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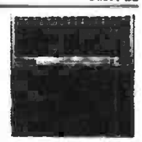

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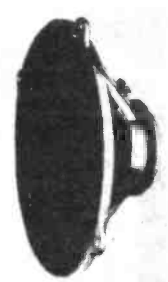

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everyday electronics

PROJECTS THEORY...

SOMETHING IN THE AIR

Change is the keynote for this time of year. Autumn is not however just trees turning beautiful hues, or television broadcasters launching new programmes. For those who have a really keen nose, there is a whiff of hot solder-flux in the air as irons warm up in their thousands throughout the land.

There are other tell-tale signs for the perceptive onlooker to note. Like the eager rummaging of junk boxes—those nondescript containers of components which will have miraculously reappeared from their summer hiding places. And the cleaning up of work-benches or, just as likely, the determined pressing of claims for a corner of the kitchen table.

In short, for thousands of constructors the word is go man, go! The most fruitful months lie immediately ahead.

The EVERYDAY ELECTRONICS reader is likely to be in the fore of all this bustle. He or she will by now have tackled the hors d'oeuvre presented last month and be eagerly seeking out the main course. Something fairly substantial to get the teeth into. The problem is deciding *which* project to go for first.

A CLEAR VIEW

No such problem arises if one is an astronomer. This month's *Clear Sky Indicator* is tailor-made for star gazers. Of general interest will be the fact that this project is actually the second of our specially commissioned designs instigated by a reader's request. So far as we are aware, the *Clear Sky Indicator* is an entirely new device. It is another excellent example of what can be achieved by the circuit designer once he is given a challenge.

Incidentally, our previous allusion to the joint enterprise between readers and EVERYDAY ELECTRONICS designers brought forth a further selection of thought-provoking ideas. All are being investigated, and designs will be appearing in our pages from time to time. (Like next month, to drop a hint.)

We are naturally delighted with this feedback and for the very positive and enthusiastic endorsement of our theme "Together We'll Make It". Make no mistake, this two-way exchange is great. It encourages—inspires is more accurate—our designers. It makes our function all the more rewarding. And we are sure the results are most warmly received by constructors.

Fred Bennett.

Our December issue will be published on Friday, November 19
See page 587 for details.

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VOL. 5 NO. 11 NOVEMBER 1976

CONSTRUCTIONAL PROJECTS

GENERAL FEATURES

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We are unable to supply back copies of Everyday Electronics or reprints of articles and cannot undertake to answer readers' letters requesting modifications, designs or information on commercial equipment or subjects not published by us. An s.a.e. should be enclosed for a personal reply. Letters concerning published articles should be addressed to: The Editor, those concerning advertisements to: The Advertisement Manager, at the address shown opposite.

Binders for volumes 1 to 5 (state which) are available for £2·10, including postage, from Post Sales Department, Lavington House, 25 Lavington St., London SE1 OPF

NEXT MONTH

Party time Projects!

SEE PAGE 587

CLEAR SKY INDICATOR

By A. J. BASSETT.

IN the field of practical astronomy, one of the most irksome and frustrating occupations must surely be that of repeatedly checking the weather in the hope of conditions suitable for the making of clear observations.

TIME SAVER

An automatic clear sky detector with remote indication facilities would obviously save the student of the skies many a frustrated journey to the telescope—only to find that cloud or haze is making observation difficult or impossible. Such a device could indicate the degree of obscurity on a meter which could be placed in a convenient position for easy observation.

The astronomer could then see at a glance whether conditions were right, and save a lot of time and wasted journeying. Just in case, at the time when weather conditions were favourable, the observer omitted to notice this either directly or on the meter, an electronic bleep signaller, or a flashing lamp, could be arranged to draw his attention so that such favourable conditions might not be wasted. Of course, the really keen astronomer might arrange to have an electronically controlled alarm by his bedside!

DIFFERENTIAL THERMOMETER

The author has considered a number of methods by which a clear sky might be detected and indicated using electronic means.

One suggested method would have utilised a differential thermometer circuit to monitor the difference between air-temperature and ground surface-temperature, since it is known that during conditions of heavy cloud cover the temperature of the ground surface tends to come closer to the temperature of the air.

