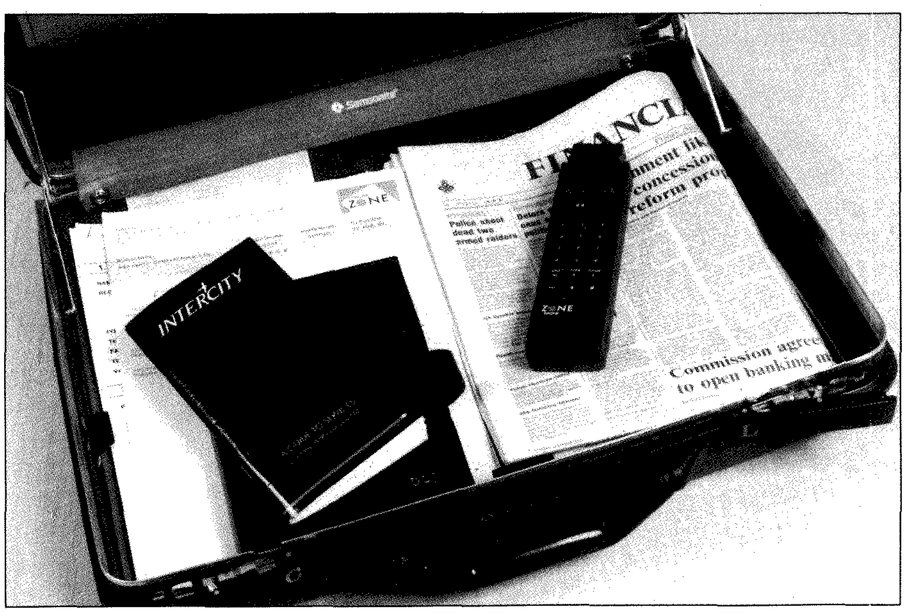
The solution, of course, is to have to foresight to obtain a patent at an early stage before anyone else thinks of the idea. An example is Mr. Hyatt who has, after many years, convinced the US Patent Office to issue him a patent for a microprocessor chip and is now hoping to collect from the US manufacturers. Although he may not have contributed one jot to the development of the PC, he is still entitled under US law to royalty on all US sales. Most inventors who fail to exploit an idea themselves are not so fortunate in finding that an independent third party does so within the life of their patent. Of course to operate in this way in the UK would probably require a prohibitive outlay in legal fees on the part of the person applying for the patent. In the US it is lawful for such cases to be taken on by a law firm on the basis that they share in any money recovered.

The patent is the key to protecting an idea while an attempt is being made to convert it into cash. The idea of the patent system is that in exchange for a description of the new idea and how it may be put to work in an industrial setting, you are given the right to prevent any other person using it as specified in the country where the patent has been granted. Getting a patent will not of itself make any money. It will, however, give a new business venture using the idea some shelter from competition as it grows.

Secrecy

The golden rule, if you are going to profit from an idea, is to keep quiet about it until you are ready to go public. On the other hand, you are going to have to talk to someone; you may need advice on components, help from the company that makes the prototype for you, testing by an independent organisation. You will certainly want to try out your idea on a friend or colleague in case there is some fatal flaw you have missed. All of these disclosures can be made in confidence. It is not strictly necessary for a confidentiality agreement to be signed. What is important is that the person you are talking to should realise they are not meant to go tell the whole world. If you are talking to a lawyer, patent agent or accountant, all of this probably goes without saying. For anybody in the commercial world, it is better to have something in writing. It doesn't have to be anything complicated, a simple letter will do. All it needs to say is that the information being discussed is to be kept confidential and not to be used for any purpose other than negotiations with you. Some companies will send a standard letter saying they don't receive

Spot the number of trademarks and patents in the case.



disclosures in confidence. The best course of action in this case is to say sorry and goodbye. There is a good chance they will call you back and agree to confidentiality anyway.

Start the clock

Once the patent application has been filed at the UK Patent Office you have established your priority date and in theory can talk freely about the invention without risking your right to patent it in almost every country of the world. Unfortunately, there are two problems.

First, inventions have a habit of developing – the process of discussion, testing and prototyping means that the final version may bear scarcely any relation to the original paper proposal.

Second, once you have established your priority date the clock starts to run – and it runs alarmingly fast. Within twelve months you have to decide on a definition of your invention for the 'claim' and, what is worse, decide whether to protect it in the UK only, or fork out for protection on a grander scale – which means big money. So, by the first anniversary of the priority date you need to be in a position to know whether your idea is a commercial starter or not. You will also need some financial support at this stage as well.

All this leads to the necessity for a plan. This should be done at an early stage and frequently reviewed and revised. Some ideas flounder at a pretty early stage for example, the realisation that only gold has the right properties for the critical component of the invention, it becomes clear that is can never be made at an economic price.

Presentation

Even a company which claims to be receptive to outside ideas is inundated by what it believes to be unworkable ideas from cranks. The best thing to do is to distinguish yourself right from the start with an impressive presentation. You may still find yourself being shown the door but do not lose heart. There are many successful ideas that have had the same thing happen. Ron Hickman, inventor of the highly successful Workmate, had to get his workbench manufactured and start selling it before Black & Decker realised it had turned away a winner and had the good sense to change its mind.

Since so much depends on your ability to present your idea that it is worth considering the best way to go about it. You will be talking to people who may wish to take a licence, put capital into the business or just lend you money. You will need to be armed with well developed ideas and some sort of working model or prototype. It is all too easy for someone listening for the first time to say that the idea simply can't work.

Ideally you should also have done at the very least some serious thinking about the uses and market for the resulting product. This is important in deciding which companies to approach and whether your idea fits into their product range.

It is also worth giving some thought to the technical problems your invention solves. It helps your patent agent sell the invention to the Patent Office and get grant of a patent, and it helps you sell the idea to the world. If there is nothing wrong with what is already on offer, why should anybody part with more money for something new?

On your own

If you are going to start your own business, the big question is: are you enthusiastic enough about the idea to get someone to provide the starting capital? One place to start is with your bank manager (start here for practice but don't expect to succeed) or a provider to seedcorn or venture capital. Obviously you will be using some of your own money, but beware of using all all of it and certainly don't start by mortgaging your home, especially if you haven't asked your wife or husband first.

A better place to start is with a company you already run since it provides a vehicle which can be used to develop and promote the new idea. The Japanese company Sony was started back in 1946 in the most hostile commercial climate imaginable provided by a defeated, war-torn and occupied country – even England in the recession of 1991 cannot be as bad as that.

Sony's first innovative product was a tape recorder. Before that it hand-made and sold low-technology heating pads in order to provide early cash flow.

Finding the right advice

If you have ever watched Tomorrow's World, you will know they sponsor, together with the Engineering Council, an innovation prize for new businesses that are turning ideas into cash – The Prince of Wales Award for Innovation and Production. Fourteen local enterprise agencies have set up a network to give entrants advice and are able to put people into contact with other specialised advisors and investors.

There is also help available from a local enterprise agency, small firms centre or business centre. Get in touch with the regional offices of the DTI and the Department of Employment. The largest local library is probably an excellent starting point.

There is also help available from various types from a solicitor, accountant or patent agent – at a price. Ask the Chartered Institute of Patent Agents (071-405 9450) for their regional list of patent agents When you are paying for advice, look for someone who knows their stuff and is enthusiastic about your business idea.

You gotta have faith

Remember that you need masses of enthusiasm. If you lack faith in your own invention then you can hardly expect anyone else to believe in it either. All businesses started at some time with some first business project. No business can be started without some initial birth pangs. Was it easy for any high tech business or indeed any business to start up? Usually any business that is successful will have started a few years ago but it takes a few years to become a big name in British business. ■

Barbara Cookson has extensive experience in patents having spent 10 years in private law practice in the UK. She currently works with the law firm Titmuss Sainer & Webb in the City of London. She is a chartered patent agent, a European Patent Attorney and a member of the Institute of Electrical Engineers.

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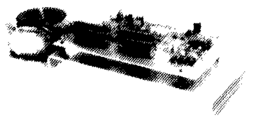

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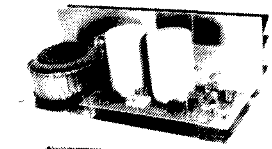

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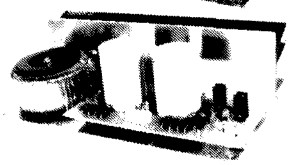

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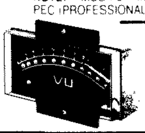

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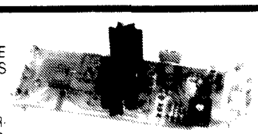

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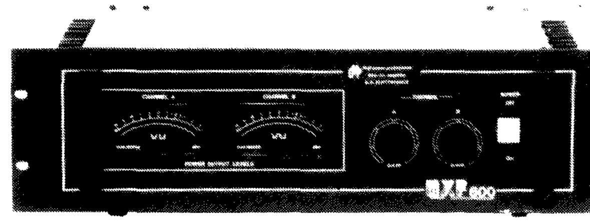

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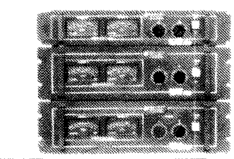

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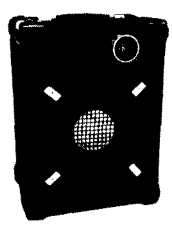

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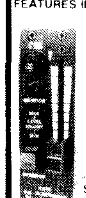

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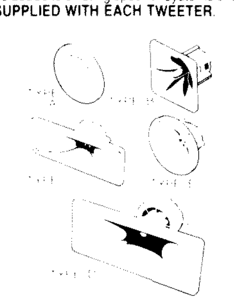

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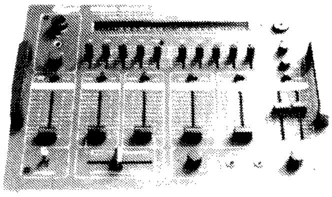

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Frequency Master

How can you construct a digitally controlled signal generator? John Becker examines some of the options and presents a solution that includes a dual frequency counter.

This project uses the VCO section of a 4046 phase locked loop (PLL) whose output frequency is monitored by computer. Using simple feedback techniques, the accuracy of the signal can be improved tremendously. All that's needed is to calculate the voltage required by the VCO to achieve a particular frequency, then to set that voltage via a DAC. This allows precise selection of any frequency between 1Hz and 1MHz. In addition, the design can be used as a dual frequency counter, simultaneously monitoring the internal signal and an external source.

Any computer with an eight bit parallel independent input/output port can be used to control the system. The desired frequency is entered on the keyboard and the monitored results displayed on the computer's screen. The unit is controlled by a Basic program but greater speed could be achieved by writing the program in machine code.

Block Diagram

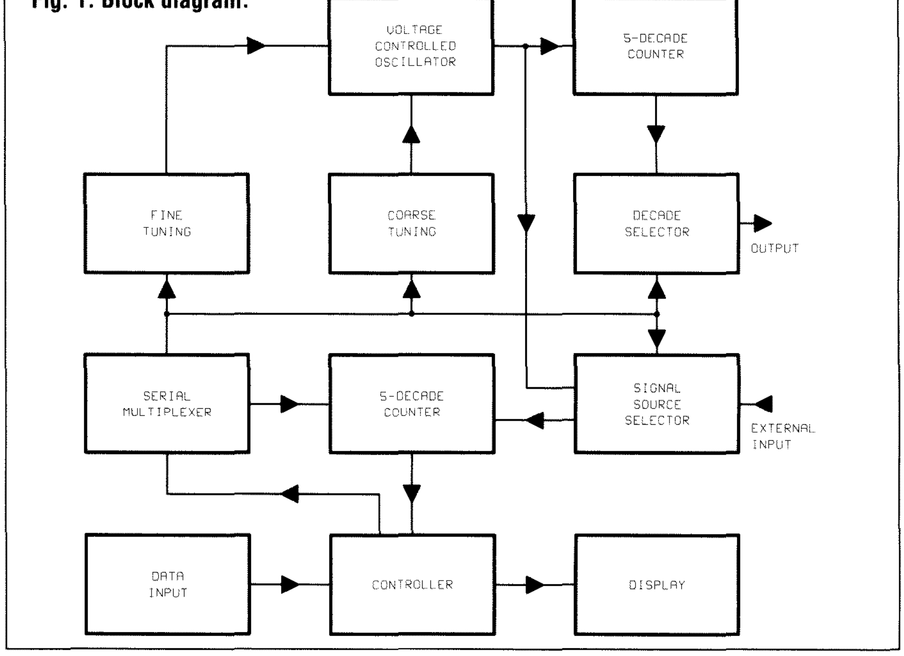
The block diagram in Fig. 1 shows the main sections of the design. A mixture of parallel and serial data is used to control the various parameters. The VCO receives tuning data from two DAC chips each of which is controlled by serial-to-parallel data latches. A multiplexed 5-decade BCD (binary coded decimal) counter counts the VCO output frequency. The duration for this is set by the controller to 0.1 seconds. At the end of this period the controller steps the counter through its multiplexed stages, reading the final total. If the correct frequency has not been set, fresh data is sent to the VCO tuners and the process repeated up to a maximum of 16 times.

The VCO has a frequency range of slightly more than one decade, from a little below 100kHz to a bit above 1MHz. A second multiplexed 5-decade counter is clocked by the VCO. Any of the counter's internal decade ranges can be selected as the output by suitable triggering from the controller giving the range of 1Hz to 99.999kHz. An additional multiplexer can switch between the counter output and that coming directly from the VCO. In the latter mode, frequencies from 100kHz to 999.999kHz are available.

Obviously, to achieve a range of 1Hz to 1MHz in 1Hz steps, one million separate control codes need to be generated, requiring a binary data length of 20 bits (220 = 1048576). Running variations on the formula it turned out that 16 bits could control the VCO with a very acceptable of level of accuracy (typically to within about 0.001% of the aimed-for frequency). By using two 8-bit DACs this degree of control was easier and cheaper to achieve than using two 10-bit devices. However, simulating temperature change effects on frequency, it became obvious that the VCO output could not be guaranteed simply by calculated control codes. It would be better if the frequency were set by a sample-and-correct technique. This approach is used in the controlling software.

A signal source selector allows for monitoring an external frequency as well as the internal VCO. Once the VCO has been set, the controlling program repeatedly switches the frequency counter between internal and external

Fig. 1. Block diagram.



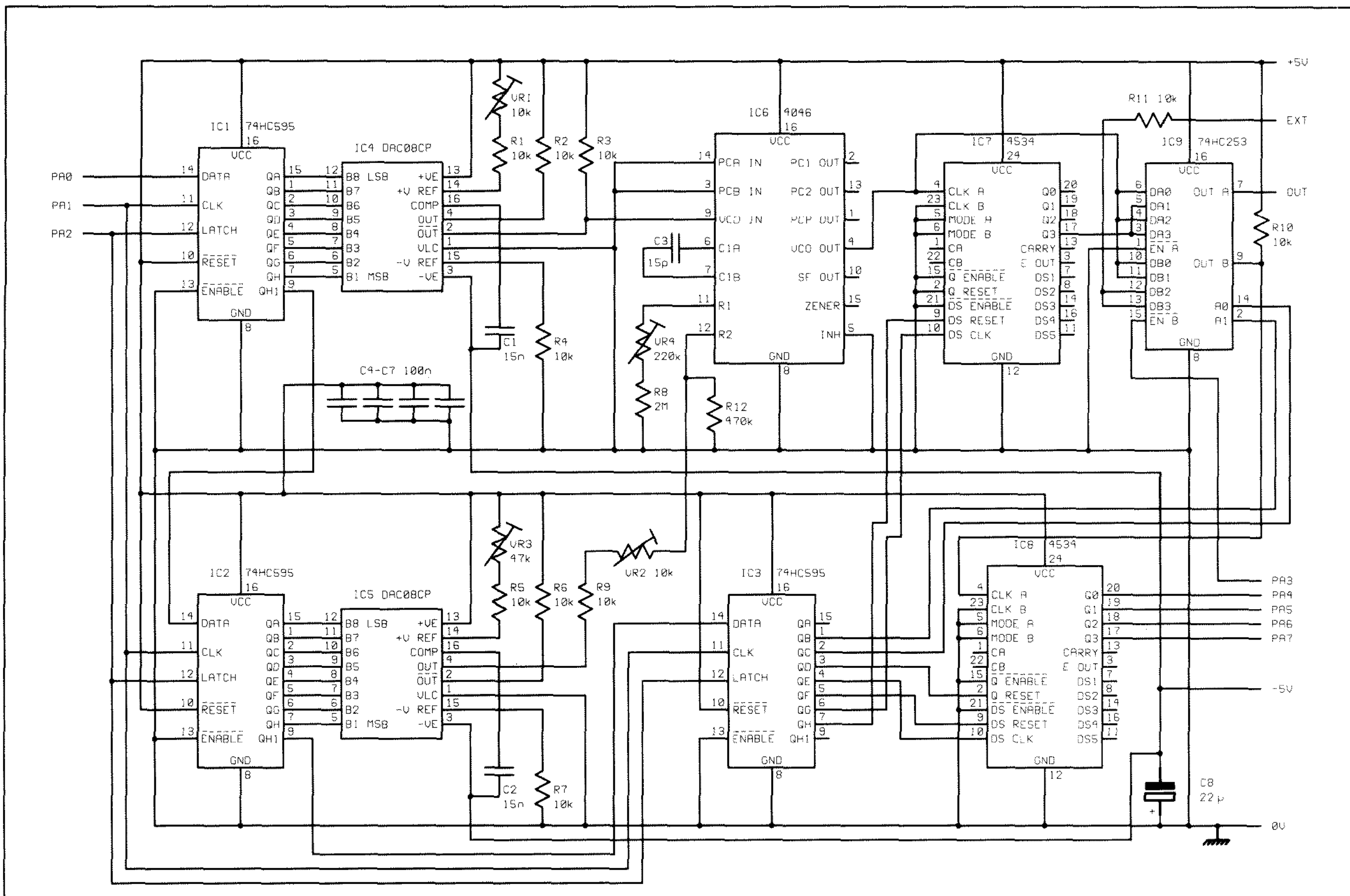


Fig. 2. Circuit diagram.

sources, displaying both results on the monitor. The VCO and its output multiplexer remain unaffected by the routing of the frequency counter.

VCO Control

Fig. 2 shows the circuit diagram for the VCO, decade counters and control devices. IC6 is the 4046 phase locked loop (PLL) chip containing the VCO. Its phase locking functions are not used. The basic frequency range is preset by C3 together with the effective currents seen by pins 11 and 12. Coarse frequency tuning is carried out by changing the current from pin 12. Fine tuning is achieved by varying the voltage on pin 9.

Both controls are derived from the DAC chips IC4 and IC5, which are controlled by the serial to parallel latching shift registers IC1 and IC2.

Only three computer output lines are needed for this part of the circuit. Each DAC produces an output voltage/current in response to an 8-bit data code presented on its inputs. The codes are sent as two consecutive blocks of 8-bit serial data clocked into IC1 and then IC2. Each of the 16 bits is separately presented to the data input pin 14 of IC1 via line PA0. Line PA1 is then clocked up and down, shifting the PA0 data into IC1. Simultaneously, the data on each internal stage of IC1 is shifted on by one place, the final bit appearing at its QH1 output. Data on this pin is presented to the data input of IC2. Since PA1 synchronously clocks both IC1 and IC2, data flows through IC1 into IC2. When all bits have been clocked in, the data is latched into the shift register outputs by a single pulse on line PA2. The outputs now retain their data until the latch is again clocked following receipt of the next serial data block.

Digital to Analogue

Fig. 3 shows the block diagram for the DAC0800. Note that +V REF and -V REF do not require voltages. It is the current flowing at these reference points that is important. Usually it is necessary to have a resistor in series with the reference inputs to control the current (there are instances, though, when the -V REF input may be tied to ground). The reference current may then be varied by changing the voltage, or by varying the resistance.

Although some DACs produce a voltage directly at their outputs, the DAC0800 produces an output current which is converted into an equivalent voltage by tying the outputs to the power line via resistors. By varying the output resistance value the overall output voltage swing range can be changed.

In this circuit the DAC outputs have been tied to the +5V line via fixed resistors. Range control is carried out by changing the current flowing into the +V REF inputs, as set by VR1 and VR3 respectively.

The twin outputs of each DAC are complimentary; when the current on one rises, the current on the other falls. The VCO produces an increase in frequency when the voltage on its pin 9 rises. Conversely, its pin 12 input requires a voltage decrease to produce a rise in frequency. For programming convenience, the inverting output (pin 2) of IC4 controls VCO pin 9, whereas the non-inverting output (pin 4) of IC5

Computer simulation.

Before building a project it can be a good idea to test the concept to prove that it works. Since data sheets for integrated circuits give all of operational details including formulae, one way of simulating the circuitry is to use a computer program. This allows various parameters to be tested and changed before any hardware is put together,

In the case of the Frequency Master, a simple program was written in Basic using the 4046 VCO frequency control formula. This was used to give a plot of frequency against various different voltages using pre-defined resistance and capacitance inputs.

The 4046 VCO has a linear voltage controlled input, two inter-related resistor inputs and a capacitor input. The output frequency is also related to the power-line voltage. Referring to Fig. 3, the frequency calculation formula is:

$$f = \frac{K\left\{\frac{VCO_{in}-1.65}{R1} + \frac{VDD-1.65}{R2}\right\}}{(C1+32)(VDD+1.6)} \text{ MHz at } 21^{\circ}C$$

where:
VDD in VDC; 5.0VDC =< VDD =< 15Vdc
VCOin in VDC; 1.65VDC =< VCOin =< (VDD - 1.35VDC)
R1 and R2 in MegΩ; R1 >= 0.005M, R2 =< 10M
C1 in pF; C1 >= 50pF
K = 0.95 @ VDD = 5VDC; 0.95 @ VDD = 10VDC; 1.08 @ VDD = 15VDC

The following Basic program illustrates the formula re-interpreted to suit a computer. The values of R1, R2 and C1 are fixed while the VCO control voltage is incremented in steps of 0.1V across the range 1.7V to 5V. Other values may be substituted. The readout displays the voltage, frequency in Hz, and the difference between the current and previous frequency calculations.

```
100 VDD=5:R1=0.01:R2=2:C1=100
110 FOR VCO=1.7 TO 5 STEP 0.1
120 X=((VCO-1.65)/R1)+((VDD-1.35)/R2):X=X*0.95
130 Y=(C1+32)*(VDD+1.6)
140 F=X/Y:F=F*1000000:PRINT VCO;F;F-Z:Z=F:NEXT
```

controls VCO pin 12.

These DACs require a ±VE power supply and there is not a pin specifically allocated for ground. In most instances, the VLC pin is tied to ground.

VCO Control

One way of changing the frequency of the VCO is to alter the resistance value between pin 12 and ground – this changes the current flowing from pin 12. A similar result occurs when changing the voltage to which a fixed resistor is connected, the current flow decreasing with an increase in tail voltage. Hence a higher voltage will result in a lower frequency. VR2 was included to provide for an initial presetting of the resistance value. In practice changing VR3 provides sufficient control. R12 limits the maximum effective resistance at pin 12.

The current flowing from VCO pin 11 also determines the output frequency and affects the frequency range controlled by the voltage on pin 9. Although the formula is complex, as a rule of thumb the higher the resistance the smaller the range. Correction of the range was allowed for by inclusion of VR4, but it was found to be only marginally beneficial in view of the control offered by VR1.

The VCO feeds its output to IC7, which acts as a frequency divider, and to the dual stage 4-way multiplexing chip IC9.

Output Divider

IC7 is a multiplexed 5-stage decade counter with BCD outputs and three clock inputs. The signal to be counted is taken to input CLK A and divided internally by a series of five decade counters, any of whose contents may be routed to the BCD outputs. Routing is determined by a second internal counter triggered via the DS CLK input. The signal and DS (digit select) counters may be reset and their outputs enabled/disabled via the control inputs shown in the circuit diagram.

The third clock input, CLK B, is not used.

IC7 is used to divide the VCO frequency by one of five factors of ten, taking the output from Q3. With the DS counter clocked to DS1, the Q3 output frequency is the input frequency divided by ten. Clocking to DS5 divides the frequency by 10000. The output is a pulsed waveform in which the pulse is high for one tenth of the count (up for the duration of one input pulse to the stage selected, down for the next nine).

The output may be taken from any of the other Q0-Q2 outputs, wiring additional leads to the relevant pins. With DS1 active, Q0 divides by two and Q1 divides by four, in both instances producing a square wave output. Q2 divides by five, but with an uneven pulse spacing. Similar ratios occur for other DS settings.

Although the unit cannot directly monitor the Q0-Q2 outputs, they can be fed to the external signal input of the frequency counter via an appropriate switch.

Multiplexer

Either the Q3 or the original VCO output may be switched through the multiplexer IC9 (Fig. 7 clarifies the chip's function). Either the VCO signal or an external signal can be routed to the frequency counter. This consists of another 5-decade counter, IC8, which is reset and enabled under computer control. First the counter is reset, then the frequency to be counted is gated through IC9 for precisely one tenth of a second under control of the PA3 line. At the end of the period, the gate is closed and a control pulse resets the DS counter. The DS clock is then triggered five times, presenting in turn each of the internal decade counters to the outputs. They are read by the computer on lines PA4-PA7. The computer then performs its calculations, repeating the VCO resetting if necessary. Once the VCO has been satisfactorily set the computer goes into monitor mode, repeatedly reading the frequency counter and displaying the results on screen.

Counter resetting, DS clocking and signal sourcing via IC9 is controlled by serial data codes clocked into IC3. This has its data input in series with the IC1/IC2 chain and is clocked and latched synchronously with them. Each fresh data code is thus sent as part of a 24-bit serial block, with latching occurring after the 24th bit. This makes the Basic program a little slow but can be improved by using machine code.

Basic Software

The Basic program in Fig. 5 was written in a version of Microsoft Basic and variations of it can be used with any computer which understands Basic and has an 8-bit parallel input/output port.

Apart from a few minor dialect changes in the code, the principal changes that may have to be made are to the three port register addresses and the frequency counter pulse duration control factor. In line 110, DRT holds the Data Direction Register address, IN holds the input register address, and OUT holds the output register address – note that other dialects of Basic use these names as commands so changes may be necessary. Check your manual for the addresses of the ports and substitute them, in decimal, for the numbers in the program.

Also in line 110 is variable Y which is set to 36. This is used to set the timing loop duration in line 360. The value should be adjusted so that the loop duration allows a positive pulse of 0.1 secs (or as near as possible) to be generated on output line PA3. (Some computers may designate their i/o port lines differently - PA3 here indicates the line which controls Bit 3. Similarly, PA0 is Bit 0 and PA7 is Bit 7.)

Depending on the the computer in use, lines 350 and 370 may not be applicable. They are used to control a system interrupt routine which takes care of internal housekeeping. Since these interruptions can affect the predictable timing of the pulse control loop, it is disabled. Some computers have a specific Basic command which will perform this action. With the 6502, four machine code commands are used: SEI, RTS and CLI, RTS, meaning turn maskable interrupts off, Return and turn them on again, Return. The respective codes are 120, 96, 88 and 96. The first two are used immediately prior to the loop, the second two immediately after it. The codes are poked into two memory locations known to be unused on the machine and then called at the appropriate time.

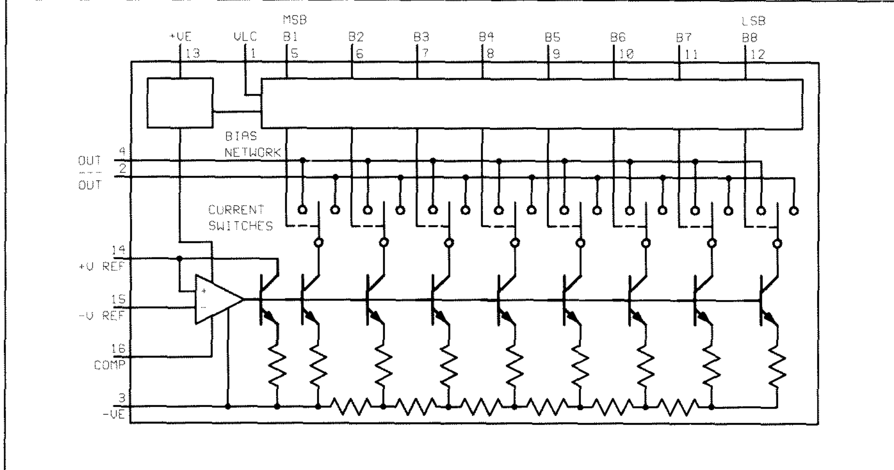


Fig. 3. The operation of the DAC0800

If interrupts cannot be disabled then lines 350 and 370 should be omitted. Frequency monitoring precision will be lost, but otherwise the program will run as intended.

Binary Chop

The program first of all requests the frequency number to be set. The program sets IC7 and IC9 to the correct decade output, then goes into its search and set routine.

Using the binary chop search algorithm an item in an ordered list can be found in a binary-related number of steps. With a sorted list of 256 items, this technique takes only eight steps to find the desired item. With a million items in the list it takes only 20 steps. This technique is used to set the VCO to the closest frequency required within 16 steps, monitoring the output frequency at each step and correcting accordingly.

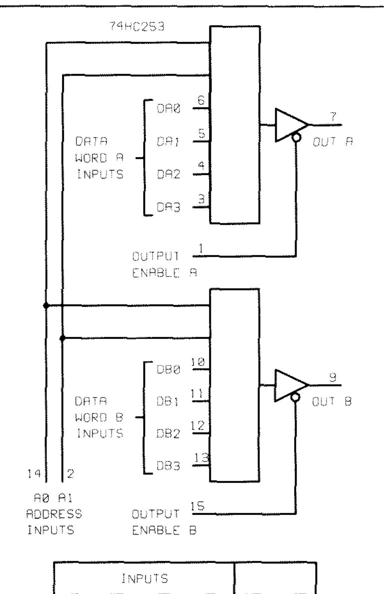
When setting the VCO, the value in S(X) is sent to the DAC controllers. The resulting output frequency,V, is monitored and compared against the desired frequency, N. If there are not the same, S(X) is increased or decreased to as necessary and the VCO is set with the new value. If, within the maximum eight steps, V doesn't equal N, the VCO is set as near as possible. For convenience, the routine is run twice, first for the coarse control DAC, then for fine control.

Decimal To Binary

In the search routine S(X) is a decimal number. It has to be sent to the shift registers as binary bits. The routine in lines 510 and 520 performs the conversion.

The important routine that sends data to the shift registers is in lines 300-320. The two-dimensional variables R(1,D), R(2,D) and R(3,D) hold the individual binary bits in order of registers 1 to 3 (variable D indicates the bit location between 0 and 7). Lines 530-600 are for information only.

The speed at which the Basic



INPUTS			
A1	A0	OUTPUT ENABLE	OUTPUT
X	X	H	Z
L	L	L	D0
L	H	L	D1
H	L	L	D2
H	H	L	D3

Z = HIGH IMPEDANCE
X = DON T CARE

Fig. 4. The multiplexer.

program sets the VCO may be increased by reducing the search routine to eight steps instead of 16. The search will be less precise, but in many instances the frequency established during the coarse setting may well be satisfactory. To shorten the search replace the statement FOR X = 2 TO 1 STEP-1 with X = 2 in line 170, then delete the NEXT statement in line 180.

Once the search and set has been completed the program goes into frequency monitor mode in the perpetual loop of line 200. To enter another frequency number, stop the program and re-run it.

Assembly and checking

If the unit is to be used with a computer that provides a ±5V power supply, the PCB in Fig. 9 is the only one needed. Sockets should be used for all ICs. Note that two of the wire links go under IC7.

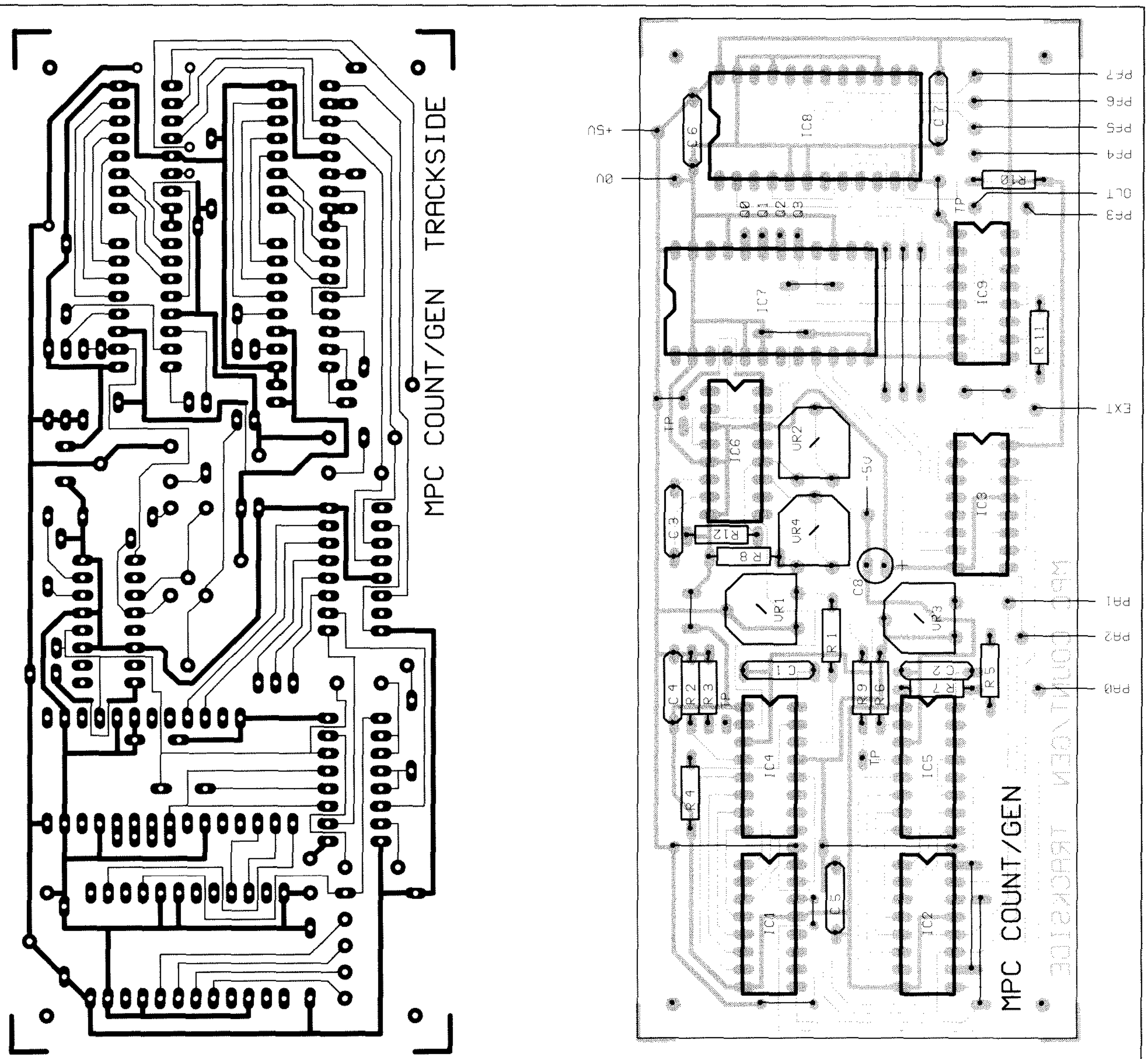
Check the soldered joints with a magnifying glass and connect up to the computer, referring to the manual for the port connection details and a suitable socket.

Set all four presets to minimum resistance and run the program to check its effective control of the circuit. An oscilloscope can be used to monitor the VCO output at pin 4 and IC9 at pin 7 (test points are included on the PCB).

VR1 and VR3 are the only presets that may need to be adjusted. To do this the DAC chips IC4 and IC5 must be set to their

```
100 REM BASIC PROGRAM FOR FREQ GEN.COUNT (FB34)
110 DRT=59459:IN=59457:OUT=59471:GATE=8:POKE DRT,15:Y=36:REM SEE TEXT
120 DIM R(3,8),S(2),F(20)
130 INPUT"NUMBER";J:R(1,7)=1:R(2,7)=1:G=0:N=INT(N):N=J
140 IF N<10 OR N>999999 THEN PRINT:GOTO130
150 DP=1:U=5:R(3,2)=1:IF N>99999 THEN N=INT(N/10):U=0:R(3,2)=0:DP=10:GOTO170
160 IF N<10000 THEN N=N*10:U=U-1:DP=DP/10:GOTO160
170 GOSUB 460:X=1:GOSUB 510:FOR X=2 TO 1 STEP -1:K=999999:GOSUB 210:S(X)=M
180 PRINT "REGISTER";X;"SET AT";M:GOSUB 510:NEXT X:GOSUB 460
190 REM CONTINUE MONITORING
200 X=2:GOSUB 290:GOSUB 340:GOSUB 390:GOTO 200
205 REM BINARY CHOP SEARCH
210 L=1:H=255
220 S(X)=INT((H+L)/2):GOSUB 510:GOSUB 290:GOSUB 340:GOSUB 390
230 IF V<9000 THEN 220
240 IF V=N THEN 280
250 IF N<V THEN H=S(X)-1:GOTO 270
260 L=S(X)+1
270 IF L=<H THEN 220
280 RETURN
290 REM SEND
300 FOR C=3 TO 1 STEP -1:FOR D=7 TO 0 STEP -1
310 A=R(C,D)+2+GATE:POKE OUT,A:POKE OUT, A AND 9:NEXT D:NEXT C
320 POKE OUT,4+GATE:POKE OUT,GATE:RETURN
330 REM TIMING
340 PRINT "REG"X;S(X),:R(3,3)=1:GOSUB 290:R(3,3)=0:GOSUB 290:REM RESET COUNTER
350 POKE 0,120:POKE 1,96:SYS 0:REM INTS OFF - SEE TEXT ABOUT THIS LINE
360 POKE OUT,GATE:POKE OUT,0:FOR A=1 TO Y:NEXT A:POKE OUT,GATE:REM 82
370 POKE 0,88:POKE 1,96:SYS 0:REM INTS ON - SEE TEXT ABOUT THIS LINE
380 RETURN
390 REM INPUT
400 R(3,5)=1:GOSUB 290:R(3,5)=0:GOSUB 290:REM RESET COUNT STAGES
410 V=0:FOR CLK=4 TO 0 STEP -1
420 R(3,4)=1:GOSUB 290:R(3,4)=0:GOSUB 290:REM CLOCK COUNTER OUTPUT
430 F=PEEK(IN) AND 240:F=(F/16)*(10^CLK):V=V+F:NEXT V:PRINT "FREQ";V*DP
440 G=G+1:F(G)=V:P=ABS(N-V):IF P<K THEN K=P:M=S(X)
450 RETURN
460 REM RESET AND CLOCK SIGNAL COUNTER
470 PRINT "SET OUTPUT"
480 R(3,6)=0:R(3,7)=1:GOSUB 290:R(3,7)=0:IF U=0 THEN RETURN
490 FOR CLK=1 TO U:R(3,6)=1:GOSUB 290:R(3,6)=0:GOSUB 290:NEXT CLK:RETURN
500 REM DECIMAL TO BONARY CONVERT
510 D=S(X):FOR T=7 TO 0 STEP -1:A=2^T:B=0:IF (D/A)>=1 THEN D=D-A:B=1
520 R(X,T)=B:NEXT T:RETURN
530 REM REG 3 ALLOCATIONS
540 REM 0     NIL    QA
550 REM 1-2     IC9 A0/1          QB/QC
560 REM 3       RESET COUNTER     QD
570 REM 4       CLOCK COUNT DS    QE
580 REM 5       RESET COUNT DS    QF
590 REM 6       CLOCK SIG DS      QG
600 REM 7       RESET SIG DS      QH
```

Fig. 4. Basic program to run the frequency master.



PCB Designs and layouts.

extreme limits, via IC1 and IC2, with codes 0 and 255. Insert the following line into the program:

```
125 S(1)=0:S(2)=255:FOR
X=1 TO 2:GOSUB510:NEXT:
GOTO 200
```

Run the program, then monitor the voltage on IC4 pin 2. Adjust VR1 until a voltage of about 1.7V is obtained. Now monitor IC5 pin 4 and adjust VR3 until the voltage reads roughly 0V. No further adjustment is necessary when running from Basic. Now delete line 125.

The setting of timing factor Y in the program may be adjusted by trial and error, or in conjunction with an oscilloscope or another frequency counter.

In the Basic program as listed, no provision has been made for monitoring an external frequency. However, this can be done by setting IC9 to gate an external signal into IC8 by setting register 3 bit 1 high, so setting IC9 pin 2 (address A1) high. If only external monitoring is needed put back line 125 and amend its end to read:

```
R(3,1)=1:GOTO 200
```

Alternatively, a toggling between internal and external is a matter of amending the end of line 200 to read:

```
R(3,1)=(R(3,1)+1) AND 1
:GOTO 200
```

This alternately sets R(3,1) high or low each time round the monitor loop while retaining the frequency search and set facility. ■

Components

Resistors	
R1-R7, R9-R11	10k
R8	2M
R1	2470k
all 0.25W 5% carbon or better	
Capacitors	
C1, C2	15n polyester
C3	15p polystyrene
C4-C7	100n polyester
C8	22u 10V electrolytic
Potentiometers	
VR1-VR	210k horiz skel preset
VR3	47k horiz skel preset
VR4	220k horiz skel preset
Semiconductors	
IC1-IC3	74HC595
IC4, IC5	DAC08CP or DAC0800
IC6	4046
IC7, IC8	4534
IC9	74HC253
Miscellaneous	
Printed circuit board, PCB supports, 16-pin DIL IC sockets, 24-pin dil IC sockets.	

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A Car Positioning Aid

Owen Bishop's electronic gadget is intended to help you park your car without the risk of scratching the body-work.

Most private garages and parking areas are cramped and putting the car away can be a nerve-wracking matter Often there is some inconveniently sited low wall or stout branch that is out of sight of anyone sitting in the driving seat. It's much easier if there is a second person to help the driver steer a safe course, but so often the driver is unassisted at such a critical moment.

Ultrasonic Ranging

The device works on the principle of an ultrasonic range-finder. The sensor is located at the rear of the garage and is low down so that its beam strikes the bumper and is reflected. It measures the time taken for a pulse of ultra-sound to travel to the bumper and back again. This gives a measure of the distance d. A display continuously indicates the distance between the bumper and the back wall of the garage. The display is mounted on the side wall of the garage where it may conveniently be viewed by the driver

Obviously this device is not restricted to locating cars; it has many other applications as a proximity meter.

Circuit Design

The main features of the aid are shown in Fig. 1. The clock oscillates at 80kHz, a frequency which is divided by 2 and by 32 to give two frequencies, 40kHz and 2.5kHz. The first signal is fed to a pair of drivers which make the ultrasonic transmitter transducer oscillate strongly at its resonant frequency. The reason for generating 80kHz and then dividing it by 2 is that the original 80kHz waveform is asymmetrical, but the divided waveform is symmetrical – its mark/space ratio is 1 – and thus suited for driving the transducer. The drivers receive an enabling input from a counter so that a tone-burst of ultra-sound lasting 0.4ms is generated every 3.2ms.

The ultra-sound reflected from any object in its path is detected by the receiver transducer. This generates an alternating voltage which is conditioned and amplified by three operational amplifiers. The amplified signal from the final stage is rectified and smoothed. It goes high (as the beginning of the reflected tone-burst arrives) every 3.2mS. Ultra-sound that is being reflected back from the point on the object nearest to the transducers has travelled a distance of 2d.

The remainder of the system consists of the logic needed to register the return of successive tone-bursts. This is controlled by a counter which has eight output terminals, numbered 0 to 7. These outputs are normally at logic low but, as the counter is incremented, they go high one at a time. The counter is driven by the 2.5kHz signal so each output is high for 0.4ms and the complete cycle takes 3.2ms.