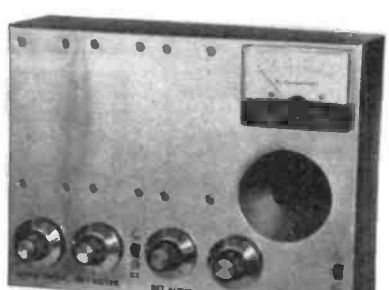
An "artificial ground" of low thermal capacity could be constructed to give rapid indication of changes, as, when the sky becomes clear, the temperature differential between air and ground increases markedly. This is because the ground can, in clear conditions, lose heat rapidly by means of infra-red radiation. In cloudy conditions this radiation is confined by reflection from the clouds, and other effects, and losses are not rapid.

However, this temperature-differential method suffers a number of drawbacks. One is inaccuracy. Because certain types of haze and cloud are virtually transparent to infra-red rays, but not to visible light, a clear sky detector based on infra-red radiation might only be of use to an infra-red astronomer, as it would give an indication of a clear sky, at times when mist or haze might impede viewing by the visible wavelengths.

Another problem is that, even with temperature-sensors of low thermal capacity, there would be a time-lag during which valuable observation-time might be lost before the detector gave an indication of favourable conditions.

REFLECTED LIGHT

Obviously it would be better to have a clear sky detector which uses as its operating-medium the same wavelengths we wish to use for observation purposes—or at least some wavelength within the visible spectrum. It would also be useful to have a detector which gives an instant indication, with no significant delay, and the instrument to be described by the

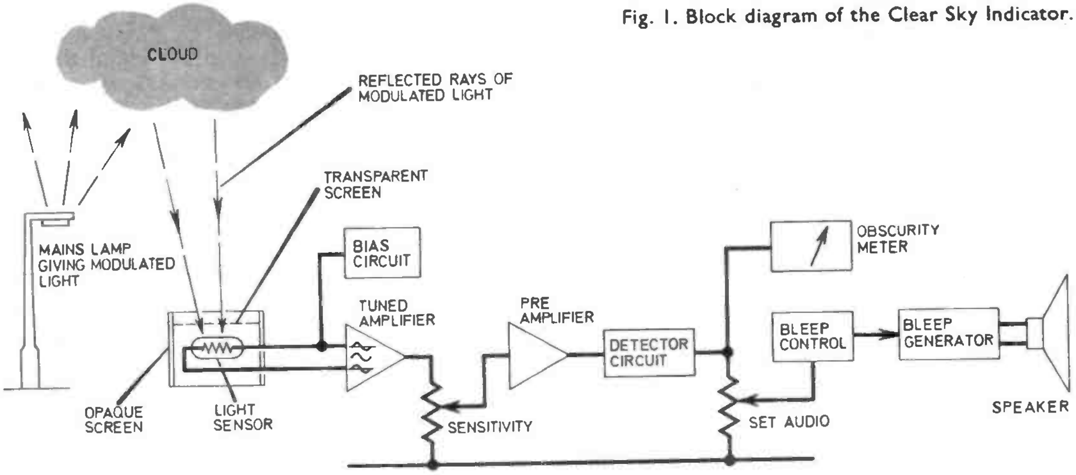


THE VERY IDEA

The idea for a Clear Sky Indicator was proposed by Mr. N. James of Weston-Super-Mare who receives our special award.

IT IS THE THOUGHT THAT COUNTS

Fig. 1. Block diagram of the Clear Sky Indicator.



author does this by detecting light which has been scattered or reflected by particles in the atmosphere.

The fewer the particles of dust, mist, fog, rain, hail, snow, atmospheric pollution and smoke, the less the light will be scattered and reflected and the clearer the sky for observational purposes.

There are a number of possible ways in which instruments might be built for the purpose of distinguishing between light which has been scattered by atmospheric particles, and light which has not been so scattered, and some of these are both costly and complex.

A simple and effective method, requiring only a modest financial outlay has been found, and should prove to be a worthwhile investment for both individual astronomers, and astronomical clubs in most circumstances.

This method relies on the detection of light from street lamps, or any other suitably modulated and powerful artificial light source. Light from street lamps and most artificial light sources can be easily distinguished and detected by electronic means. This is because it is modulated at a multiple of the supply frequency, and in the British Isles, where the supply frequency is 50Hz, the modulation frequencies which usually predominate are 100Hz and 300Hz.

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BASIC SYSTEM

If a light sensor connected to a circuit timed to 100Hz is pointed at the sky, the output from the tuned circuit will depend upon the amount of artificial light reflected back from atmospheric impurities, and particles. Fig. 1 shows a block diagram of the system.

The light sensor, which may be a cadmium sulphide cell, a cadmium selenide cell or a suitable photosensitive transistor or diode, is protected from the direct rays of artificial lighting by a black-painted screen or surround.

It receives light from the sky, including any artificial light which may be reflected by atmospheric particles or cloud.

The sensor is likely to be situated in the open, on the observatory roof or in a garden, and is connected by means of a length of screened wire or coaxial cable to the 100Hz tuned circuit, which may be situated comfortably indoors together with the remainder of the electronic circuitry. The 100Hz tuned circuit also acts as a sensitive amplifier. This function is to separate the 100Hz signal both from the d.c. level produced by ambient lighting and from other frequencies and to boost it to a level sufficient to operate the meter and the bleep indicator circuits.

SENSOR MOUNTING

A method of mounting the light-sensor in a black-painted metal container such as a tin-can is shown in Fig. 2. The container is first well cleaned and any hazardous sharp edges removed. A hole is made near the bottom of the container for cable entry using a P.V.C. or rubber grommet, and then it is painted inside and out, all over first with Kurust rust-preventive paint, then with blackboard or matt black paint. If the black is insufficiently bound to withstand the weather, a coat of tough outdoor quality varnish may be used finally.

In areas where there is plenty of outdoor artificial lighting, as from a nearby town or major road, an inexpensive cadmium sulphide photosensitive resistor, (a type ORP-12), may be used.

It is mounted in place by soldering to a length of tagstrip or connecting block screwed to the base of the container. One terminal is connected to the inner wire, which is also connected to the metal of the container. The container then serves three purposes: Protection of the photocell from direct artificial lighting; electrical screening; partial protection against weather.

The cable is secured inside the container by means of a cable-clamp, and the point of entry through the grommet, and the area around the grommet protected by an application of black outdoor-grade sealing compound such as Black Bostik.