The sequence of operation at each stage of counting is:

- 0 clear the shift register
- 1 enable the transmitter
- 2-6 shift the registers as the retiring tone-burst is received
- 7 transfer the data in the registers to the latches

Although the shift register used has six registers, only the first four are used in this circuit. The shifting of the registers allows the output of the rectifier to be sampled at

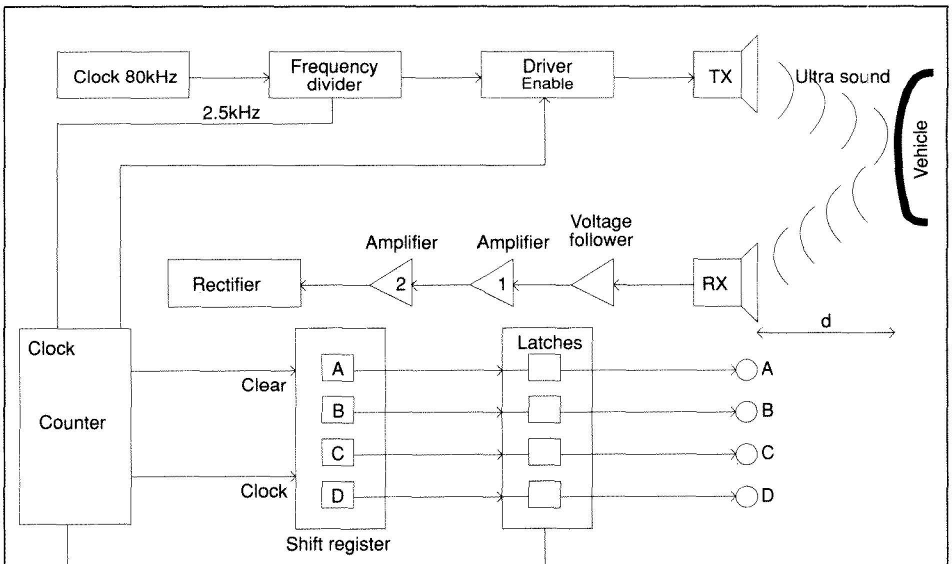

Fig. 1 System diagram.

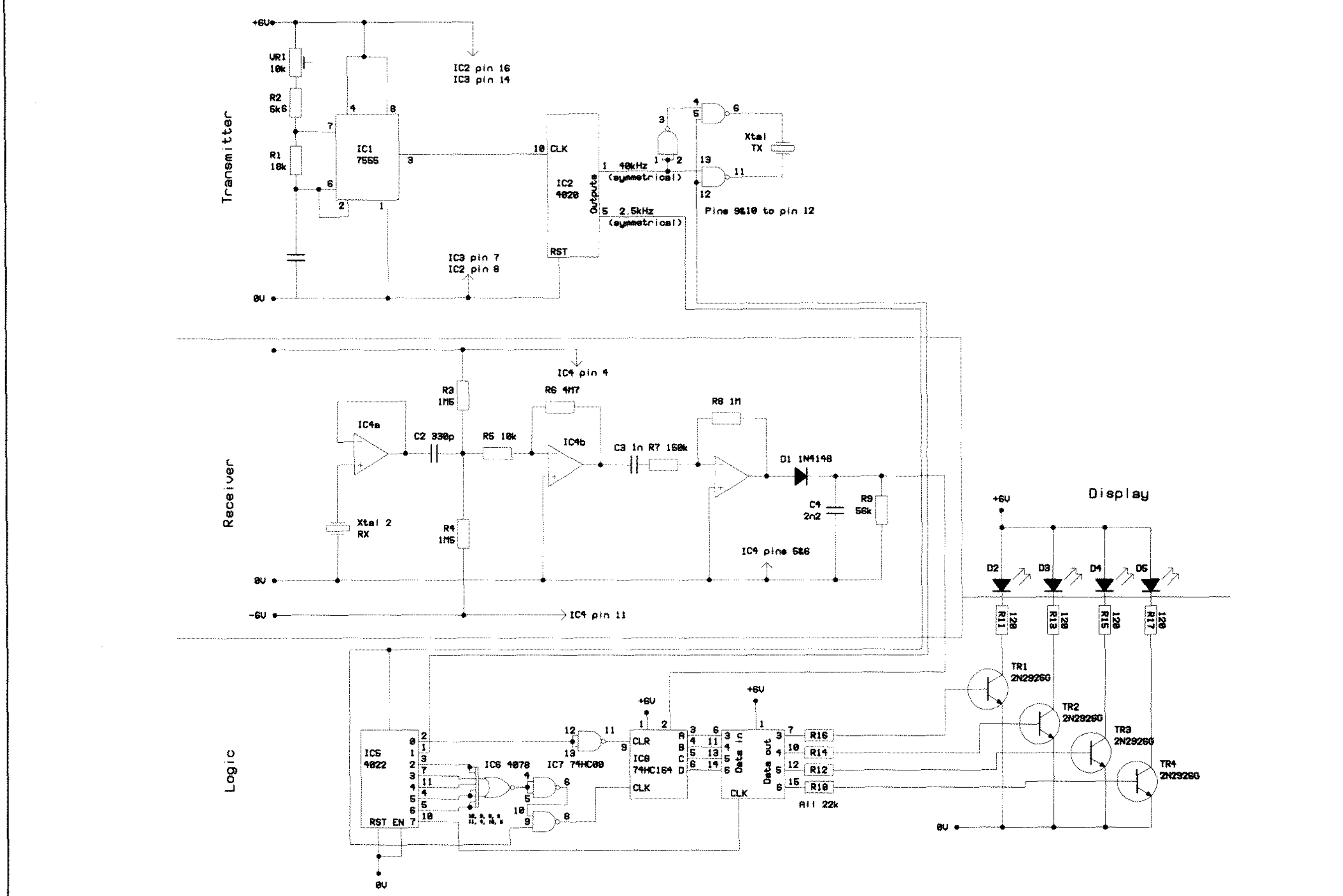

Fig. 2. Circuit diagram.

intervals of 0.4ms and later to store and view the data obtained.

As the car approaches the sensor unit, first lamp A lights up, followed by lamps B, C and finally D. Once a lamp is lit it stays lit. When the car is within 30cm of the sensors the LEDs light in strict sequence without flickering.

Circuit Details

The clock (IC1, Fig. 2) is an astable multivibrator based on the well-known 555 timer IC in its CMOS version, the 7555. The variable resistor VR1 allows the frequency to be set to 80kHz. IC2, a 14-stage ripple counter/divider, divides the frequency by two and by 32. The 40kHz symmetrical waveform from stage 1 of the divider is fed directly to a NAND gate. It is also inverted and fed to a second NAND gate. The other input of these two gates is controlled by the level from the sequential counter (IC5, see later). When this is high the 40kHz signal passes through the gates and their outputs switch rapidly from high/low to low/high, applying an alternating voltage to the transducer crystal XTAL1. This causes it to emit ultra-sound. When the level from IC5 is low, the 40kHz signal does not pass through the gates and no ultra-sound is produced. Thus the level from IC5 is used to produce short tone-bursts of ultra-sound.

The ultra-sound detected by the receiver crystal XTAL2 causes an alternating sine-wave voltage to appear across its terminals. The three amplifiers which follow are all contained in IC4. The first amplifier is used as a voltage follower. Its output goes to C2 which, in conjunction with R3 and R4, acts as a high-pass filter. This removes any low-frequency component of the signal, such as arises from picking up the mains frequency from nearby cables. IC4b is a high-gain inverting amplifier, with gain of 470. Its output swings strongly, almost to the positive and negative supply voltages, when ultra-sound is being received. IC4c gives a further stage of amplification, becoming saturated on each voltage swing, so that its output is virtually a square wave at 40kHz, alternating between +6V and -6V.

The rectifying action of D1, C4 and R9 is as follows. On the positive half of each cycle, current flows through D1 and charges C4. The current leaks away continuously through R9, but the values of C4 and R9 are chosen so that the voltage on C4 is well over +3V whenever a signal is being received. This is equivalent to logical high. When there is no signal the voltage across C4 drops rapidly to zero, giving a logical low output.

The heart of the logic circuit is the counter IC5, driven by the 2.5kHz signal from IC2. The action of this counter has already been explained in outline. Output 0 is inverted by a NAND gate and goes to the CLEAR input of the shift register IC8. As 0 goes high at the beginning of the counter's cycle, the output of the NAND gates goes low resetting the registers. Output 1 then goes high, enabling the two NAND gates that drive XTAL1. This produces the 0.4ms tone-burst.

Outputs 2 to 6 go to a NOR gate, the output of which is low when any one of the outputs 2 to 6 is high. This output is inverted by a NAND gate, so that pin 6 of IC7 is high during the whole of stages 2 to 6 of

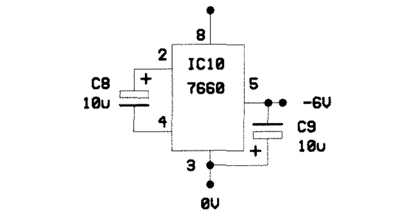

Fig. 3. Negative power supply.

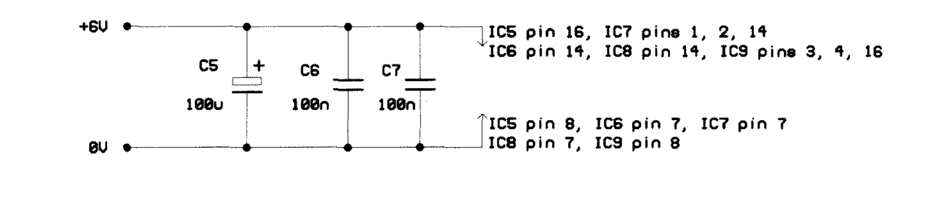

Fig. 4. Power smoothing circuitry.

the counting. This controls the 2kHz signal passing through the third gate of IC7 to the CLOCK input of IC8. The result is that the register is clocked on 5 times at 0.4ms intervals during stages 2 to 6 (figure 3). Output 7 of the counter goes to the clock input of the latches IC9. As this output rises from low to high, data present in the shift registers is transferred into the latches. It is held there until the next time output 7 goes high, when it is replaced by the new data then in the resistors. The outputs of the registers are fed to transistors, which are used to switch LED indicators on or off. A high output from a latch turns on the corresponding transistor and makes the LED light. The LEDs and their series resistors could be replaced by filament lamps of 6V rating and taking up to 100mA, or by miniature relays which could be used to switch mains-voltage lamps.

Fig. 3 also shows the sub-circuit, a 7760 voltage converter, used to obtain the -6V supply for IC4. Note the polarity of C9. So that the ICs can function properly it is important to smooth out surges and voltage spikes on the supply lines caused by switching in other parts of the circuit. The 100µF capacitor across the supply lines where they enter the logic board and the two 100nF capacitors placed on either side of the diode-switching transistors help to achieve this – see Fig. 4.

Construction

The sensor circuits are built on three boards, the transmitter, receiver and logic boards. These may be built and tested one at a time.

The transmitter board is arranged so that the ultra-sound is directed through a hole in the side of the case.

Ultra-sonic transducers are usually sold in pairs and although they may look alike they are electronically different. They can be identified by a serial number, or by a colour code as specified in the manufacturer's or retailer's catalogue.

The transducer is fixed to the board by adhesive or a small lump of Blu Tack. Short wires are wrapped around and soldered to the terminals of the transducer, passed through the holes at F31 and 31 and soldered there.

The transducer on the receiver board is connected to the circuit by a short length of screened cable. Usually one of the terminal pins is directly connected to its metal case . This terminal should be soldered to the screen of the cable, the other end of the screen being twisted and passed through hole K29. The core of the cable connects the other – insulated – terminal pin to G29.

The display normally requires a

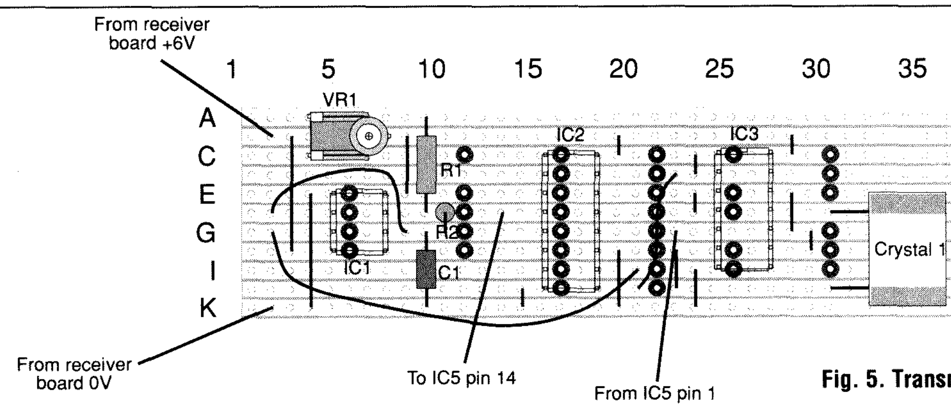

Fig. 5. Transmitter board.

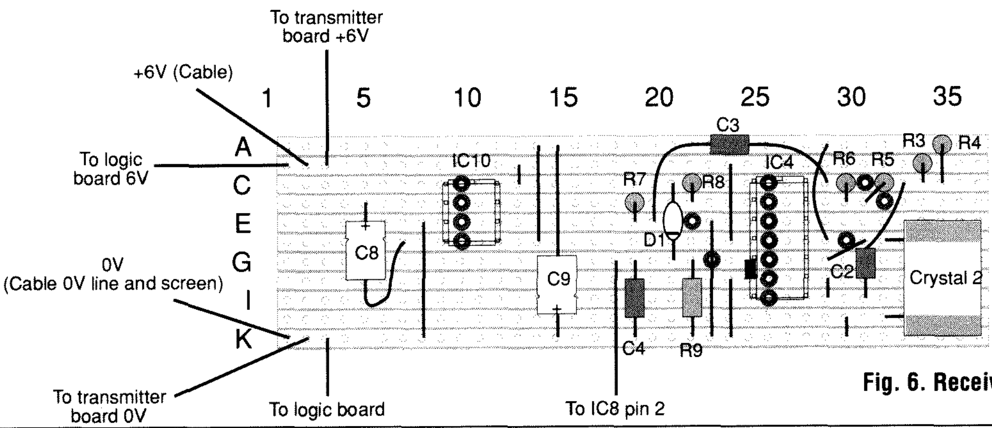

Fig. 6. Receiver board.

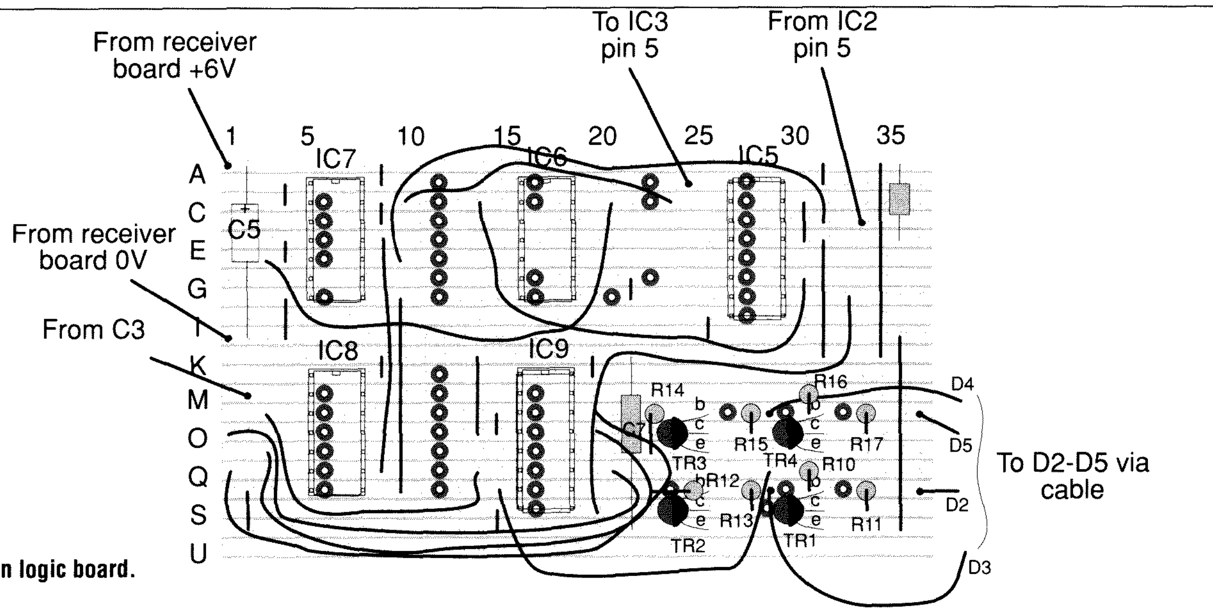

Fig. 7. Main logic board.

separate box, on the lid of which are mounted the 4 display LEDs, a power-switch and an LED (D6) to indicate that the power is on – see figure 9. Suitable colours for the LEDs are yellow for D2-D4, indicating Caution, red for D5, indicating Stop and green for D6. The latter LED needs a resistor – R18 – in series to limit the current. The screening – if any – of the cable is connected to the OV rail of the receiver board.

The circuit requires only 20mA when quiescent (including the power-on LED), and an additional 20mA for each display LED illuminated. A battery holder containing 4 type cells is sufficient to provide the power, and there is plenty of room for such a battery in the display box.

Setting Up

The circuit needs no setting up in the electronic sense, but the positioning of the sensor and display boxes need to be considered carefully. It is best to mount them temporarily until the final positions have been decided. Operating it at a lower level leads to complications as wheels, hub-caps, and wings pass in front of the transducers.

The display is mounted wherever the driver finds it convenient.This could be centrally above the garage door, or on the wall close to the final position of the driver's window. ■

Components

Resistors

(carbon 0.25W, 5% or metal film 0.6W, 1%)

R1	5k6
R10,R12,R14,R16	22k
R2	18k
R11,R13,R15,R17	120
R3,R4	1M5
R18	180
R5	10k
R6	4M7
R7	150k
R8	1M
R9	56k
VR1	10k miniature horizontal preset

Capacitors

C1,C2	330p polystyrene
C3	1n polystyrene
C4	2n2 polystyrene
C5	100μ electrolytic
C6,C7	100n polyester

Semiconductors

D1	1N4148 silicon signal diode
D2-D5	LEDs, high intensity, 5mm diameter (3 off yellow, 1 off red) and plastic mounts (optionally bezel-mounted)
D6	LED, 3mm diameter, green, and plastic mount
TR1-TR4	2N2926G (green spot) NPN transistor

Integrated circuits

IC1	7555 CMOS timer
IC2	4020BE CMOS 14-stage ripple counter/divider
IC3,IC7	74HC00 CMOS quadruple 2-input NAND gate (2 off)
IC4	TL064C quadruple low-power operational amplifier
IC5	4022BE CMOS 8-stage counter with 1-of-8 outputs
IC6	4078BE CMOS 8-input NOR gate
IC8	74HC164 CMOS 8-bit shift reg
IC9	74HC174 CMOS Hex D-type latch
IC10	7660 voltage converter

Miscellaneous

XTAL1,XTAL2 ultrasonic transducers (transmitter and receiver pair, 40kHz)
S1 single-pole single throw-toggle switch
stripboard 11 strips by 37 holes (2 off) and 20 strips by 36 holes, cut from two sheets 95mm x 63mm (Vero 10346);
1mm terminal pins (29 off)
8-pin d.i.l. sockets (2 off)
14-pin d.i.l. sockets (5 off)
16-pin d.i.l. sockets (3 off)

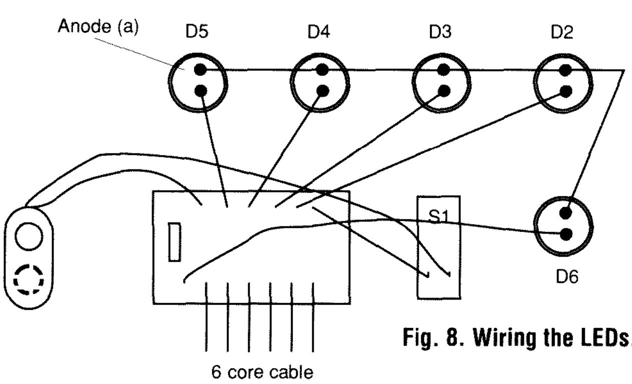

Fig. 8. Wiring the LEDs.

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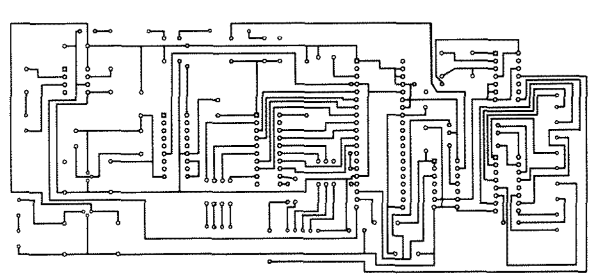
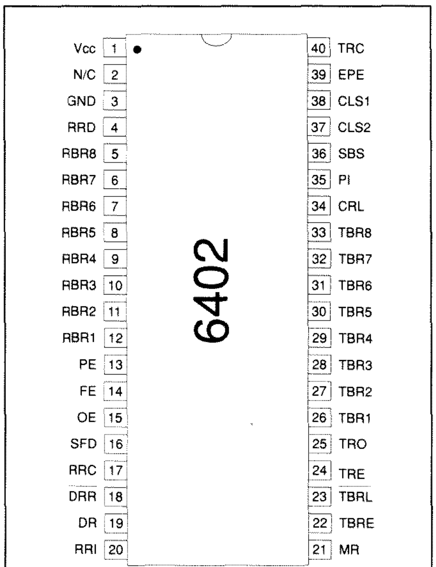


The 6402 UART

The first in the Data Sheet series looks at the industry standard Universal Asynchronous Receiver Transmitter serial communications chip.

Serial communications systems provide a useful way of sending data from one device to another over a single wire. Because most data is held and processed in parallel form there is a need for a standard way to translate the data from parallel to serial and vice versa. The 6402 UART (Universal Asynchronous Transmitter Receiver) does this job very neatly and is flexible enough to allow a number different of parallel and serial formats. The connections for the standard 40 pin package and a functional diagram plus various tables should prove useful to anyone wanting to design a system using this device.



Pin connections for the 6402

Transmitter Operation.

The transmitter section of the 6402 takes parallel data adds start, stop and parity where necessary and sends it in serial form through the TRO pin.

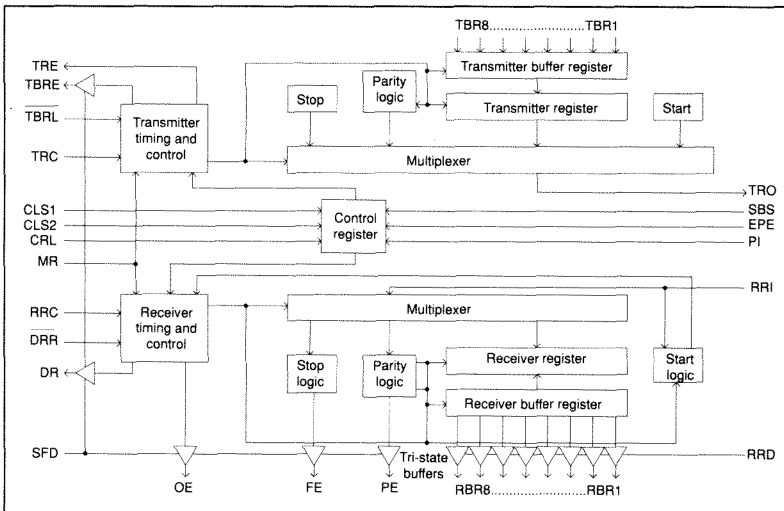
The timing of the transmitter operation is shown in Fig. 1. At point 1, data is loaded from the inputs TBR1-8 into the transmitter buffer register. The $\overline{\text{TBRL}}$ input is set low to accomplish this. If character word lengths less than 8 bits are being used only the least significant are used. For example, a five bit character would used bits TBR1 to TBR5 leaving TBR6 to TBR8 unused.

At point 2 the rising edge of $\overline{\text{TBRL}}$ clears the TBRE output and by 1 clock cycle later, the data to be transmitted is transferred to the transmitter register causing the TRE flag to be cleared and transmission to start. TBRE will then be set high again since the transmitter buffer register is empty and available for new data. The data from the transmitter register is clocked onto TRO at 1/16th of the clock frequency supplied to TRC.

Point 3 sees another load of data latched into the transmitter buffer register. However, the move to the transmitter register is delayed until the previous transmission is complete. At point 4 the data is automatically transferred to the transmitter register since it is now empty – as signified by TRE's brief pulse – and transmission of this character gets underway.

Receiver Operation

Data is received into the chip via the RRI input. When no data is coming in, the RRI should be set high. The data is clocked into the chip at 1/16th of the rate defined by RRC using the timing diagram in Fig. 2.



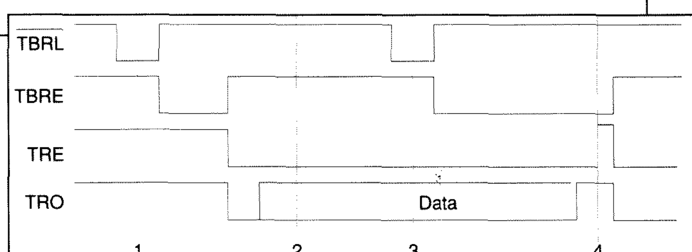
How it works.

Control word					Bits	Parity	Stop
CLS2	CLS1	P1	EPE	SBS			
0	0	0	0	0	5	Odd	1
0	0	0	0	1	5	Odd	1.5
0	0	0	1	0	5	Even	1
0	0	0	1	1	5	Even	1.5
0	0	1	X	0	5	None	1
0	0	1	X	1	5	None	1.5
0	1	0	0	0	6	Odd	1
0	1	0	0	1	6	Odd	2
0	1	0	1	0	6	Even	1
0	1	0	1	1	6	Even	2
0	1	1	X	0	6	None	1
0	1	1	X	1	6	None	2
1	0	0	0	0	7	Odd	1
1	0	0	0	1	7	Odd	2
1	0	0	1	0	7	Even	1
1	0	0	1	1	7	Even	2
1	0	1	X	0	7	None	1
1	0	1	X	1	7	None	2
1	1	0	0	0	8	Odd	1
1	1	0	0	1	8	Odd	2
1	1	0	1	0	8	Even	1
1	1	0	1	1	8	Even	2
1	1	1	X	0	8	None	1
1	1	1	X	1	8	None	2

The control word is clocked in under CRL.

...tion	Symbol	Description
	Vcc	+Ve power supply
	N/C	Not connected
	GND	Ground (0V)
	RRD	Receiver Register disable. A high level forces the receiver holding register outputs RBR1-RBR8 to high impedance .
	RBR8	Receiver Buffer Register bit 8. Holds the received data byte bit 8 – data formats of less than eight bits are justified towards bit 1.
	RBR7	Receiver Buffer Register bit 7.
	RBR6	Receiver Buffer Register bit 6.
	RBR5	Receiver Buffer Register bit 5.
	RBR4	Receiver Buffer Register bit 4.
	RBR3	Receiver Buffer Register bit 3.
	RBR2	Receiver Buffer Register bit 2.
	RBR1	Receiver Buffer Register bit 1.
	PE	Parity Error. Goes high when the received parity doesn't match that set by the control bits. It remains active until parity matches on a succeeding character. When parity is none, it is low.
	FE	Frame Error. Goes high if the first stop bit of the received is wrong. It stays active until the next valid character's stop bit is received.
	OE	Overrun Error. Goes high if the data received flag is not cleared before the last character was transferred to the receiver buffer. It is cleared at the next character's stop bit if Data Received Reset is sent low.
	SFD	Status Flags Disable. Set high forces the outputs PE, FE, OE, DR and TBRE to high impedance.
	RRC	Receiver Register Clock. Timing at 16 times the receiver data rate.
	DDR(*)	Data Received Request. Set low clears the data received output (DR) to low.
	DR	Data Received. Goes high when a character has been received and is available in the RBR.
	RRI	Receiver Register Input. Serial data supplied to here is clocked into the receiver register.
	MR	Master Reset. Set high clears PE, FE, OE, DR, TRE and TBRE and sends TRO high. Less than 18 clocks after MR goes low, TRE goes high. MR doesn't clear the RBR but should be used at power up.
	TBRE	Transmitter Buffer Register Empty. Goes high when data is transferred to the transmitter register for serial transmission. The transmitter buffer is then ready for new data.
23	In(*) TBRL	Transmitter Buffer Register Load. Set low transfers data from the data inputs TBR1-8 to the TBR. Transition from low to high requests data transfer to the transmitter register. If this is busy then transfer is automatically delayed until it is ready.
24	Out TRE	Transmitter Register Empty. Goes high when a character has been transmitted including the stop bits.
25	Out TRO	Transmitter Register Output. Start, character, parity and stop bits emerge here in serial form.
26	In TBR1	Transmitter Buffer Register bit 1. Data is transferred from here to the TBR where it is moved to the TB and shifted out serially via TRO. Character lengths up to eight bits can be input on TBR1-8. If the character length is less than eight bits then bits 8, 7 and 6 may be ignored.
27	In TBR2	Transmitter Buffer Register bit 2.
28	In TBR3	Transmitter Buffer Register bit 3.
29	In TBR4	Transmitter Buffer Register bit 4.
30	In TBR5	Transmitter Buffer Register bit 5.
31	In TBR6	Transmitter Buffer Register bit 6.
32	In TBR7	Transmitter Buffer Register bit 7.
33	In TBR8	Transmitter Buffer Register bit 8.
34	In CRL	Control Register Load. Set high transfers data to the control register from CLS2, CLS1, PI, EPE and SBS.
35	In PI	Parity Inhibit. Set high stops parity checking and generation in conjunction with CRL.
36	In SBS	Stop Bit Select. Set high defines 1.5 stop bits for 5 bit characters and 2 stop bits for other lengths. Used in conjunction with CRL.
37	In CLS2	Character Length Select 2. In conjunction with CLS2, CLS1, both low selects 5-bits. CLS2 low, CLS1 high, 6-bits, CLS2 high, CLS1 low, 7-bits and both high, 8-bits. Used in conjunction with CRL.
38	In CLS1	Character Length Select 1. See CLS2. Used in conjunction with CRL.
39	In EPE	Even parity Enable. With PI low, a high level on EPE selects even parity and low, odd. Used in conjunction with CRL.
40	In TRC	Transmitter Register Clock. Timing at 16 times the transmitter data rate.

point 1 the Data Received Reset) is set low to clear the Data ved output to low. The chip is ble to receive data and when it stop bit it transfers the character the receiver register to the ver buffer register. Character s of less than eight bits will have unused bits set to zero. At this a check is made for an overrun which happens when a character een received e DR is d. The next is made for ty error and output will be asserted if this occurs. At point 3, half a clock cycle later, DR is sent high and the frame error is checked for. If the stop bit was incorrect then the FE pin goes high. Having received the character and signaled its arrival on DR, the chip goes back to monitoring the RRI for the next start bit. ■



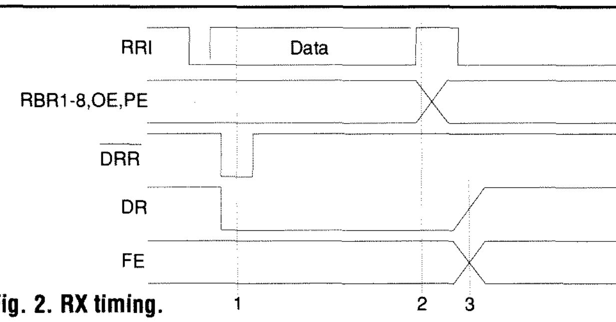


Fig. 2. RX timing.

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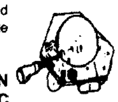

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Basic Electronics

The final part of Owen Bishop's introductory series looks at oscillators and electromagnetic radiation, and describes how to build a simple radio receiver.

To conclude this series we look at one of the earliest and still one of the major applications of electronics – radio communication. Before we do this, we need to pick up one of the topics mentioned last month and consider it in more detail.

LC tuned circuit

Looking at Fig. 1, suppose that it starts off with the capacitor fully charged, as in (1). At this instant no current is flowing in the circuit, so there is no magnetic field in the inductor . This has negligible resistance and the capacitor discharges through it causing a magnetic field to appear in the inductor coil (b). The capacitor eventually becomes fully discharged (c) and at this point the current should cease to flow and the magnetic field collapse. But, an inductor generates a back EMF to maintain any current through it which continues to flow in the same direction as before. This charges the capacitor but in the opposite direction. The capacitor eventually becomes fully charged again as the current dies away (d). This state lasts only an instant since the whole process repeats from (a) but with the current flowing in the opposite direction. The frequency at which this changeover or oscillation takes place is given by:

$$f = 1/(2\pi\sqrt{(LC)})$$

These oscillations can continue for quite a long time since the only loss is due to the resistance of the circuit converting some of the energy to heat. By topping up the capacitor at precisely timed intervals it will oscillate indefinitely. The situation is similar to pushing someone on a swing. If the swing is pushed regularly at the wrong moment, it will slow down. However, if it is pushed at the right time it will keep on swinging and even get higher.

In a Colpitts oscillator, energy is supplied to the LC circuit by using a transistor to produce an alternating voltage across it. This is kept in phase with the oscillations in the circuit by tapping off a signal from the capacitor and feeding it back to the transistor. In another type of oscillator, the Hartley oscillator, the signal is tapped off from the inductor coil and used in a similar way.

EM radiation

Listed in order of increasing wavelength, electromagnetic (EM) radiation starts with gamma rays (10-12pm where the p starts for pico or 10^{-12}), X-rays, ultraviolet , visible light, infra-red , microwaves and radio waves (about 1cm up to 1km or more).

Like all forms of EM radiation, radio waves spread out from their source in all directions and, potentially, can travel indefinitely into space. However, they can be absorbed, reflected or refracted and are affected by EM and gravitational fields.

EM radiation is a combination of two oscillating forces, one electrical and the other magnetic, vibrating at right angles to each other and at right angles to the direction in which the waves are travelling.

Any electrical event that produces rapid changes of electron velocity can be a source of radio waves. A natural example is a lightening strike, and a artificial example is the spark produced when a switch is opened. Either of these events causes a surge of electromagnetic radiation, which spreads out from the source and is detectable by a radio receiving circuit. Some of the earliest radio transmitters relied on the production of sparks to generate the signal.

In the aerial or antenna of a modern radio transmitter, electrons

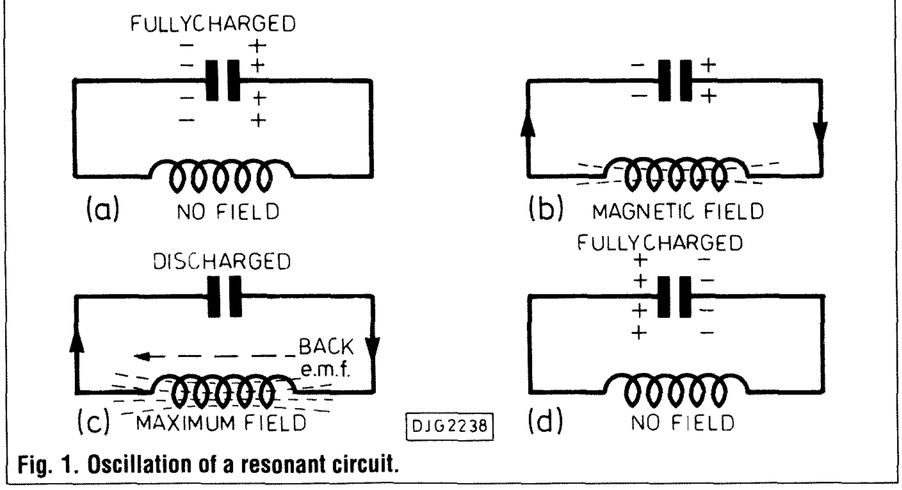

Fig. 1. Oscillation of a resonant circuit.

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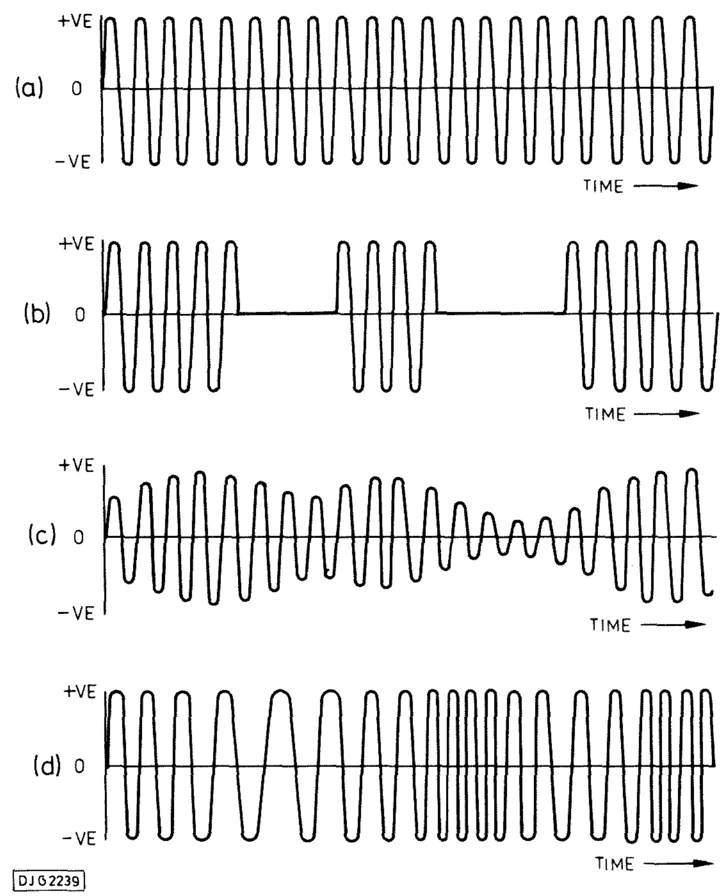

Fig. 2. Ways of modulating a carrier wave:
a) unmodulated carrier b) interrupted carrier
c) amplitude modulation d) frequency modulation

are accelerated to and fro by an alternating electric field. The energy for this field comes from the transmitter circuit. The oscillations of the electrons generate electric and magnetic forces (i.e. radio waves) which spread out from the antenna.

Modulation

The oscillator of a radio transmitter produces a sine wave of constant amplitude and frequency (Fig. 2a) – known as a carrier wave, since it is used to carry information. Putting information onto this carrier is known as modulation and the simplest way of doing this is to turn it on and off repeatedly. This produces an interrupted carrier wave (Fig. 2b) which can be used to transmit a code, such as the Morse.

A more sophisticated method is amplitude modulation (AM), as shown in Fig. 2c. Fig. 3 shows how the information to be transmitted (speech, music) is picked up by a microphone, amplified by an audio frequency (AF) amplifier and fed to a circuit called a modulator which superimposes the audio signal onto the carrier. Fig. 4a shows the original carrier wave and Fig. 4b shows the audio signal. In the modulated carrier wave of Fig. 4c, the frequency of the wave is that of the carrier, but the amplitude varies according to the audio signal. Since the frequency of the carrier is so much higher than that of the audio signal, the amplitude of the carrier follows the shape of the audio signal almost exactly.

Another way of adding signal information to the carrier is frequency modulation (FM), as shown in Fig. 2d. This requires a different type of modulator circuit to slightly increase or decrease the carrier frequency according to the audio signal. A third method of modulation is phase modulation (PM), in which the phase of the carrier is varied according to the audio signal.

Transmitters

The carrier wave of a transmitter is produced by a radio-frequency (RF) oscillator (Fig. 3) which may be based on a LC circuit (Colpitts or Hartley). Unfortunately, these circuits have frequency stability problems under a range of operating conditions. One solution is to use a piezo-electric crystal in the circuit. Now, the capacitor and inductor pair form an oscillating circuit with the latter being part of a RF transformer allowing the oscillating signal to appear on the coil feeding the aerial. The oscillations are maintained by the fluctuating collector potential of the transistor. This also causes the crystal to vibrate at its natural frequency, which is close to that of the tuned circuit. The vibrations of the crystal act as feedback, varying the base current to the transistor and hence the collector current and potential. Whereas the tuned circuit

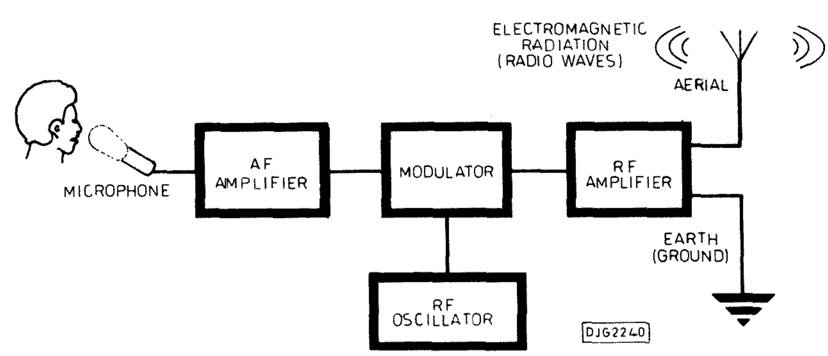

Fig. 3. Block diagram of a radio transmitter.

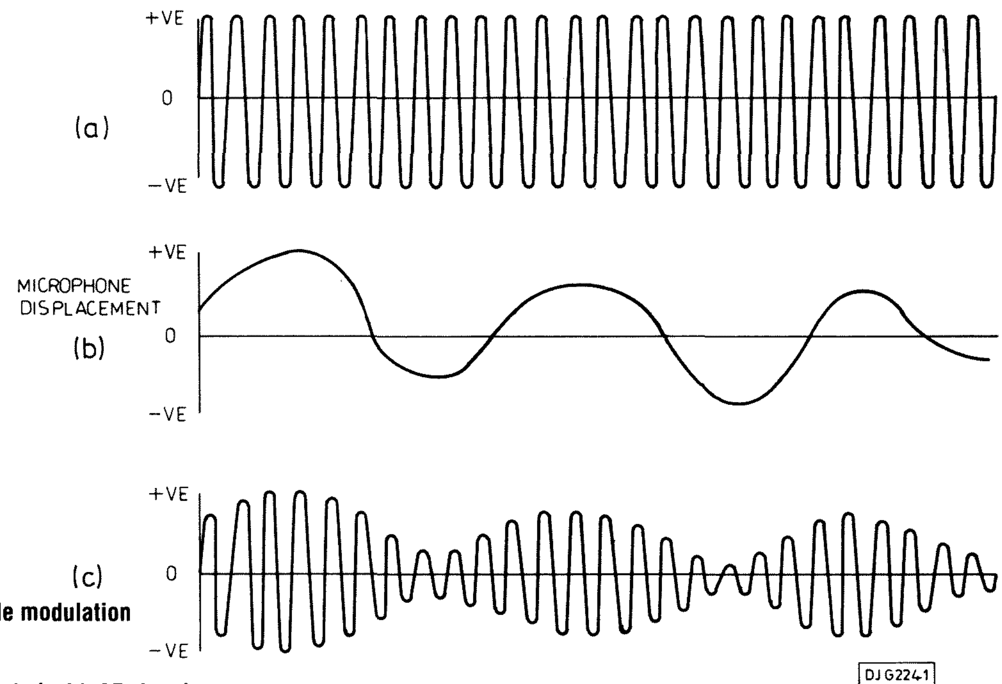

Fig. 4. Amplitude modulation
a) carrier.
b AF signal.
c) carrier modulated with AF signal.

is able to resonate to a range of frequencies around its theoretical resonant frequency, the crystal oscillates at a frequency that is determined by its physical dimensions.

Crystals are made to exacting standards and a typical radio oscillator crystal is precise to 30 parts per million (ppm), and varies by only 50 ppm over the normal range of operating temperatures.

Radio transmission

In Fig. 3 the carrier wave is fed directly to the aerial but, in most transmitters, there is an RF amplifier to increase the power before it is sent to the aerial. This consists of a simple metal rod or, for transmitters in the medium-wave and long-wave bands, it may be a wire or array of wires suspended above ground on tall masts. EM radiation spreads out in all directions which gives wide distribution of the signal but is wasteful of energy. By suitable design of the array it is possible to concentrate the radiation and increase the transmission range in one particular direction. In the UHF bands the aerial is much shorter and is often mounted at the focal point of a parabolic metal or wire-mesh reflector. Such as dish not only has the advantage of maximising transmission range but gives a certain amount of privacy to transmissions.

Reception

The first requirement in a radio receiver is an aerial to intercept the radio waves. In the early days of radio, the aerial was a wire several metres long, suspended as high as possible above the ground (Fig. 5), known as a 'long wire' aerial. Its ends were attached to insulators so that there was no direct conduction of the signal to the ground. Radio waves passing through such an aerial exert forces on the forces on the electrons in the wire, resulting in an alternating current.