WEATHER PROTECTION

An additional piece of hard-

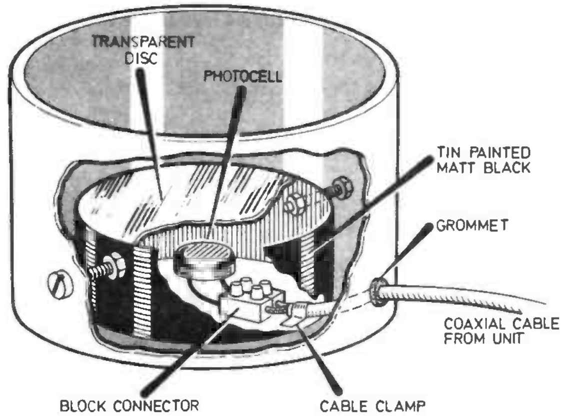


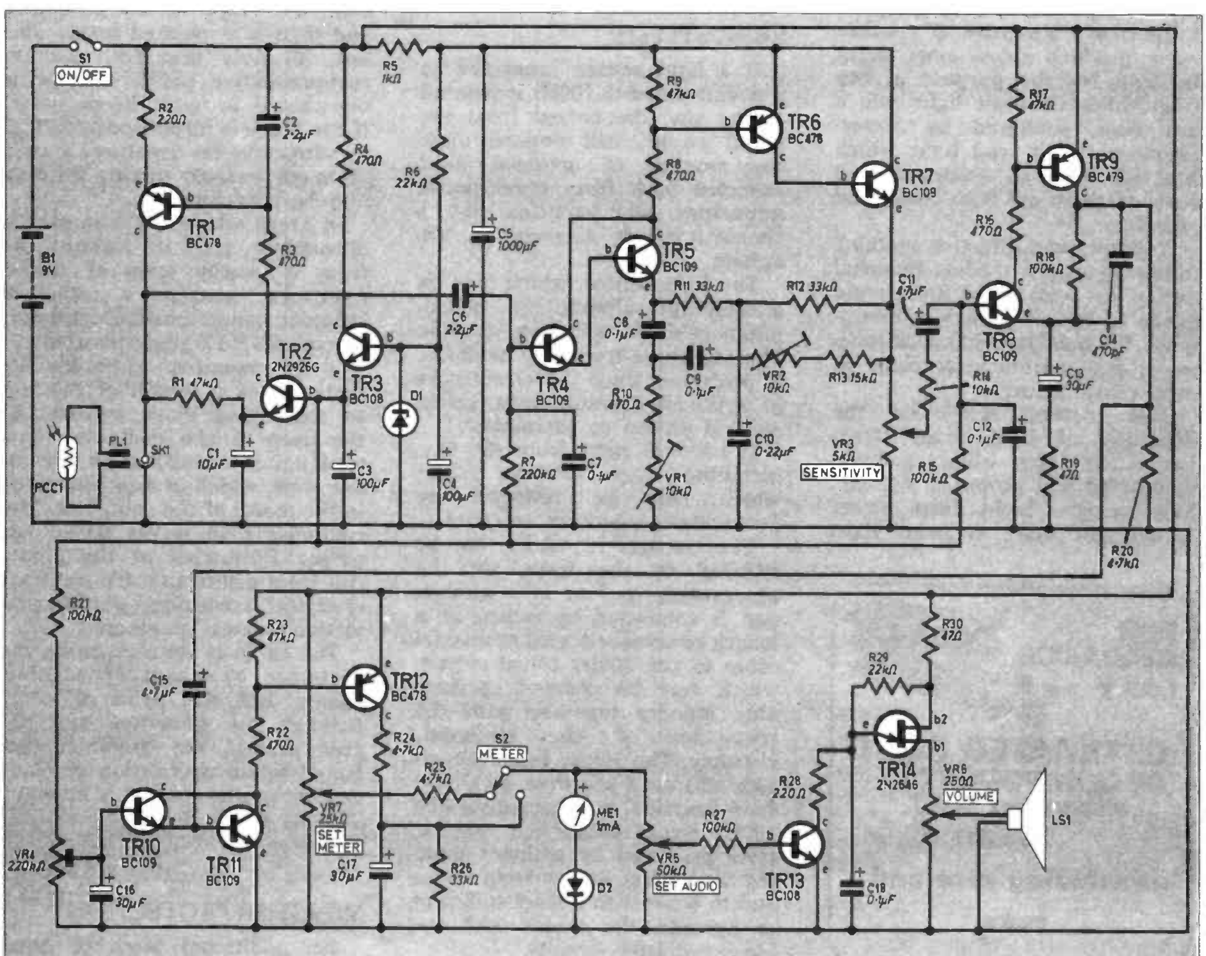
Fig. 2. Mounting arrangements for the photocell.

ware designed to slip over the top of the photocell-container for protection against dust and rain can be made from a metal container of slightly larger diameter than that containing the photocell, and open at both ends. A disc of clear glass or plastic is fitted over one end of the photocell housing. This disc is surrounded by the further cylindrical piece of metal to prevent entry of light from the sides. This piece may be fastened to the metal tube which carries the disc, by means of three screws or brackets, and all metal parts painted in the same way as the photocell container.

This method of protection against rain has a number of advantages. If a polythene sheet were tied over the container, as protection against rain, or a plain flat piece of glass rested on top, artificial light would be likely to enter by scattering from the glass or polythene, and also there is greater danger that water might leak back in.

In most areas a disc of glass or clear plastic should be satisfactory, but in difficult areas where there is not much outdoor artificial lighting a disc of clear quartz would be better as this transmits a wider spectrum. Also in difficult areas, improvement may be made by using, instead of the cadmium sulphide cell, a photo-sensitive cell of cadmium

Fig. 3. Circuit diagram of the Clear Sky Indicator.



selenide, or else a photo-sensitive transistor or diode.