A simple 'long-wire' wire aerial is intended to receive a wide range of wavelengths. The exact length of the wire itself is immaterial, the general rule being that the longer the wire, the stronger the reception. Aerials for UHF and VHF are generally designed to receive only a limited range of frequencies. The length of the receiving element is important. In a commonly-used type of aerial, the dipole, the total length of the aerial is half the radio wavelength (Fig. 6). At the centre of the aerial the fluctuations in current produced by the radio wave are at a maximum, while fluctuations in voltage are at a minimum. The aerial is split at this point and connections made to the receiver. A simple dipole may be combined in the aerial array with one or more metal rods which act as reflectors and directors (Fig. 7). These not only enhance the strength of the reception but give the array directional sensitivity. It can be 'aimed' at the transmitter, receiving signals from it strongly, yet ignoring signals from other transmitters not in line with the

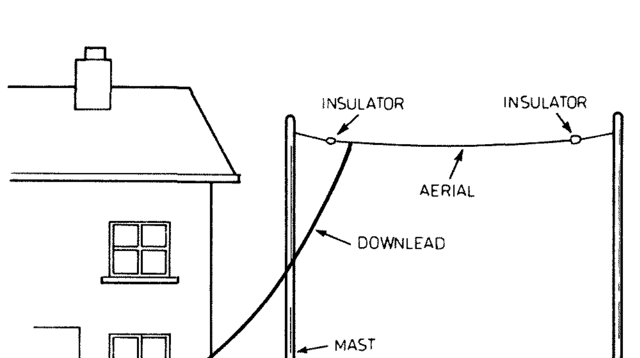

Fig. 5. A long wire aerial

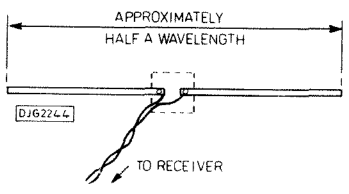

Fig. 6. A dipole aerial.

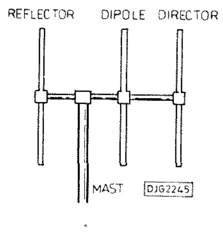

Fig. 7. A 2-Element receiving mast.

array.

With present-day radio receivers in the medium and long wave bands, a rod of material, known as ferrite, is normally used. This is a composite material with a high magnetic permeability – if the rod is placed in a magnetic field, the magnetic lines of force tend to bunch together and pass through the rod, rather than pass by on either side of it. When radio waves arrive, their magnetic component is concentrated by the rod to produce a strong alternating magnetic field within it. For maximum effect the rod is placed so it is perpendicular to the arriving wave, making it directional. The rod has one or more coils wound round it and, as the field in the rod alternates in response to the radio waves, an alternating current is induced in the coil. The coil is connected as the inductor in an LC tuned circuit (Fig. 1) and as there is usually more than one coil, each can be used for receiving different wavebands.

AM receiving circuits

The simplest type of AM receiver is illustrated in Fig. 8. There is very little in this receiver, apart from the tuned circuit consisting of the inductor L1 and the variable capacitor VC1 – to allow the circuit to be tuned to different radio frequencies. This type of receiver is known as a tuned radio frequency receiver. The inductor consists of about 85 turns of enamelled copper

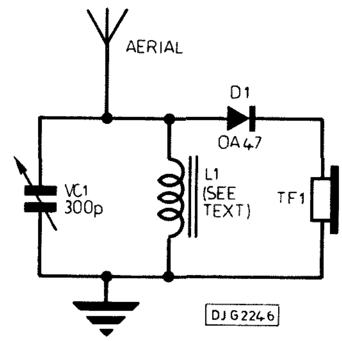

Fig. 8. A simple radio receiver.

wire wound on a ferrite rod. Although the rod is acting as an aerial, as described above, it doesn't supply enough power and a 'long wire' aerial must also be attached to one side of the tuned circuit, the other side being connected to Earth.

Fig. 9 shows what happens when this circuit is receiving an AM radio signal. If the circuit is tuned to the correct frequency, it resonates and the signal appearing across it is as shown in Fig. 9a. This is a replica of the transmitted signal with an amplitude of a few millivolts. The action of the tuned circuit can also be explained by considering it to be a band-pass filter. At frequencies lower than the tuned frequency, the signal passes to Earth through the inductor. At frequencies higher that than the tuned frequency, the signal passes to Earth through the capacitor. At the tuned frequency the signal appears across the combined high impedances of the inductor and capacitor connected in parallel. It can not pass to Earth and is available to pass to the next stage of the receiver circuit.

The next step in reception is rectification or detection which, in the circuit of Fig. 8, is performed by the diode D1. This takes the place of the crystal of the early crystal sets where the diode consisted of a fine wire, the 'cat's whisker', touching against a crystal of galena, a mineral consisting mainly of lead sulphide. The diode in Fig. 8 conducts only during the positive-going half of the waveform, producing the rectified signal shown in Fig. 9b. This is still an RF signal but the carrier part is no

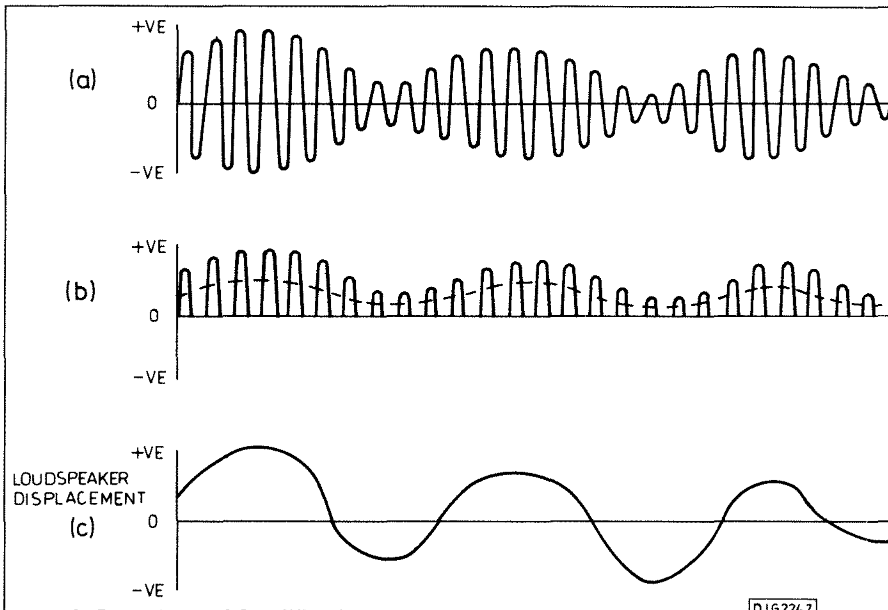

Fig. 9. Detection and Amplification.
a) Signal in tuned circuit of receiver.
b) Rectified signal (the dashed line represents the average voltage).
c) Average voltage amplified and resulting in AF displacement of loudspeaker cone.

longer required and is removed by means of a low-pass filter. In practice, there is no need to use a resistor and capacitor specially for this. The resistance of the diode and the capacitance of the earphone TF1 together do the job. The signal that passes through this filter is the average voltage, shown in Fig. 9b by a dashed line. This is an AF signal, a replica of the original audio signal (Fig. 4b), and can be heard in the earphone.

Investigation 1

Radio receiver with amplification

This circuit (Fig. 11) has tuning and detection stages and an amplifier.

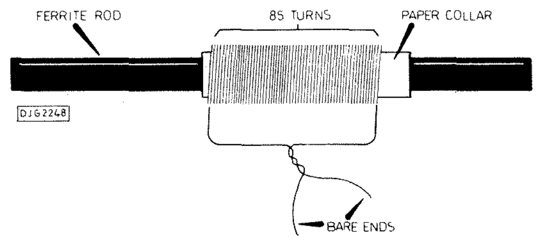

Fig. 10. Making the tuning coil for Investigations 1-3.

Assemble the circuit as in Fig. 13. The circuit diagram shows a loudspeaker. This is of the high-resistance (64Ω) type, not one of the low-resistance types (4Ω , 8Ω , or 12Ω) more commonly used in audio circuits. With a really powerful transmitter near by, it is possible to obtain enough power to operate the speaker, but you may have to place your ear close to hear clearly. Alternatively, use a crystal earphone.

Selectivity

You will probably have noticed that, unless you have only one strong transmitter in your neighbourhood, it is not easy to tune the receiver so as to receive only one station at a time. This is because the tuned circuit is capable of resonating to a greater or lesser extent over a fairly wide range of frequencies. It is not selective. The situation becomes worse at night when the strengthening of the ionosphere helps bring in more and more distant stations. Selectivity may be improved in a number of ways, all of which result in more complicated circuits which can not easily be assembled on a breadboard. Fortunately there are several ICs available which include almost complete radio circuits on a single chip. One of these is the ZN414, which contains 4 radio-frequency amplifiers and a transistorised detection stage. As a result of the RF amplifiers a 'long wire' aerial is not required. The ZN414 in is used in this month's module.

The superhet

The superheterodyne receiver employs a commonly used technique for improving the selectivity of AM reception. Its circuitry is shown in Fig. 12 and is more complicated than that of any of the receivers described in this article,

The superhet depends on the phenomenon known as beats. When two waves of similar form and amplitude but slightly different frequencies are combined, the resultant shows regular changes of amplitude, or beats. This effect can be noticed if two people whistle the same note and then one changes slightly. The combined tones produce a throbbing effect whose frequency depends on the notes and their differences. Fig. 13 illustrates this. A shows a wave at 200Hz (20 waves in 0.1s) and B a similar wave, but at 202Hz. C we shows both these waves drawn in thin lines and the sum of A and B is drawn in a thick line. Its amplitude varies or beats with a frequency of 2Hz. The rule is that, if we combine two waves of frequency f1 and f2, the beat frequency is the absolute value of the difference between them.

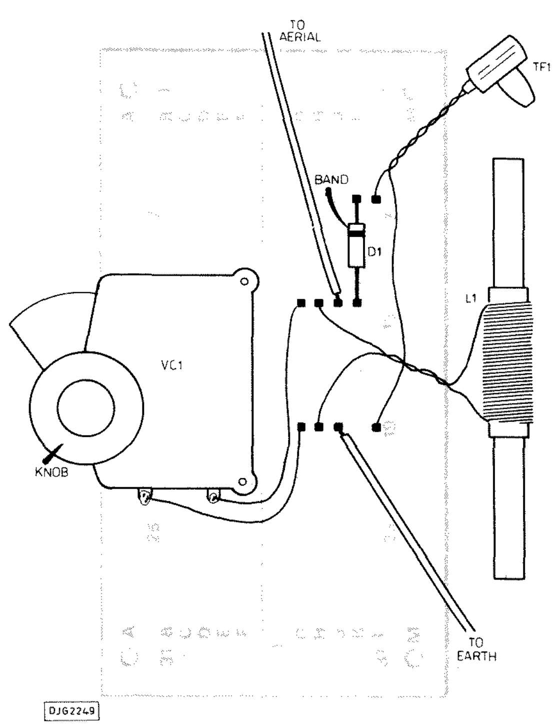

Fig. 11. The circuit for Investigation 1.

The superhet receiver uses an RF oscillator, operating at an intermediate frequency (IF). When the receiver is tuned to a particular station, the IF oscillator is tuned to a frequency that differs by a fixed amount from the station frequency. Usually this is 455kHz above the station frequency and is mixed with the signal from the aerial in a mixer circuit. The result is a new RF signal which beats at a frequency equal to the difference between the station and IF frequencies, that is, at 455kHz. The amplitude modulation of the station signal is superimposed on this, just as it was on the original transmitted signal. The point about this process is that whatever the stations frequency a modulated 455kHz signal is always produced. This is then amplified with a narrow band-pass filter to ensure that only a signal at exactly 455kHz is passed which means that the receiver is very selective. Stations on nearby wavelengths produce an IF other than 455kHz and so do not pass through the filter. There is also the advantage that, since the amplifiers and subsequent stages of the receiver always have to operate at 455kHz, they can be designed to give their best performance at this frequency.

Module of the month

Single-chip AM receiver

This radio (Fig. 14) relies on the LC circuit as the tuning element. The output from this goes to the IC, which has a high-impedance input stage, and is amplified by four RF amplifiers before reaching the transistor based detector. The output pin of the IC (pin 1) is also the pin through which it is powered. Power is supplied by a constant-voltage generator circuit, based on TR1, from the R3/R4 network.

There is feedback from the output of the IC to this network

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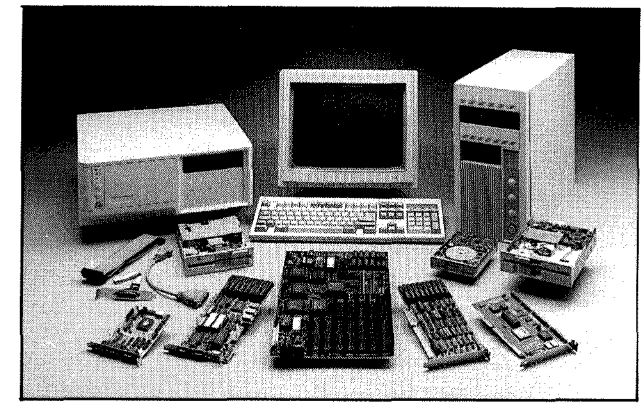

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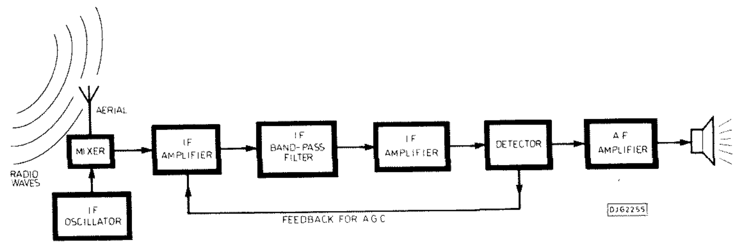

Fig. 12. Block diagram of a superheterodyne receiver.

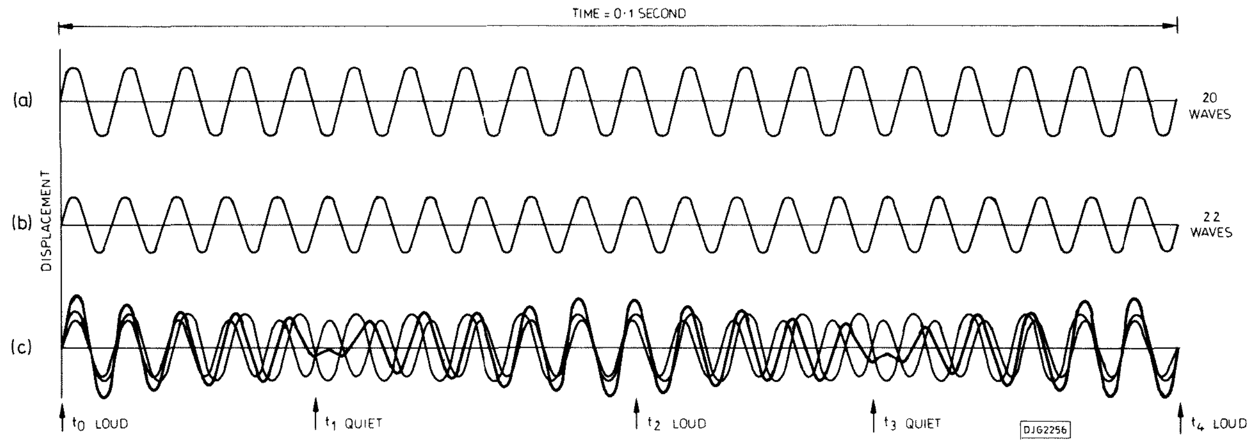

Fig. 13. Interference between two wave trains, producing beats.

which gives what is referred to as automatic gain control. Gain is decreased for strong stations and increased for weak stations. This has the effect of compensating for fading which may occur under poor reception conditions. It also has the effect that signals from strong local stations are not amplified as much as those from weaker stations. They are less likely to swamp the signals from weaker stations operating on nearby wavelengths. This helps to improve the apparent selectivity of the receiver, though this is not a true improvement of selectivity as such. As before the circuit can be built on stripboard.

The quality of reception depends very much on the voltage supplied to the IC which must be in the range 1.2V to 1.6V. The voltage can be altered by substituting resistors of different values for R1 and R2. With low voltage, the sensitivity of the receiver is reduced. This also introduces the problem that electrical interference from other sources, such as thunderstorms, becomes more noticeable. With high voltage strong stations may swamp the circuit. The resistors may also be changed to allow the receiver to operate on other battery voltages in the range 3V to 12V.

Since this module includes one stage of amplification it can be used on its own, with earphones, as a self-contained radio receiver. It requires no aerial or earth.

Details for winding the coil are given in Fig. 11. All connections should be kept as short as possible. In particular C3 must be soldered as close as possible to pin 3 of IC1. Connect the tuning capacitor VC1 so that its fixed plates are wired to the junction of R4 and C2, and its movable plates to pin 2 of IC1. The circuit should be housed in a small plastic enclosure. Mount VC1 on the lid or front panel and fix the aerial rod and coil to the inside of the box. Any loudspeaker mounted on the box should be positioned as far away as possible from the aerial rod. The relevant component values are given in Fig. 14 and the circuit can be constructional on a piece of stripboard – as in the previous modules in this series.

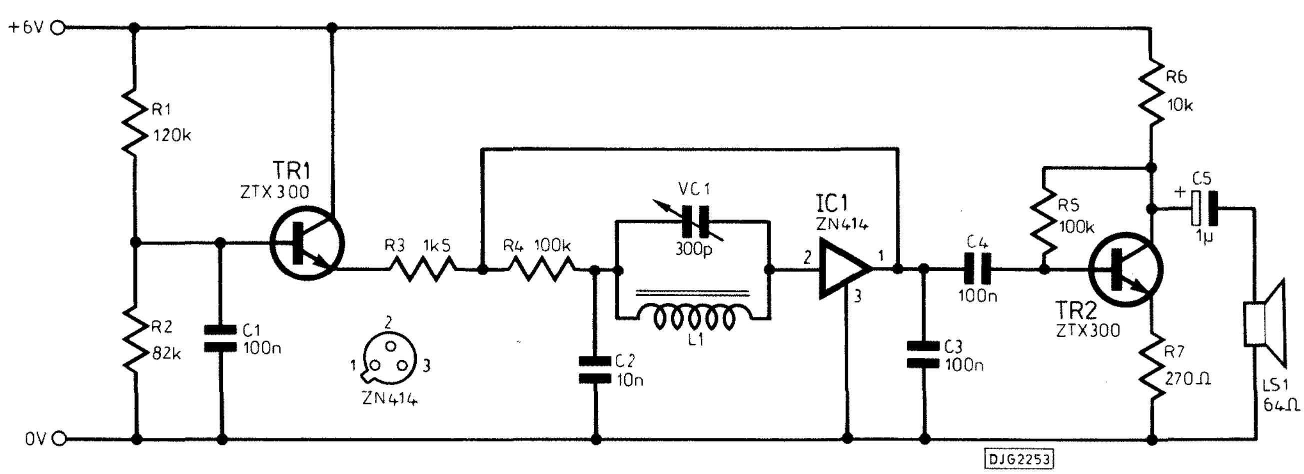

Fig. 14. AM Radio Receiver based on the ZN414 radio IC.

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K579. This pack contains 10 assorted battery powered motors (mostly 3V) + 90 gears etc; 16-60mm dia + worms and shafts. Amazing value.
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Specification:

Model Number:	**BM41012**	
Input:	115/230V, 50/60Hz	
Outputs:	+5V 3.75A	
	+12V 1.5A	
	-12V 0.4A	
Total Wattage:	65W	
Price	**£14.95;**	**100 + 11.21**

We've also discovered a small quantity of an Astec model offered previously. Regrettably we've had to increase the price, but they still represent outstanding value for money. Enclosed in a steel case 203 × 112 × 60mm is a PCB 197 × 106mm. Input and Outputs are via pins on the PCB.

Specification:

Model Number	**AC9231**	
Input	115/230V, 50/60Hz	
Outputs	+12V 2.5A	
	+5V 6A	
	12V 0.5A (+or -)	
	5V 0.5A (+or -)	
Total Wattage	50W	
Price	**£17.95;**	**100 + 13.46**

We still have good supplies of yet another Astec model. This one is partially cased, the overall size being 160 × 104 × 45mm. The PCB measures 160 × 100mm. Input and Outputs are on flying leads, all colour coded. There is also an additional IEC socket to extend mains to another unit.

Specification:

Model Number	**AA12531**	
Input	115/230V, 50/60Hz	
Outputs	+5V 5A	
	+12V 0.15A	
	-12V 0.15A	
Total Wattage	50W	
Price	**£6.95;**	**100 + 5.21**

Also still available: An Astec 'bare board' model. The PCB is standard Eurocard size, 160 × 100mm. Input and Outputs are on right angle PCB pins. This is a very compact model offering excellent value for money.

Specification:

Model Number	**AC8151-01**	
Input	115/230V, 50/60Hz	
Outputs	+5V 2.5A	
	+12V 2A	
	-12V 0.1A	
Total Wattage	40W	
Price	**£12.95;**	**100 + 8.91**

Z8887 Made by STC, this 160 × 100mm PCB is attached to an aluminium chassis 165 × 102 × 65mm and has a single 5V 6A output. Supplied with connection details, we can offer these at fraction of their normal cost!
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G712 As above, but mounted onto a rigid base plate complete with 3 4mm terminals for power connections. A mounting bracket which clips into the base is also provided to accept a variety of components including switches and pontentiometers, etc **£6.95**

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Price **£1.00**

Z1810 Cell enclosed in black heatshrink with wires attached at both ends.
Price **£1.00**

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Price **£3.95**

Z1830 Saft 40 RF310 back up Nicad battery PC mounting on 70 × 22.5mm centres. Rated 3.6V. 10mAH (20mA). Overall size 76 × 28 × 8mm.
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TIPP31	**100 + 0.07**
	1k + 0.04
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	1k + 0.04
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BDW93 Darlington	**100 + 0.20**
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Amateur Radio Explained

Ian Poole, aka G3YWX, reveals what Q codes mean, what King Hussein and Rajiv Ghandi have in common and why radio waves bounce around the world.

For most people amateur radio conjures up images of Tony Hancock in his brilliant comedy The Radio Ham – someone with hundreds of pounds worth of equipment talking to people in Japan about the weather, playing chess with people in Birmingham and trying unsuccessfully to help people sinking in the middle of the Atlantic.

Amateur radio is far from this. It covers a wide range of interests from the technical to plain relaxation. Some people enjoy the fascination of listening or talking to stations on the other side of the world. They may choose to take up the challenge of contacting as many countries as possible. There are many interesting places where people have set up stations. Often people based in remote scientific stations will have an amateur station so that they can spend some of their spare time talking to people around the world. Some well known statesmen and heads of government like King Hussein of Jordan and Rajiv Ghandi hold amateur licences and it is occasionally possible to talk to them.

Another aspect of the hobby is the challenge of construction, especially when the project can be tested on the air with the possibility of a long distance contact.

Many other people enjoy relaxing and chatting over the air to friends across town, or possibly using their equipment in the car to make a long journey more interesting. It is even possible to help the community by participating in one of the emergency groups which are set up all over the country to help in the event of disaster. These groups are widely used to set up emergency communications quickly and help relay important messages. Recently they have come into action on a number of occasions – two examples were the air crash at Lockerbie and the storms of early 1990.

In fact, whatever one's interest in electronics and radio there is always something in amateur radio to keep a healthy interest. This is proved by the ever-increasing numbers of radio amateurs and listeners all over the world.

How It Started

Amateur radio can trace its origins to the very beginnings of radio. At the end of the nineteenth century people like Hertz, Marconi and many others began to experiment with wireless, as it was called then. At this time there were no regulations, and as the implications of radio began to be realised the government decided a form of licence was needed. This was first issued in 1905 as a licence for experimentation and it continued in this form until the outbreak of the First World War, when amateur operation was banned and all equipment impounded.

No further activity took place until 1921 when a new form of licence was issued. It became necessary to pass a theory examination and a Morse test as well as outlining a set of experiments before a licence would be granted.

At this time radio was still in its infancy. Amateur experimenters were only allowed to use the short wave bands, which were thought to be of little use, as the long wave bands were reserved for long distance communications. However, in late 1923 amateurs proved the worth of the short waves when they conducted the first transatlantic contacts.

Many other improvements were taking place. Transmitters and receivers were being improved all the time as was knowledge about propagation and the ionosphere. Much of this knowledge was contributed by radio amateurs. Unfortunately all of this came to an end in 1939 when the Second World War broke out and all amateur operation ceased.

After the cessation of hostilities new licences were not issued until 1946. Gone was the need to define a set of experiments before a licence would be issued as were many of the other petty restrictions. Now it was only necessary to pass the theory examination and a Morse test.

In the years that followed licence conditions were improved to enable amateurs to do considerably more. Television transmissions were permitted and so was mobile operation from cars. Later on a Class B licence was introduced, which originally allowed operation on frequencies above 430 MHz but now permits operation on amateur bands above 30 MHz. Recent modifications to the licence have allowed low powered remote control of equipment, digital repeater facilities and so forth. This enables the amateur licence to keep pace with technology.

Today a licence is still needed to transmit. The theory examination called the Radio Amateur's Examination, or RAE for short, is

Radio Basics

There are two main ways of transmitting information via radio waves, amplitude modulation (AM) and frequency modulation (FM). Both take audio signals and impose them on a radio frequency 'carrier', the wavelength of which is anywhere from 160m to 3cm. The important point is that the frequency of this carrier is generally higher than the frequency of the audio signals being imposed upon it. Audio frequencies range from 20Hz to 20kHz and radio frequencies start at around 1MHz and go upwards.

AM uses the audio signal (Fig. 1a) to vary the amplitude or volume of the carrier to produce the signals shown in Fig. 1b. This consists of the carrier frequency itself and two copies of the audio signal either side of it, the whole thing being moved up to centre on the carrier frequency. The 'spread' of the signal in frequency terms is now quite wide and contains redundant information – a copy of the audio signal and the carrier. Both of these can be filtered out, making more efficient use of the radio spectrum, to give a single sideband (SSB) signal as shown in Fig. 1c. At the receiver a beat frequency oscillator (BFO) is used to reproduce the original signal so that it can be demodulated in the usual way – basically a matter of amplifying and rectifying the radio signal.

Frequency modulation varies the frequency of the carrier in time with the audio signal being transmitted. This produces quite a wide bandwidth but has the advantage of being almost immune to changes in volume such as noise. Because of the wider bandwidth required, FM transmitters are operated at frequencies in the VHF (Very High Frequency from 30MHz to 300MHz) and UHF (Ultra High Frequency from 300MHz to 3000MHz) bands. Unfortunately these have the disadvantage that signals cannot be transmitted over the horizon since they are not normally reflected by the ionosphere, apart from under unusual weather conditions or by special techniques such as meteor scatter.

As a meteor hits the Earth's atmosphere, it is travelling so fast that it leaves behind a trail of ionised gas. This temporary ionised layer or area is reflective to high frequency signals and allows occasional communication over distances as large as 2000km. The trails can be found at around 100km up in the atmosphere and occur at fairly predictable times. The optimum time for a connection is early in the morning since at this time the Earth is moving towards orbital meteors rather than away from them. There is also a set distribution of meteors around the sun which creates a peak around July. This and other new areas allows amateur radio enthusiasts to keep up with and sometimes lead the field in communications technology.

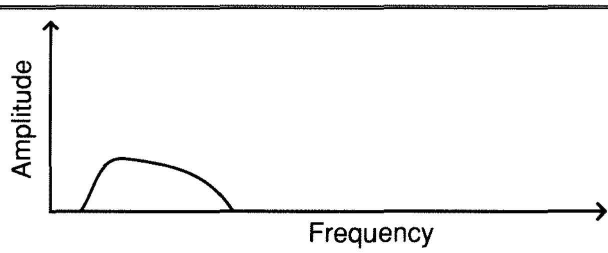


Fig. 1a. Spectrum of an audio signal.

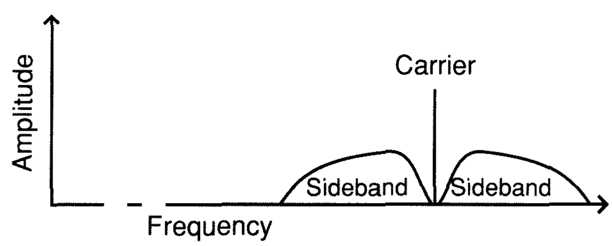


Fig. 1b. Spectrum of an amplitude modulated signal.

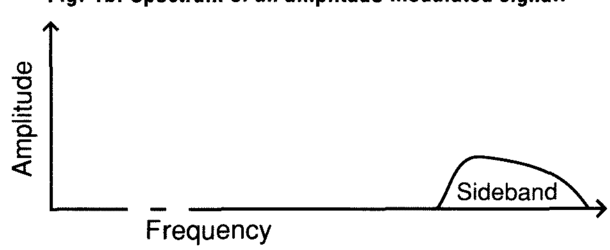


Fig. 1c. Spectrum of a singal sideband signal (upper sideband).

required for both the Class A and B licences. The syllabus covers a lot of basic theory likely to be used in the course of running an amateur station. It also includes questions about the licensing conditions. The Morse test needed for the Class A licence requires the candidate to be able to send and receive at a speed of 12 words a minute. Both examinations require a little study and preparation but most applicants are able to pass them relatively easily.

Amateur Transmissions

Amateur licences permit a wide variety of different types or modes of transmission. Amplitude modulation (AM) is not used very often because it is not as efficient as many of the other modes. Single sideband, or SSB for short, is the favourite mode for long distance contacts. Frequency modulation is the favourite for VHF and UHF local and mobile contacts. It has the advantage that signal variations can be all but removed if the signal is above a minimum strength. This makes it particularly suitable for mobile applications where signal strengths will vary as the car moves along.

Though most transmissions are voice, Morse code is still very popular because it can be understood at very low signal strengths. This can enable a contact to be made where no other method could get through.

Amateur Bands

Amateurs are not allowed to transmit just anywhere in the frequency spectrum, they can only use the bands which are allocated to them. Fortunately there are a lot dotted over most of the spectrum – see figure 2. The lowest frequency band, 160 Metres, stretches from 1.81 MHz to 2.0 MHz. It is just above the top end of the Medium Wave band and many transistor radios can be adjusted to cover it without much difficulty. Other bands such as the 40 and 20 Metre bands are often covered by radios with a short wave band. There is also a good selection of bands in the VHF and UHF portion of the spectrum, for example the Six Metre band, which has recently been released for amateur use, covers 50 to 52 MHz – this is where some of the old VHF BBC 405 line

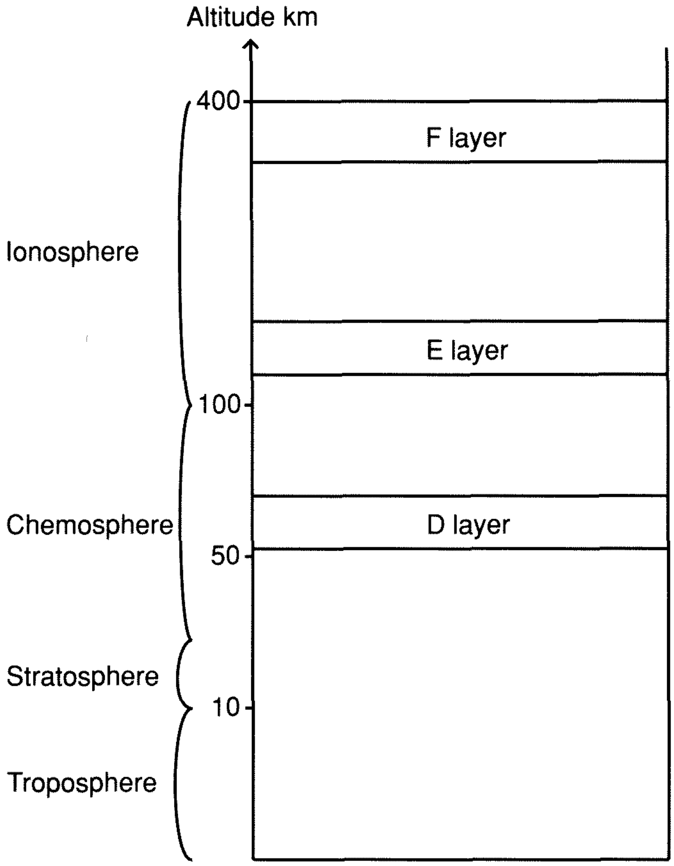


Fig. 3. Layers in the atmosphere.

transmissions used to be.

Further up in frequency there are several more bands. These are not as popular as some of the lower frequency ones but with technology advancing more people are beginning to use them. They also provide new challenges for radio amateurs as very little commercial equipment is available.

Frequency limits (MHz)

1.81	2
3.5	3.8
7	7.1
10.1	10.15
14	14.35
18.068	18.168
21	21.45
24.89	24.99
28	29.7
50	52.0
70	70.5
144	146
430	440
1240	1325
2310	2450
3400	3475
5650	5680
5755	5765
5820	5850

Fig. 2. UK amateur bands.

Propagation

The wide variety of bands available allows radio amateurs to take advantage of the characteristics of different frequencies. Some bands support long distance contacts whilst others give good reliable communications with less interference over short distances. The way in which signals propagate changes from day to day and over the course of a day. Many people find the study of propagation very interesting. Accordingly a little understanding of the basic concepts will help any short wave listener or licensed amateur to know the best times and frequency bands to contact a particular area.

There are two main areas which affect the propagation of radio signals. The first is the ionosphere. This is a region of the atmosphere about 100 to 400 km above the earth's surface. In it there are different ionised layers – see figure 3. The lowest of these, the D layer, is only present during the day and tends to absorb low frequency signals. This is why at night it is possible to hear signals from much further afield. As the frequency rises the signal will pass through the D layer and come to the E layer. This will reflect the signals so that they are bounced back to Earth – see figure 4. As the signal frequency increases still further the effect of the E layer is reduced so that the signals will eventually pass through and reach the F layer. This is quite changeable. During the day it splits into two layers, called the F1 and F2 but at night they combine. Signals reaching them will be bent back to earth, but as the frequency increases they will pass through to reach the next layer or travel out into space. Generally the maximum frequencies which are reflected by the ionosphere are very roughly confined to the HF portion of the spectrum i.e. frequencies below about 30 MHz. These reflections enable signals on the short waves to travel vast distances. However they cannot fully explain how signals manage to travel from one side of the earth to the other. This happens because a signal can be reflected several times off the ionosphere and ground.

The second area affecting the propagation of radio signals is the troposphere. The frequencies which it affects are up into the VHF and UHF portion of the spectrum. Changes in the refractive index of the air cause the signals to curve round the earth's surface, extending the coverage. This often happens when areas of high pressure are over the country, although other weather conditions can be the cause. Whilst radio amateurs make the most of it and enjoy the long distance contacts which can be made, it can be an inconvenience to TV watchers because of interference from stations outside the normal range.

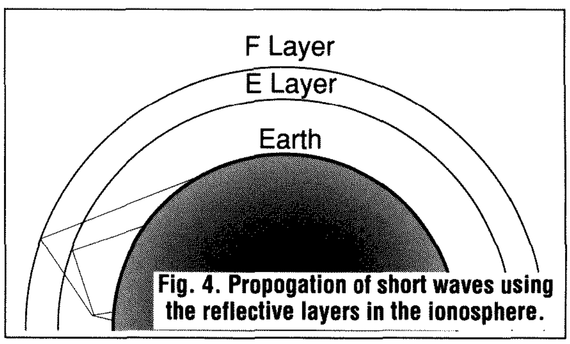


Fig. 4. Propogation of short waves using the reflective layers in the ionosphere.

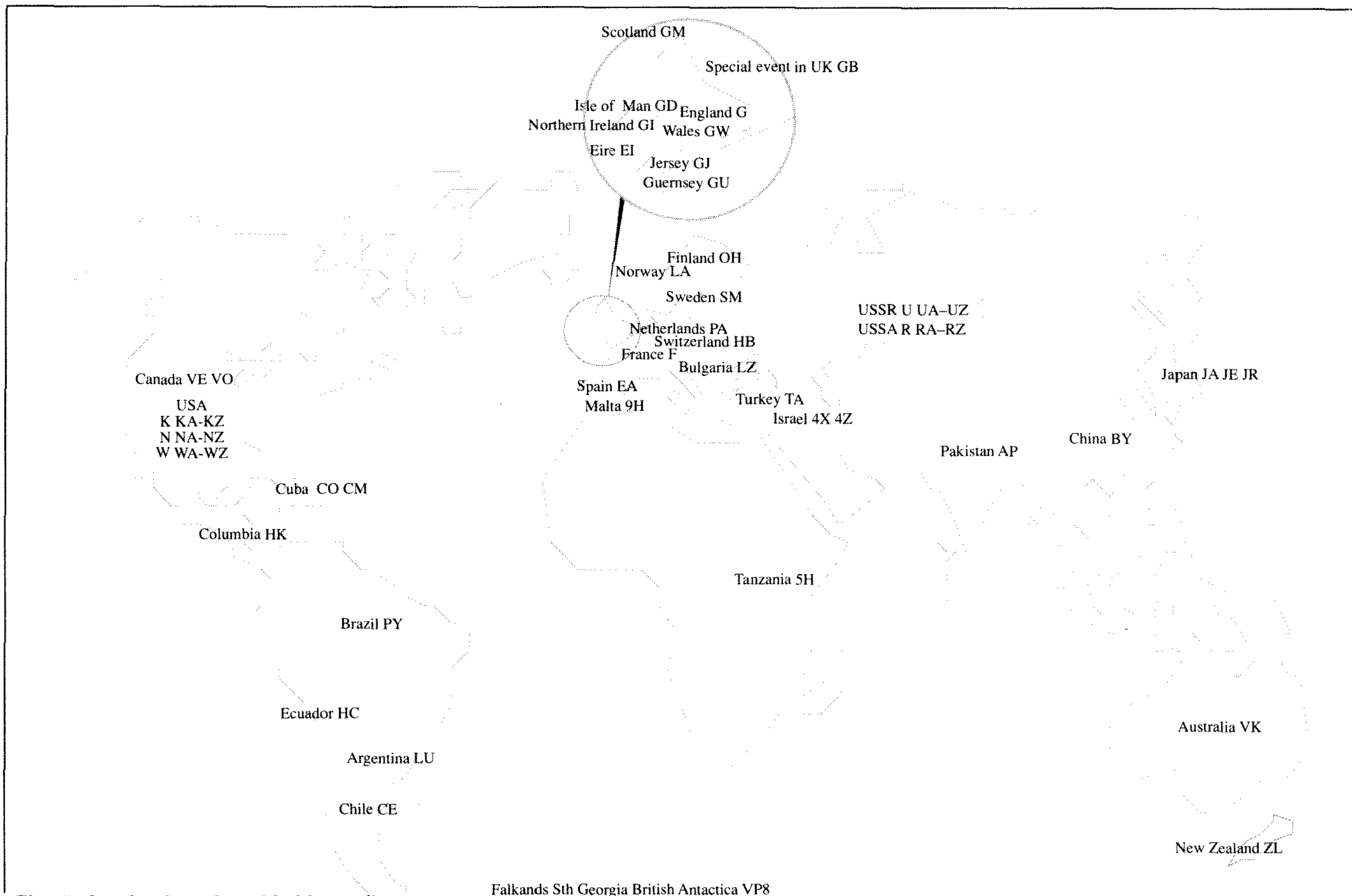


Fig. 5. A selection of worldwide prefixes.

Callsigns

Listening on the amateur bands it is possible to hear stations from all over the world. Each station is given its own particular callsign when the licence is issued. From this it is possible to determine which country it comes from and sometimes a specific area within the country as well.

As an example, take the callsign G3YWX. It consists of two parts: the prefix up to and including the last number (in this case G3) and the serial letters. By comparing the prefix with a list such as the abbreviated one in figure 6 it is possible to locate the station. G3 means the station is located in England.

BFO	Beat frequency oscillator
CW	Continuous wave (used to denote a Morse signal)
DX	Long Distance
FB	Fine Business
HI	Laughter
Mod	Modulation
PA	Power Amplifier
SWL	Short Wave Listener
TVI	Television Interference
WX	Weather
XTAL	Crystal
XYL	Wife
YL	Young Lady
73	Best Regards
88	Love and Kisses

Fig. 6. Common abbreviations.

Jargon

There is a lot of other jargon associated with the amateur radio. Fortunately much of it can be learnt quite easily. It has come about for a number of reasons. One is that in the early days words had to be abbreviated to be sent by Morse code without taking too long. Many of these abbreviations have been carried over into the general 'ham' vocabulary. Another reason for their widespread use is the international nature of the hobby. As many people cannot speak English fluently the use of abbreviations as a sort of code can help.

Some are quite obvious, for example TVI is short for television interference, but others, like 73, are not. It is said that this particular one originated from the days of the old railway telegraph operators when they used to send two dashes six dots and two dashes as a form of greeting before a message. Over the years this became corrupted to 73.

Other codes are used. One is the RST code. This is used when giving signal reports and it is very useful because it helps give a standard by which several reports can be compared. The basic system is shown in Fig. 7 and consists of a number for the readability, strength and tone. When using speech only the readability and strength sections are used, tone is used for Morse.

Another well known code is the Q code used in professional communications. Some of the codes have been adopted for amateur use. Although they are defined, as shown in Fig. 8, in a question and answer form, in speech their basic meaning is often carried over. For example one may talk of having a instead of a contact or a QRP transmitter instead of a low power transmitter.

QSL Cards

Another Q code which has been adopted in a special way is QSL. Generally it means "Do you acknowledge receipt?" or "I acknowledge receipt", however amateurs have taken to sending postcards to confirm a contact. These cards are, not surprisingly, Readability, Strength and Tone

Readability
R1 Unreadable
2 Barely readable
3 Readable with difficulty
4 Readable with little difficulty
5 Perfectly readable

Strength
S1 Barely detectable
2 Very weak signals
3 Weak signals
4 Fair signals
5 Fairly good signals
6 Good signals
7 Moderately strong signals
8 Strong signals
9 Very strong signals

Tone
T1 Extremely rough note
2 Very rough note
3 Rough note
4 Fairly rough note
5 Note modulated with strong ripple
6 Modulated note
7 Near DC note but with smooth ripple
8 Near DC note but with trace of ripple
9 Pure DC notes

Fig. 7. RST code.

called QSL cards. Although not every contact deserves a card, it is nice to have one for an interesting contact or a new country.

Listeners can also send cards to give reception reports in the hope of receiving a card back. When doing this it should be remembered that many amateur stations receive a lot of these cards which are usually of little use. Any reports sent should give some useful information. Also return postage should be included. If the station is abroad this can be done using an International Reply Coupon (IRC).

As one may imagine sending plenty of cards to all the corners of the world can be expensive. In order to reduce the cost most of the national radio societies like our Radio Society of Great Britain (RSGB) operate what is called a QSL Bureau available to listeners and licensed members alike. The system operates by sending cards in bulk. The station owner will send his cards to the bureau in batches of ten, twenty or more. The RSGB collects cards from all over the UK and sends them to other countries in bulk or to members in batches. This obviously takes more time, but it saves a tremendous amount in postage!

Collecting cards can be fascinating, almost a hobby in its own right. Some of the cards are very bright and colourful, others even have photographs on them. In fact people often use them to put up around the wall in the radio room as a form of decoration, showing the variety of countries and places which have been contacted or heard.

Equipment

For those interested in listening in, the choice of equipment is very important, and there is a wide variety of receivers on the market these days. Domestic portable receivers which cover the short wave bands are not really suitable because most amateur transmissions use either SSB or Morse which require the receiver to have a BFO (Beat Frequency Oscillator).The cheapest form of receiver is one of the 'World Band' types which are becoming more popular these days. They generally cover frequencies from the long wave band right up to 30 MHz and the broadcast FM band. Those which could be used for amateur radio listening have a frequency synthesiser with keypad frequency entry to enable accurate location of frequencies and the normal tuning knob for scanning around the bands. They also possess the essential BFO.

The cost of these receivers varies quite widely. The most expensive can cost several hundred pounds but at the bottom of the market there are a number at around £90 which can be found in high street electrical stores.

The next step up is a proper communications receiver. These are generally larger and have a better performance. They are more expensive, but the extra investment may be worth while if anything more than casual listening is envisaged.

Clubs and Societies

To anyone starting out in a hobby it is helpful to be able to get advice from people who have some experience. Amateur radio is no different and fortunately there are plenty of clubs and societies all over the country. They will be only too pleased to welcome a new member

QRM Is there any (man made) interference?
There is (man made) interference.

QRN Is there any atmospheric noise?
There is atmospheric noise.

QRO Shall I increase power?
Increase power.

QRP Shall I decrease power?
Decrease power.

QRT Shall I stop sending?
Stop sending.

QRU Do you have any messages for me?
I have no messages for you.

QRV Are you ready to receive?
I am ready to receive.

QRZ Who is calling me?
You are being called by......

QSL Can you acknowledge receipt?
I can acknowledge receipt.

QSP Can you relay a message?
I can relay a message.

QSY Shall I change to another frequency?
Change to another frequency.

QTH What is your location?
My location is ....

Fig. 8. Q codes.

and offer advice.