CIRCUIT

Now to consider what goes on at the other end of the screened cable, Fig. 3, is the circuit diagram depicting a practical realisation of the block diagram of Fig. 1, in terms of readily available electronic components.

Transistors TR1, TR2 are parts of a bias circuit which controls the bias necessary to use the photocell, in a way in which will ensure good sensitivity to 100Hz modulated light under a wide range of lighting conditions.

Transistor TR3, together with Zener reference diode D1 provides a steady reference voltage for the photocell bias circuit, and also for the pre-amplifier and tuned circuit, with resistor R4 limiting the current through TR3 to prevent damage when C4 charges.

Transistors TR4, 5, 6, 7, together with associated components, from a tuned circuit which may be readily tuned to 100Hz. Although this circuit may appear to be fairly complicated, and much simpler circuits can be built which will readily be tunable to 100Hz, the author found that in practice this circuit gives good results.

From the tuned circuit the signal passes via sensitivity control VR3 to a pre-amplifier TR8, 9 which raises level sufficiently to feed the meter driver circuit TR10, 11, 12.

The output of the meter driver feeds a smoothing capacitor C17 which not only helps to prevent the meter movement from undergoing vibration at 100Hz but also provides a smoothly varying voltage whose level is monitored by the audio generator circuit TR13, TR14.

The voltage across C17 is dependent upon the signal received by the photocell, and as this voltage drops below a certain level the alarm tone will sound. It is possible to set the level at which the alarm sounds by means of VR5, to give an audible indication of clear sky conditions.

CONSTRUCTION

Most of the circuit is constructed on three similar pieces of 0·15 inch matrix Veroboard each measuring 10 strips by 25 holes as depicted in Figs. 4, 5, and 6. The more skilled constructor who seeks miniaturisation may use 0·1 inch matrix Veroboard and following the same diagrams.

Assembling of the components on the three boards is fairly straight forward and should present few problems, however, a couple of points may be worth

Components

Resistors

R1	47kΩ	R16	470Ω
R2	220Ω	R17	47kΩ
R3	470Ω	R18	100kΩ
R4	470Ω	R19	47Ω
R5	1kΩ	R20	4·7kΩ
R6	22kΩ	R21	100kΩ
R7	220kΩ oxide	R22	470Ω
R8	470Ω	R23	47kΩ
R9	47kΩ	R24	4·7kΩ
R10	470Ω	R25	4·7kΩ
R11	33kΩ	R26	33kΩ
R12	33kΩ	R27	100kΩ
R13	15kΩ	R28	220Ω
R14	10kΩ	R29	22kΩ
R15	100kΩ	R30	47Ω

All ¼W ±10% carbon except R7

Capacitors

C1	10μF elect. 10V	C10	0·22μF 35V tantalum
C2	2·2μF 35V tantalum	C11	4·7μF 35V tantalum
C3	100μF elect. 10V	C12	0·1μF 35V tantalum
C4	100μF elect. 10V	C13	30μF elect. 15V
C5	1,000μF elect. 10V	C14	470pF ceramic disc
C6	2·2μF 35V tantalum	C15	4·7μF 35V tantalum
C7	0·1μF 35V tantalum	C16	30μF elect. 15V
C8	0·1μF 35V tantalum	C17	30μF elect. 15V
C9	0·1μF 35V tantalum	C18	0·1μF 35V tantalum

Potentiometers

VR1 10kΩ skeleton preset
VR2 10kΩ skeleton preset
VR3 5kΩ log. carbon
VR4 220kΩ skeleton preset
VR5 50kΩ lin. carbon
VR6 250Ω wirewound
VR7 25kΩ lin. carbon

Semiconductors

TR1 BC478 silicon *pnp*
TR2 2N2926G silicon *npn*
TR3 BC108 silicon *npn*
TR4, 5 BC109 silicon *npn*
TR6 BC478 silicon *pnp*
TR7, 8 BC109 silicon *npn*
TR9 BC479 silicon *pnp*
TR10, 11 BC109 silicon *npn*
TR12 BC478 silicon *pnp*
TR13 BC108 silicon *npn*
TR14 2N2646 unijunction
PCC1 ORP12 photocell (see text)
D1 BZY88 6V8 (6·8V 400mW Zener diode)
D2 OA202