There is also the Radio Society of Great Britain. This organisation publishes a monthly magazine, Radio Communication, full of articles and news about amateur radio. It also runs a QSL bureau, organises contests, negotiates with the licensing authorities to obtain better conditions and performs a whole host of other functions. For further information the address is RSGB, Lambda House, Cranborne Road, Potters Bar, Herts. EN6 3JE.■

The Integrated Circuit Story

It is an undisputed fact that the silicon chip has come to dominate the electronics scene. Where and when was the concept invented? Ian Poole reports.

If it were not for the invention of the integrated circuit (IC) most of today's electronics could not be made in a cost-effective or practicable way. Computers would be large and very costly, and the personal computer would only be a dream. Many other everyday pieces of electronic equipment would be different too. Car electronics, clocks and even the humble transistor radio would not have the number of facilities we have come to expect. Yet, in spite of its dominance, the integrated circuit had very humble beginnings. In fact the scientists at Bell Laboratories, where the transistor was invented, did not believe they were possible.

Immaculate Conception

It was not long after 1947, when the transistor was invented, before people started to wonder if several transistors could all be put onto the same piece of silicon. One of the reasons for this was that equipment was becoming increasingly complicated.

The first investigation into methods of overcoming the problems of size and reliability was based around thermionic valve technology. In the early 1950s the US Government was looking at ways of improving circuit assembly. It funded a project, known as Tinkertoy, to investigate the possibility of screen printing components onto a ceramic base. As transistors were still very much in their infancy at the time, conventional valves formed the mainstay of the project.

As the project got underway, a number of other ideas were slowly being developed. For example, as early as 1952 Dr G. Drummer from the Royal Radar Establishmen (RRE)t in Britain proposed that it might be possible to build a circuit as a solid block without any interconnecting wires. Unfortunately he did not suggest any practical ways in which the idea might be realised. Meanwhile, in the US, the Radio Corporation of Americs (RCA) was investigating methods for making a phase shift oscillator on a single piece of silicon. However, the project was somewhat before its time because the technology did not exist to enable any real progress to be made.

The next milestone occurred in Britain when the RRE placed a contract with Plessey to investigate the feasibility of making an integrated circuit. Unfortunately, before any progress was made, Texas Instruments announced its first IC.

Tinkertoy Transistors

By 1957 the US Government was trying to update Tinkertoy to use transistors. The work was shared between a number of contractors causing different comp-anies to work separately along similar lines.

Without ICs products such as the Sharp IQ would not be possible.

The first years of the IC.

The first main use of semiconductors was in rectifiers – devices for converting the positive and negative voltages of alternating current into positive voltages only. Later they were used in early radio sets where a wire, known as a 'cats whisker', touched to a crystal of Lead Sulphide or Silicon formed part of the tuning circuit.

1948 The Germanium transistor was discovered by John Bardeen and Walter Bratain working at Bell Telephone Laboratories.
1949 William Shockley outlined some of the basic theories behind semiconductors and invented the junction transistor.
1956 Bardeen, Bratain and Shockley were awarded the Nobel prize for their work in developing the transistor. Shockley also started the Shockley Transistor Corporation, one of the first Silicon Valley firms. Eight engineers eventually left to form Fairchild and later two of these, Robert Noyce and Gordon Moore, founded Intel (and became millionaires in the process).
1958 Jack Kilby, working for Texas Instruments, fabricated the first integrated circuit which was used in a calculator replacing a number of discrete components.
1964 The number of components per IC rose to around 10.
1969 M E Huff Jr. working for Intel, designed the first microprocessor, the 4004. National Semiconductor and Rockwell also also entered the field. However, Texas Instruments, Motorola and Fairchild continued to manufacture high power semiconductors and ICs for calculators thinking that microprocessors were not very important.
1970 The average number of components per chip rose to around 1000.
1972 Intel launched the 8008 microprocessor as an upgrade to the 4004.
1973 Intel launched the 8080, one of the most widely used microprocessors ever, running 20 times faster than the now outdated 4004.
1975 Motorola entered the market with the 6800 and General Instruments and Texas also entered the fray – Texas began second sourcing the 8080 ensuring its availability and establishing it as the front runner.
1976 The number of components per chip jumped over the 32000 mark and the age of the Integrated Circuit had begun.

A year after the start of the project, a bright young engineer named Jack Kilby joined one of the companies in the project, Texas Instruments. He had a number of ideas of his own which he wanted to follow through. Normally this wouldn't have been possible but, having very little leave entitlement, he offered to work through the annual holiday shutdown. In two weeks he was able to make tremendous progress.

Kilby set about making three phase shift oscillators on a germanium substrate. The first of these was made to work on 12th September 1958. Soon afterwards he made a batch of multivibrators. The dawn of the integrated circuit age had arrived.

As with so many other inventions, when the technology is ripe the idea is discovered by several people at the same time. Robert Noyce of Fairchild (who died only recently) reasoned that instead of making a large number of transistors on a single piece of silicon, cutting them up into single devices, packaging them into their cans and then reassembling them, the stages of splitting and reassembling could be done away with. By following this reasoning through Noyce developed the ideas which form the foundation of modern IC manufacturing. Kilby and Noyce are now jointly credited with the invention of the IC.

Space Race Technology

The integrated circuit was not an instant success and it was 1961 before any ICs were available commercially. Even then they were used by very few people.

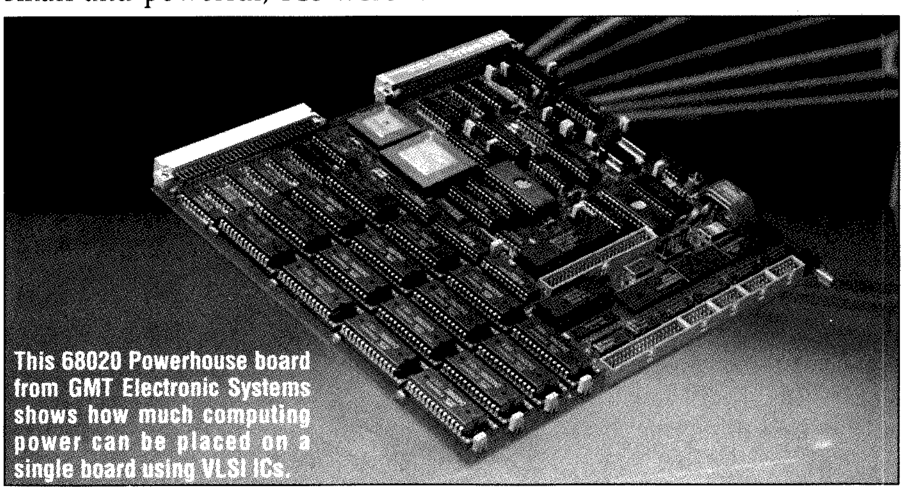
Only two companies manufactured ICs, Texas with its 51family and Fairchild with the Micrologic series. ICs were very expensive because they used new technology and demand was not large enough to bring prices down. However, the impetus needed to get the new technology off the ground did not take long to arrive. In May 1961 President John F Kennedy said it was the intention of the US government to have a man walk on the moon before the decade was out.

With NASA now in the market for new technology which was both small and powerful, ICs were in great demand and prices started to fall. The range of ICs began to expand as more money was put into research.

ICs Hot Up

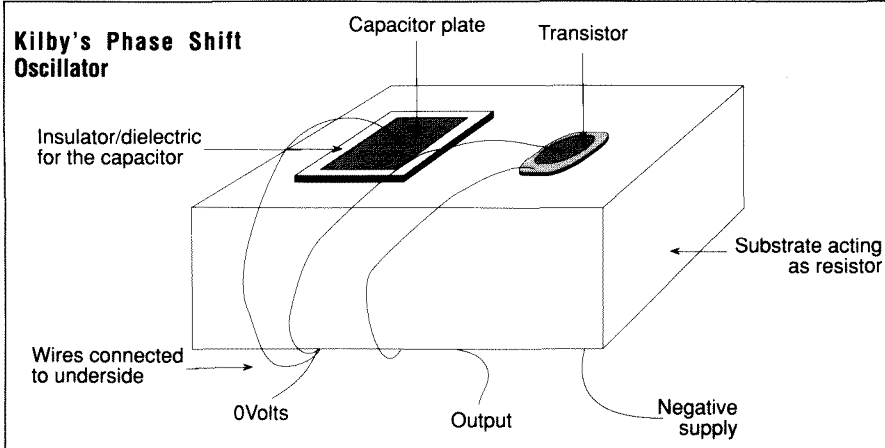
Although virtually all the initial development work had been done in the States other countries soon started producing their own ICs. Europe saw many large companies enter the field; Mullard, Philips, Ferranti and Plessey were but a few. Japan started to look at the idea very seriously as well. The Nippon Electric Company (NEC) in particular was close on the heels of the Americans.

Reliability and yield were steadily increased by manufacturing process improvements, and more and more components were put onto each chip. The problem to crop up was that of heat



This 68020 Powerhouse board from GMT Electronic Systems shows how much computing power can be placed on a single board using VLSI ICs.

Kilby's Phase Shift Oscillator



dissipation. Even the small amount of heat generated by a tiny IC had to be removed from the chip. Efficient methods of removing heat had to be found or, better still, less heat had to be generated.

The answer came in the form of a new transistor technology. FETs (Field Effect Transistors) had only just been brought onto the market and IC designers jumped at the opportunity of being able to use the new MOS (Metal On Silicon) technology. They saw the possibility of reducing heating by many orders of magnitude and, at a stroke, the scale of integration rose yet again.

In 1966 Texas Instruments was the first company to introduce a MOS device – a binary to decimal converter. Many other devices followed and ICs were now in a position to gain even more prominence in electronics.

With MOS technology the possibility of Very Large Scale Integration (VLSI) was in sight. The first step along this path was taken by Fairchild. In 1967a device with over a thousand transistors appeared– a RAM chip intended for use in computers. Unfortunately it was still more expensive than the magnetic core memory in use at the time and was not marketed. Even so it showed what could be done and was a step toward the future.

New on the Scene

It was about this time that Noyce and one of his colleagues left Fairchild to found Intel. Progress in this new company was swift. In less than a year it had designed, tested and started to manufacture a bipolar static RAM. Having done this it started to develop other memory devices.

The Microprocessor

In the early 1970s electronic calculators came onto the market. Even though they contained ICs which had a high level of integration, these calculators still contained a relatively large number of chips. Seeing the requirement for a more general set of ICs, Noyce and his team set about designing devices which would reduce the chip count and, as a bonus, could be used in other applications. They came up with four ICs; the 4004 processor, a ROM, a RAM and a chip to control input and output functions.

Intel was not sure about marketing this set of chips because it was primarily a memory company. Even though the idea was new it went ahead hoping it might increase memory sales. The 4004 was reasonably successful, though the microprocessor boom was yet to start. The next device from Intel was the 8008, but users found it had several shortcomings. Some redesign was undertaken and it was relaunched as the 8080. This soon received its seal of approval when the Digital Equipment Corporation decided to use it in their PDP range of computers.

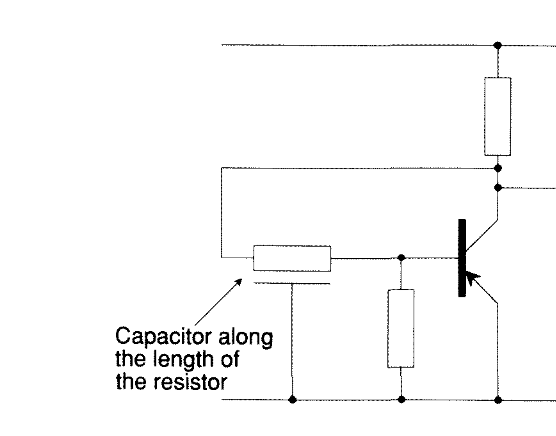
Intel was not the only manufacturer producing microprocessors. Motorola was close on its heels with the launch of its 6800. This also proved to be successful and fierce competition broke out between the two companies. Following on from the original 8-bit devices some 16-bit processors were designed. Intel launched its 8086 in 1986 and Motorola followed a year later in 1987 with the 68000. Intel managed to score a coup when their device was chosen for use in the IBM PC leading to the 80286, and eventually the 32-bit 80386.

Microwave ICs

Whilst microprocessor technology forms a very large part of today's IC manufacture it is by no means the only development. Many other types of IC are being manufactured. It is only necessary to look at satellite TV to see ICs being used at frequencies of thousands of Megahertz for amplifiers and signal processing. This has only been made possible by a considerable amount of research into new materials and new methods of manufacture. Monolithic microwave ICs made from gallium arsenide are breaking all the speed records.

Thirty Years On

It is about 30 years now since the first ICs were produced. In this time they have developed from an idea which many people thought would never be viable to become the central element in today's electronics industry. ■



Equivalent circuit of Kilby's Phase Shift Oscillator.

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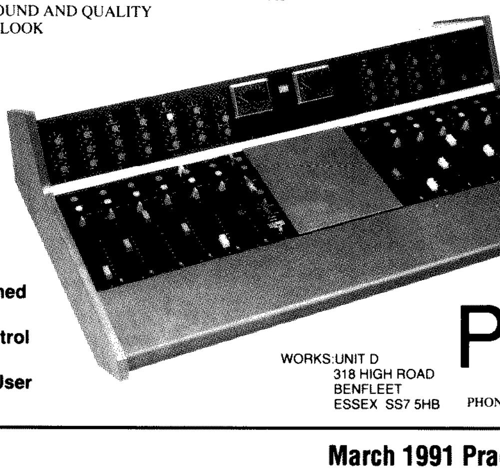

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PRACTICAL ELECTRONICS
SCIENCE AND TECHNOLOGY

We chart the changing face of electronics with a look at the past 25 years of PE.

March 1966

Priced at 2/-6d, the March 1966 PE was a special issue featuring printed circuit boards and how to make them. Of the seven constructional projects, the most novel modulated an RF carrier with the output from a guitar allowing it to be played back through an AM radio. In the editorial, mention was made of how pay TV had just started in Westminster and Southwark in London. This allowed viewers to pay cash in advance for each program they watched and was considered quite a novel idea if unlikely to get very far.

1976

The constructional projects this month 15 years ago were a synchronome (an electronic metronome), a car/caravan clock, a peak level indicator and a total harmonic distortion filter allowing measurement of THD from 100Hz to 1kHz. The Industry Notebook column mentioned that the European Space Agency (ESA) was performing feasibility studies on direct colour TV reception from satellites – something now taken for granted. A PE kit report examined the Sinclair Black Watch. At £14.95 this was a build it yourself digital wristwatch which gave hours and minutes or minutes and seconds in red numerals on its black display. These days the technology is so cheap that better watches than this are given away with petrol.

1981

In 1981, PE looked at the Cegmon machine code monitor for the UK101 computer, one of the very first kit computers available to hobbyists. An interesting topic in the patents review section concerned that holy grail of electronics, 3DTV. The first patent, filed by the Marconi Company, used a camera with two lenses and cross polarised LCD filters. The second, by one William Etra of Oakland, California, described a system to process normal 2D images to 3D using colour fringing. For all of this activity, even in the 90's no one has yet produced a commercial system though patents are still filed quite frequently.

1986

Barry Fox's Leading Edge described how the now famous Cable News Network (CNN) reached Britain via satellite links. However, not too many people were receiving it as the government was only just getting around to licensing satellite dishes – a complete home system cost in the region of £2000. Projects included a Spectrum hardware restart, clock timer, fibre optic link and Amstrad I/O. ■

Computer Aided Design

Kenn Garroch looks at designing PCBs on an IBM compatible computer using the CAD packages BoardMaker 1 and 2..

With IBM PC type computers becoming so cheap – a PC XT now costs as little as £500 – many people will at last find it worthwhile to buy one for word processing, small databases, perhaps spreadsheets and a little programming. Anyone who is interested in electronics and wants to design printed circuits boards (PCBs) will find another use for their PC: computer aided design (CAD).

There are a number of PCB CAD packages available for PCs covering a whole range of capabilities. Board Maker from Tsien (pronounced 'syen') is a middle of the range package that comes in two forms. Version one provides the basic facilities for designing circuit schematics and PCBs using libraries of standard components. Version two expands on this to provide a number of extra utilities as well as an autorouter. This takes a basic design and automatically routes the PCB tracks from component to component, saving a lot of time and effort.

Getting started

Installing Board maker is pretty much the same for both versions and the package should work on any PC that is 100% IBM compatible – in other words virtually all PCs. Board Maker comes in two versions, and for both setting up is simply a matter of putting the relevant floppy disk into the drive, and typing INSTALL at the prompt. Since it is more expensive version two comes with a dongle. This is a piece of hardware used to protect the software from being copied. In practice, the software can be duplicated very easily, simply by copying the disks with the DOS diskcopy command – which should be done anyway in case something happens to the originals. As there is only one dongle and making another would prove difficult, the software can only be used on one machine at a time, effectively copy protecting it.

Although the package can be installed on a dual floppy disk machine, the best performance is gained by installing it on a hard disk. This is automatically done by a program which sets up all of the files, directories and programs as needed. The next step is to type BM at the prompt to start the program up giving access to the PCB, schematic and library editors.

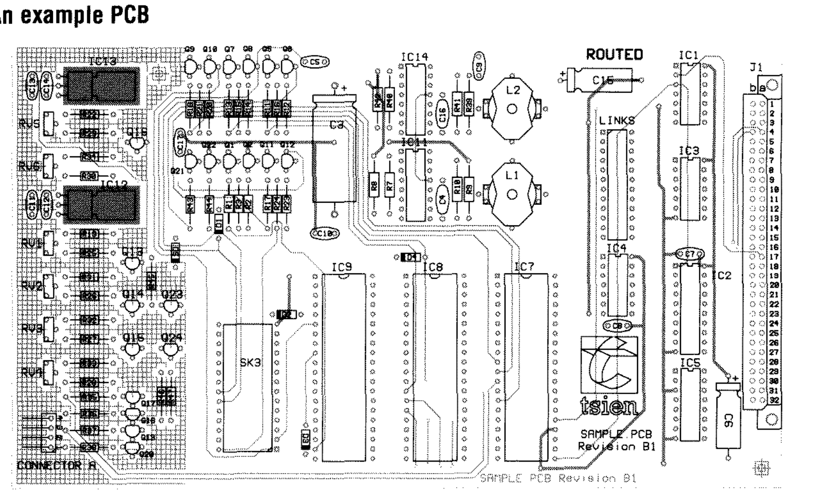
Board Maker can be operated in three main ways, using the arrow keys (or numeric keypad) to move the cursor around the screen and return to pull down menus, or with a two button mouse to control the cursor and menus. Alternatively, most of the commands have keyboard shortcuts, especially for those which are most frequently used.

The quality of the display depends on the type of display hardware available on the PC. Most systems will support CGA (Colour Graphics Adapter) or EGA (Enhanced Graphics Adapter) though the best results can be seen with a VGA (Versatile Graphics Adapter). Version one of Board maker only supports these three. Version two can also cope with Hercules and MCGA (Multi Colour Graphics Adapter) though the former does have trouble with one of the printout selection screens. By making judicious use of the zoom and pan facilities, even the simplest system provides a reasonable display.

Menus

The three sections or operating modes in Board Maker, PCB, Schematic and library editors, operate in more or less the same way. There are eight menus, File, Edit, Add, Tools, Option, Config,

An example PCB



Net(version 2 only) and Library. The last two cannot be seen on some of the display adapters but are available on the file menu as well as via a keyboard shortcut. Depending upon the operating mode, the selections available from the menus vary. For example, in PCB editing mode, it is possible to select the library menu and activate all of the functions. However, those that are not applicable give an error message. It would have been better simply to put unavailable options in dimmed text or even remove them from the menus altogether. Other menus, mainly the Options menu, change their contents depending upon the type of operation in progress.

Loading, saving, exiting and so on are available from the File menu. The Edit menu allows the four main graphics operations, track, pad, text and symbol to be altered and the Add menu is used to place new ones. Again, depending on the operating mode, other items will be added to these menus – nets in PCB mode, designators and references in library mode. There was a little confusion here in that PCB library mode added Nets to the menu and then gave an error when it was used – Tsien should look at rationalising its menu system to resolve such conflicts.

The Tools menu gives a selection of useful gadgets from block selection, zoom and highlighting, to changing the cursor type, turning the grid on and off and changing the units – inches to millimetres. Most of the selections also have keyboard short cuts and, in general, they are fairly mnemonic – Z for zoom, G for grid size and so on. Most of the tools are of the on/off type and it would have been better to separate them from those which actually provide a function such as block and zoom.

The content of the Option menu depends entirely upon the operating mode. It provides an area for extra commands. Normally it reads 'No mode selected' but as soon as, say 'add track', is invoked, it changes to provide a plethora of additional actions such as circles and arcs, shift, kill, repeat and layer control (only applicable in PCB editing). Using the Option menu in this way makes the package easy to get to grips with since basic board layouts and schematics can be done without having to use Options at all. As the user gets more familiar with the environment, all of the additional facilities become available at the drop of a menu. On the other hand, having the contents of a menu change depending on what is happening can be confusing, especially when the changes are inconsistent.

Setting up operating parameters such as track widths, pad and hole sizes, which layers should be used and the like is the job of the Config menu. In practice this is not really a menu but a setup page. When selected, the computer screen changes to text mode and reveals the current state of the settings. Once any of these have been set or altered, they can be saved in a file so that they automatically load the next time Board Maker is started up.

The final two menus are Library and Net. The first provides the user with a way to view the various component libraries. This can be done either by looking at the component names, or the actual symbols. The second menu, is not available in version one since it doesn't support Nets. However, in version two it provides facilities to hide, show, edit, import and export nets and, if the autorouter is present, run it. All of these menus can be accessed by holding down the control key and pressing the initial letter of the menu causing it to appear. This does have the effect of moving the cursor up to the menu itself since it used to make a selection. Unfortunately, it isn't returned to its original position when the menu item is selected. When using Board Maker with the cursor keys only, this is very annoying since it means that the cursor has to be tracked all the way back to its previous position, usually far from the menu – with a mouse this is not a problem and using the keyboard short cuts also sorts it out.