Miscellaneous

ME1 1mA moving coil meter
LS1 80Ω miniature moving coil loudspeaker.
B1 9V alkaline manganese battery and connecting clip
S1 s.p.s.t. slide switch
S2 s.p.d.t. slide switch
SK1 coaxial socket and plug to suit (PL1)
Veroboard 10 strips by 25 holes 0·15 inch matrix (3 off)
Chassis approx. 200 x 150 x 60mm, screened lead approx 500mm, connecting wire, knobs (4 off), 6BA fixings. TV type coax length as required, materials for photocell mounting.

See **Shop Talk** page 571

mentioning. One is in the use of the Vero spot face cutter or a drill bit to remove copper conductor at the points indicated. As there are three similarly sized boards, each with a different pattern for removal of the conductor, it is important to be sure cuts are made in the correct places. Check that the connections of each board do in fact correspond with the circuit.

The circuitry may be assembled in an aluminium box or chassis measuring approximately 200 x 150 x 60 mm, which should be readily available commercially. This size box will accommodate the three 0·15 inch matrix circuit boards, meter and controls, together with a 9 volt alkaline-manganese battery as shown in Fig. 7, or alternatively three 0·1 inch matrix boards together with a mains power-supply and voltage regulator circuit may be fitted.

MAINS SUPPLY

If a mains power supply is used be sure to keep mains wiring away from the inputs to the three circuit boards, as this would induce 50Hz hum; also keep the mains transformer away from the panel meter as the magnetic field from the transformer could upset the meter if the two are adjacent to one another.

SCREENING

Use screened audio wire for connections to the inputs of the three circuit boards, to the sensitivity control VR1 and to the photocell input socket. Television v.h.f. coaxial cable may be used to connect from the unit to the photocell.

Stranded connecting wire may be used for the remainder of the circuit.

Once the circuit boards have been wired and checked to ensure that they do provide the correct circuit they may be mounted in place using 6BA nuts and bolts, together with insulating spacers to keep the copperstrips away from the metal. Before mounting board 3, however, ensure that the negative wire of C15 can easily be disconnected and re-joined from the top of the board. This may be done by soldering this end of the capacitor to a terminal join or pin inserted in the board.

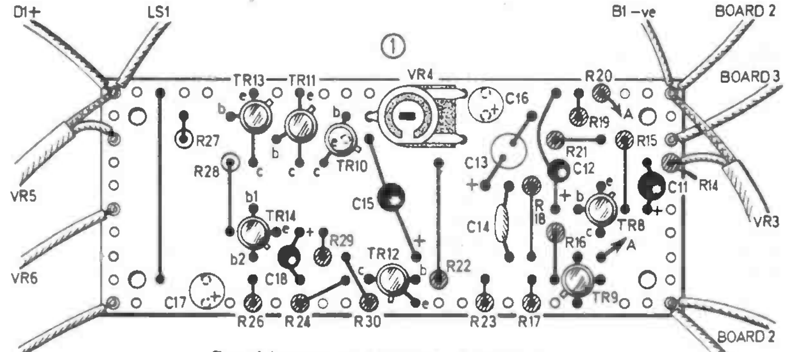
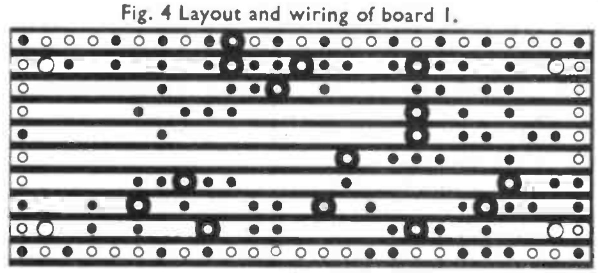


Fig. 4 Layout and wiring of board 1.