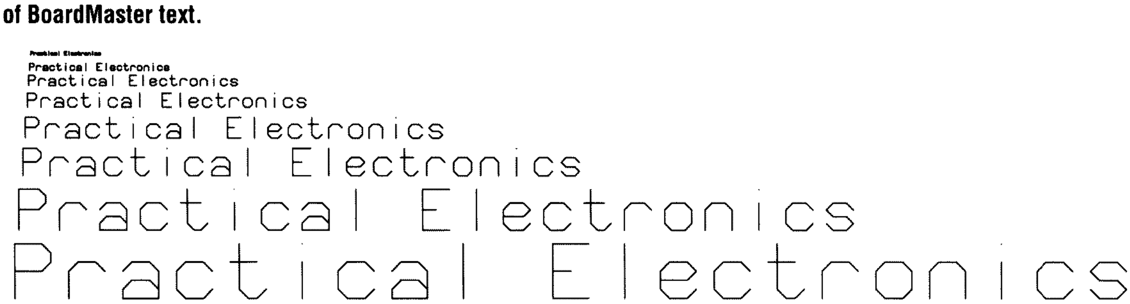
Designing Schematics

Board Maker's simplest use is in designing schematic electronics circuit diagrams. The component libraries supply many of the standard outlines such as ICs, transistors, resistors, capacitors, and so on. The computer's function keys are used for all of the basic add and edit commands. Once they are known, setting out a design is quick and easy.

The normal way to set out a schematic is to put down symbols and connect them together with tracks. The width of the tracks are set to the minimum – see examples – and using the grid, lines can be kept to neat and tidy right angles. Joins between links are defined by pads whose holes are set to the smallest possible. As well as tracks, pads and symbols, text can be added to the diagram. Each letter is actually made up from a small piece of track and there are eight possible sizes. However, there doesn't seem to be any way of adding new characters or changing the character set.

Once sections of the circuit have been set up, they can be moved or copied in sections using the block command. This also provides the ability to copy and mirror areas and even fill them – for example where a ground plane is needed. Unfortunately there is no facility to export or import blocks to and from

Examples of BoardMaster text.



disk. The edit functions also provide similar facilities for individual symbols, tracks, text and pads. With a track that consists of multiple points or nodes, the edit function allows the user to move from point to point and move or delete each one without interfering with the rest.

Designing PCBs

PCBs are set out in much the same way as schematics. The symbol library is different in that it now holds component outlines and pin positions to scale. In addition, up to eight copper layers plus upper and lower silk screen can be set up to give 10 layers altogether. Depending on the graphics screen type being used, each of these will be designated with a different colour or grey shade. The Config menu also allows these colours to be changed and turned off so that specific layers can be examined without the others interfering. Unfortunately, there is no relationship between schematics and PCBs. A schematic file cannot be loaded into the PCB designer and converted into a PCB layout.

To make the design and implementation of PCBs even easier, Board Maker version two supports nets. These are used to define portions of the circuit that are connected together and allow design rules and auto-routing to be implemented, Nets also make keeping track of the various components and connection on a board very easy. Since each electrical circuit or net can be given a name and each of its connections to a component can also be named – for example the ground net may connect with IC1 or even 7400 pin 7 – a circuit can be traced through by referring to actual device or component names and connections. Setting up a net is simply a matter of joining all of the components which connect to it together in a 'rat's nest' – just a set of point to point line connections

Design rule checking

When designing a circuit board, an important consideration is how close tracks and holes are allowed to be. If, as in most cases, the board is to be soldered up by hand, then it is best not to make the tracks too close together. The design rule check (DRC) allows the tolerances for track to track, track to pad and pad to pad to be set. If, when laying out the board, a rule is violated, the DRC puts up an alert and the problem can be solved there and then. Since it relies on nets for its operation, DRC is only available in Board Maker version two.

Kenn - The main differences between the packages upgrade paths prices and details at work.

Autorouting

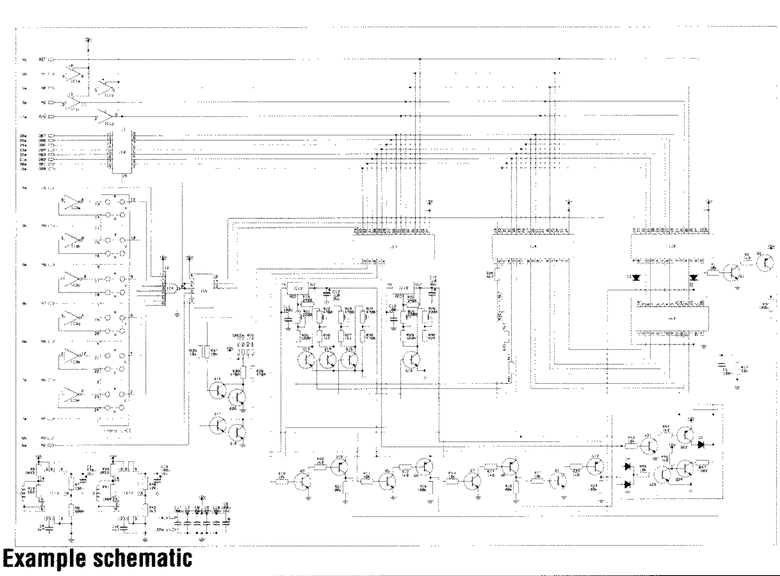
An add on available to version 2 is the autorouter. This takes a set of pre-defined nets and converts them into tracks. It automatically routes the tracks around the board from component to component. This may sound good but it does have a few drawbacks. Firstly, it can be a little slow, secondly it can't doe single sided boards and thirdly, it relies somewhat on the components being set out in a reasonable way. According to the author, single sided boards would take longer to lay out with an autorouter than they could be done manually. Because it is necessary to look ahead a large number of tracks, the microprocessors used in PC XT's and even AT's are nowhere near fast enough.

Improvements

Board Maker 1 is a pretty good buy. It takes all of the hard work out of PCB design and layout. Output is available in a number of formats, from drilling machines and encapsulated postscript to dot matrix. Version 2 while more expensive provides a few nice add ons such as networks and DRC that help with more complex boards. There are a few improvements that could be made to the system. It would be nice to be able to go from a schematic to a PCB design and then autoroute it – it would also be nice to be able to autoroute single sided boards but this probably won't be available for some time. On the more realistic side, a facility to be able to go into the library editors from the main design systems instead of having to return to the main menu every time. There is also an amazing amount of inconsistency in the user interface, especially the menus. For repetitive operation, some sort of macro definer would be a boon and the ability to define a new character set would be great.

At £95 Board Maker 1 is one of the best schematic and PCB design systems I have seen on the PC – most of the circuit diagrams and PCBs in the magazine were produced using it and until something better turns up, they will probably continue to be.

Tsien UK 0223 277777
Cambridge Research Labs
181A Huntingdon Road
Cambridge CB3 0DJ
BoarMaker 1 £95 ex VAT
BoardMaker 2 ££295 ex VAT
BoardMaker 2 with autorouter £495 ex VAT ■



Example schematic

ADVERTISERS INDEX

Barry Fox

The big switch to digital audio began ten years ago and it is now a worldwide standard. When will TV and Video go the same route?

All domestic video and TV is analogue. So-called 'digital' TV sets and video recorders convert the analogue signal into digital code for some processing stages. This makes the circuits easier to integrate and widens the choice of special effects.

Professionals now use digital video recorders, which record digital code instead of analogue waveforms onto tape. Domestic digital video recorders are expected over the next few years. But before that we are likely to see digital TV transmissions. The advantage is that by converting a TV signal into code before transmission, and drastically compressing the code, it is possible to broadcast several programmes in the frequency spectrum needed for a single analogue transmission, or transmit a high definition signal in the bandwidth allocated for conventional programmes.

When you convert a signal into digital code, the bandwidth or space needed needed to record or transmit it with error correction increases by a factor of around 50:1. But the potential for digital compression is so vast that, with modern processing techniques, the loss can be turned into a gain. The digital version of the signal takes up less space than the original. Also, whereas an analogue signal suffers visibly (or audibly) from noise and interference, a digital signal remains immune as long as the decoder is able to distinguish between wanted and unwanted bits of information.

In the UK work on digital TV is under way at laboratories now owned by National Transcommunications Ltd, formerly the IBA Engineering Division.

NTL has a research contract to try and double the number of television stations available. Mike Windram, Head of NTL's Experimental and Development Department, says that results are "very encouraging".

Currently Britain's terrestrial TV transmissions use 44 of the 48 frequencies in the UHF band to provide four services (BBC1, BBC2, ITV and Channel 4). The plan to provide a fifth service relies on releasing two frequencies currently used by domestic video, satellite and games equipment, but is foundering because the service will reach only 70% of the population and cause interference to the equipment. Whoever wins the franchise will have to pay for retuning of all affected domestic equipment, which could cost hundreds of millions.

NTL's engineers believe that by using digital coding techniques, they can slot in another four nationwide services without causing any interference.

TV transmitters must be a long way apart if they use the same frequency, otherwise viewers suffer interference. For each transmitter site there are many 'taboo' channels which cannot be used because they cause interference.

NTL's system is called SPECTRE (Special Purpose Extra Channels for Terrestrial Radiocommunication Enhancements) and converts TV pictures into compressed digital code before transmission. The code is then broadcast from the same transmitters as the PAL analogue broadcasts, but at much lower signal strength and on taboo frequencies.

Because the signals are weak they do not interfere with distant transmitters. Because they are digital they can still give clear pictures on any set equipped with a decoder. NTL's computer model suggests that each transmitter site could use at least four taboo frequencies without causing inteference. Viewers will be able to receive the new signals with existing TV roof aerials. The system would be ideal for subscription or pay-per-view TV services, where a decoder is needed anyway.

The difficult part is to squeeze enough bits per second into Britain's standard TV channels, which are 8MHz wide. NTL's starting brief was that that the must be no loss of quality compared with analogue transmissions.

When a PAL TV signal is directly converted into digital code the resultant data stream runs at 216 Mbit/s. Clearly there is no hope of transmitting this in an 8 MHz channel without compression.

The system used is called DCT, Discrete Cosine Transform, with motion compensation, temporal interpolation and predictive coding. To cut a long, complicated story short, the DCT encoder breaks each picture down into blocks, compares them in successive pictures and records how they differ. The less change there is, the larger the blocks can be, with less code needed to describe them.

The encoder also describes and predicts how block patterns move from picture to picture. Imagine an actor moving across the screen. His shape is coded once, but then only the position on screen which he occupies is coded, along with any change of shape caused by changing perspective.

The system interleaves full reference or key frame pictures with partially coded pictures which contain only updating information. The ratio of key frames to updating frames can be fixed or vary with the programme material. The digital code adapts itself to the amount of information to be recorded, with the size of the coding steps changing according to the picture.

Using these techniques NTL has achieved a compression factor of 18:1. With digital stereo sound, and error correction, this gives a total data rate of 13.5 Mbit/s. By using multi-level phase shift keying to modulate the transmitted carrier with the code, NTL can fit it all into one 8MHz channel. On Air tests are expected to begin in 1992. ■

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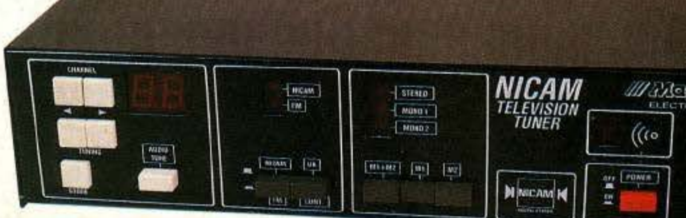

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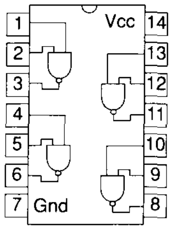

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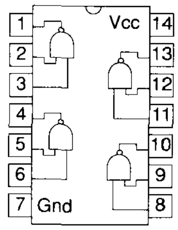

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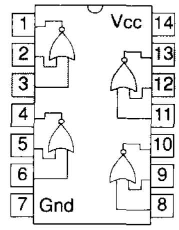

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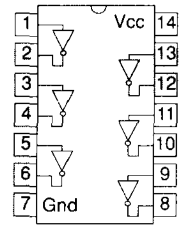

Hex inverter
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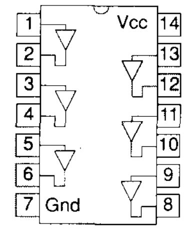
06ochv
16ochv 1004b
1005b



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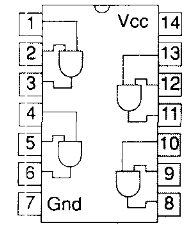

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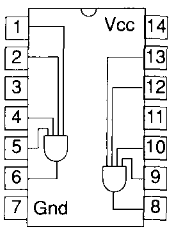

Dual 4 i/p
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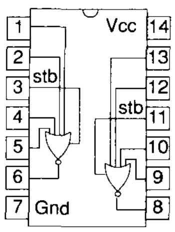
21



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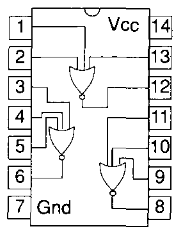

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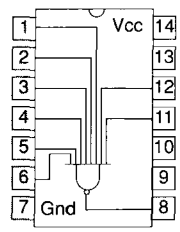

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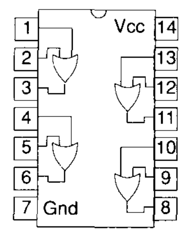

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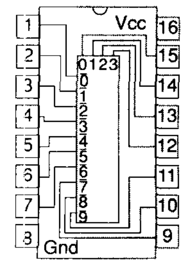

BCD to
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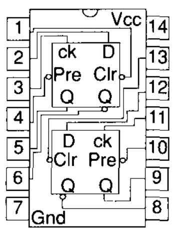
decoder
42



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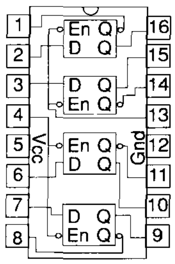

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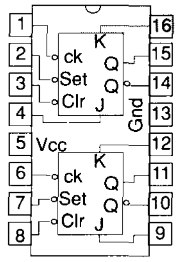

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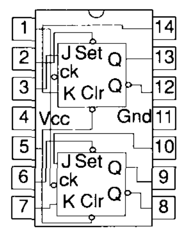

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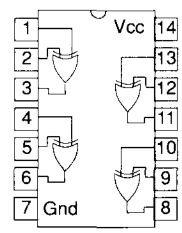

Quad 2 i/p
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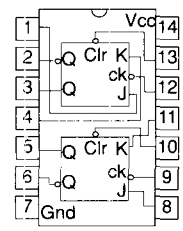
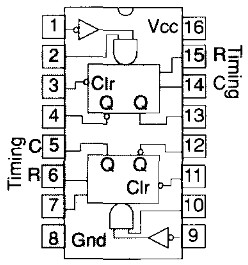
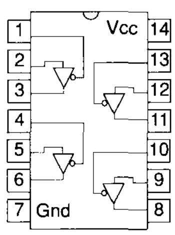


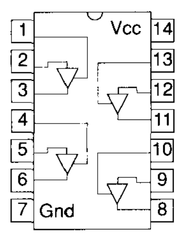
Dual JK
bistable
107



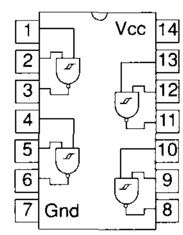
Dual Re-triggerable
monostable
123



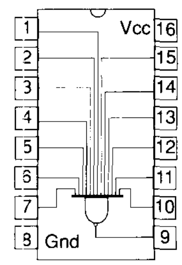
Quad tri-state buffer
with invert controls
125



Quad tri-state
buffer
126



Quad 2 i/p
Schottky NAND
132



Single 13
input NAND
133

Logic Gates

Buffer
in out

in	out
0	0
1	1

Inverter
in out

in	out
0	1
1	0

OR
in 1
in 2
out

in1	in2	out
0	0	0
0	1	1
1	0	1
1	1	1

NOR
in 1
in 2
out

in1	in2	out
0	0	1
0	1	0
1	0	0
1	1	0

AND
in 1
in 2
out

in1	in2	out
0	0	0
0	1	0
1	0	0
1	1	1

NAND
in 1
in 2
out

in1	in2	out
0	0	1
0	1	1
1	0	1
1	1	0

Exclusive OR
in 1
in 2
out

in1	in2	out
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive NOR
in 1
in 2
out

in1	in2	out
0	0	1
0	1	0
1	0	0
1	1	1

TTL Types

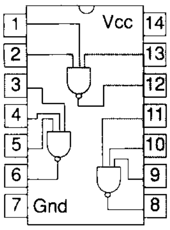
Standard transistor transistor logic (TTL) is built using bipolar technology which is based on NPN junctions. This gives high speed but consumes quite a lot of power. The time taken for the signal to traverse a gate, the gate delay, is normally around 15ns. The supply current per gate is 4mA but other types of fabrication improve on this considerably.

Low power TTL, denoted by an L in the device number (74L), operate at much lower power than standard TTL. Unfortunately, the gate delays are longer. The typical gate delay is 90ns with a power consumption of 0.5mA.

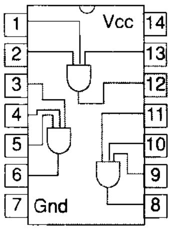
Schottky TTL is another improvement on the original design that gives much higher speed. Gate delays are in the region of 7ns but power consumption increases accordingly to 6mA per gate.Schottky TTL can operate at switchin 125MHz. Devices using this technology have a numbers – 74S.

To get around the high power consumption pr standard Schottky a low power version is avail delays for this type of chip are 15ns but the pc reduced to 0.4mA. Low power Schottky has ar device numbers. Another improvement is the a Schottky (74AS) which runs approximately twi with half the power consumption.

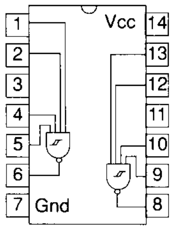
For applications that requiure very fast switchi (74HS) can be used. Gate delays are typically consumption 5mA per gate.



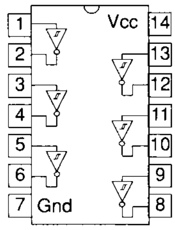
Triple 3 i/p NAND
10 12oc
1010b



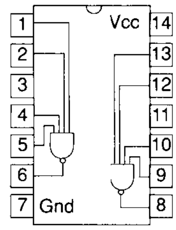
Triple 3 i/p AND
11 15oc 1011b



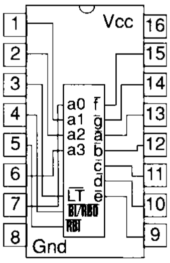
Dual 4 i/p Schottky NAND
13



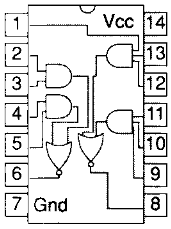
Hex Schottky inverter
14



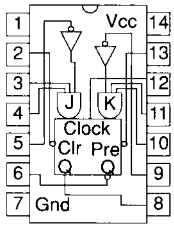
Dual 4 i/p NAND
20 22oc 40b
140 1020b



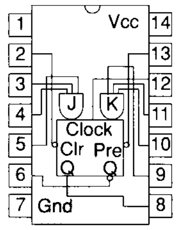
BCD to 7 segment decoder
47ochv 48



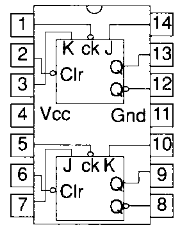
Dual AND OR Invert
50 51



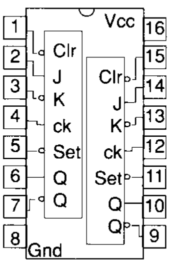
Single JK bistable with inv i/p
70



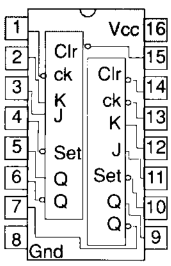
Single JK bistable
72



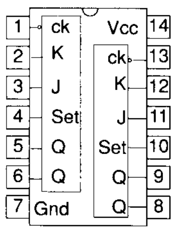
Dual JK bistable
73



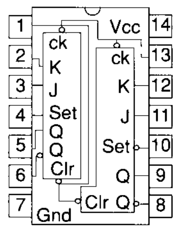
Dual JK bistable
109



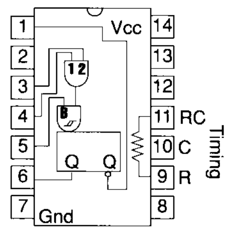
Dual JK bistable
112



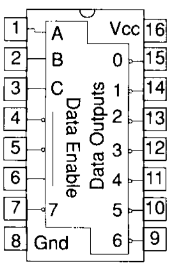
Dual JK bistable
113



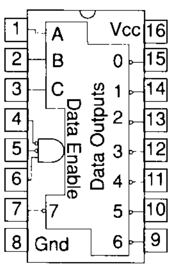
Dual JK bistable
114



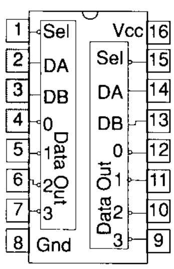
Monostable
121



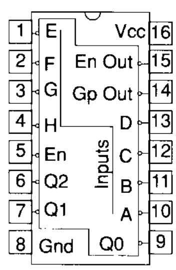
3 to 8 line decoder
137



3 to 8 line decoder
138



Dual 2 to 4 line decoder
139



8 to 3 line octal encoder
148

PRACTICAL
ELECTRONICS
SCIENCE AND TECHNOLOGY

Key
oc Open Collector
b Buffered
hv High Voltage

g speeds up to
an S in their

oblems of
lable. Gate
wer per gate is
n LS in the
advanced
ce as fast but

ng, high speed
6ns and power

TTL Specifications

The fan out or number of inputs that can be driven from an output is 10. The power supply must remain within 5% of 5V. Decoupling capacitors of about 0.1μF should placed across the supply lines for every four to five chips.

Standard TTL
Supply Voltage 4.75V to 5.25V
Input

low	+0.8V max, -1.6mA
high	+2.0V min, 10μA

Output

low	+0.4V max, 16mA
high	+2.4Vmin, -400μA

Low power
Supply voltage 4.75V to 5.25V
Input

low	+0.7Vmax, -0.18mA
high	+2.0V min, 10μA

Output

low	+0.3Vmax, 2mA
high	+2.4Vmin, -100μA

Schottky
Supply voltage 4.75V to 5.25V
Input

low	+0.8V max, -2mA
high	+2.0V min , 50μA

Output

low	+0.5V max, 20mA
high	+3.4V min, -1mA

Low power Schottky
Supply voltage 4.75V to 5.25V
Input

low	+0.8V max, -0.4mA
high	+2.0V min, 40μA

Output

low	+0.5V max, 8mA
high	+2.45V min, -400μA

High speed
Supply voltage 4.74V to 5.25V
Input

low	+0.8V max, -2mA
high	+2.0V min, 50μA

Output

low	+0.4V max, 20mA
high	+2.4V min, -500μA