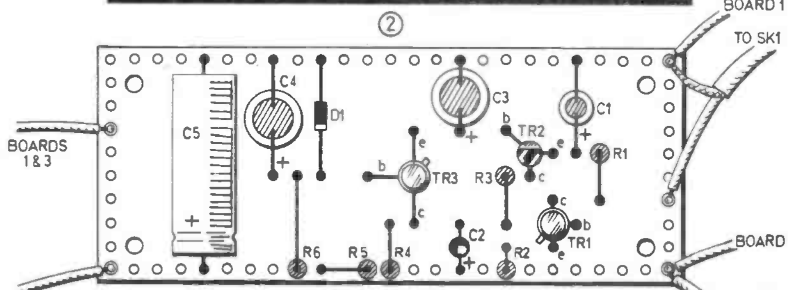
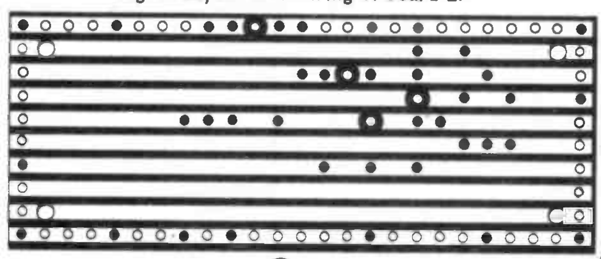


Fig. 5. Layout and wiring of board 2.



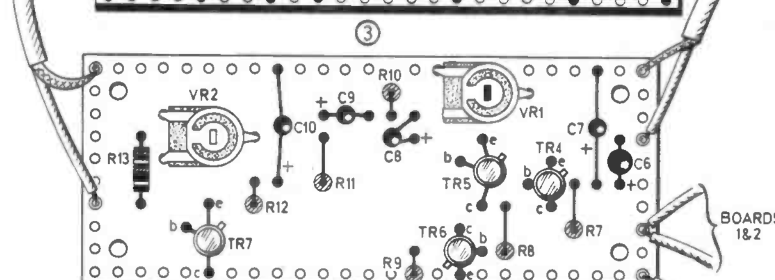
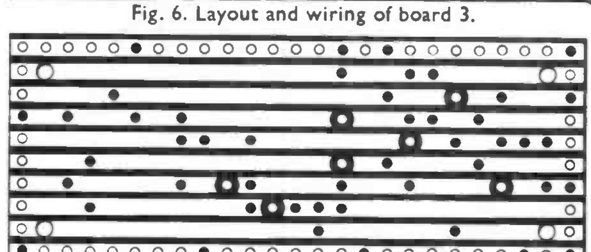
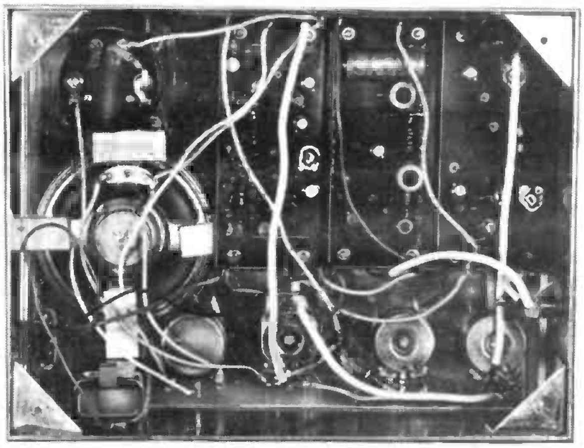
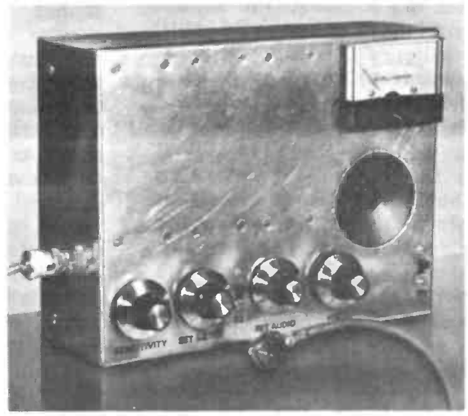


Fig. 6. Layout and wiring of board 3.



CLEAR SKY INDICATOR





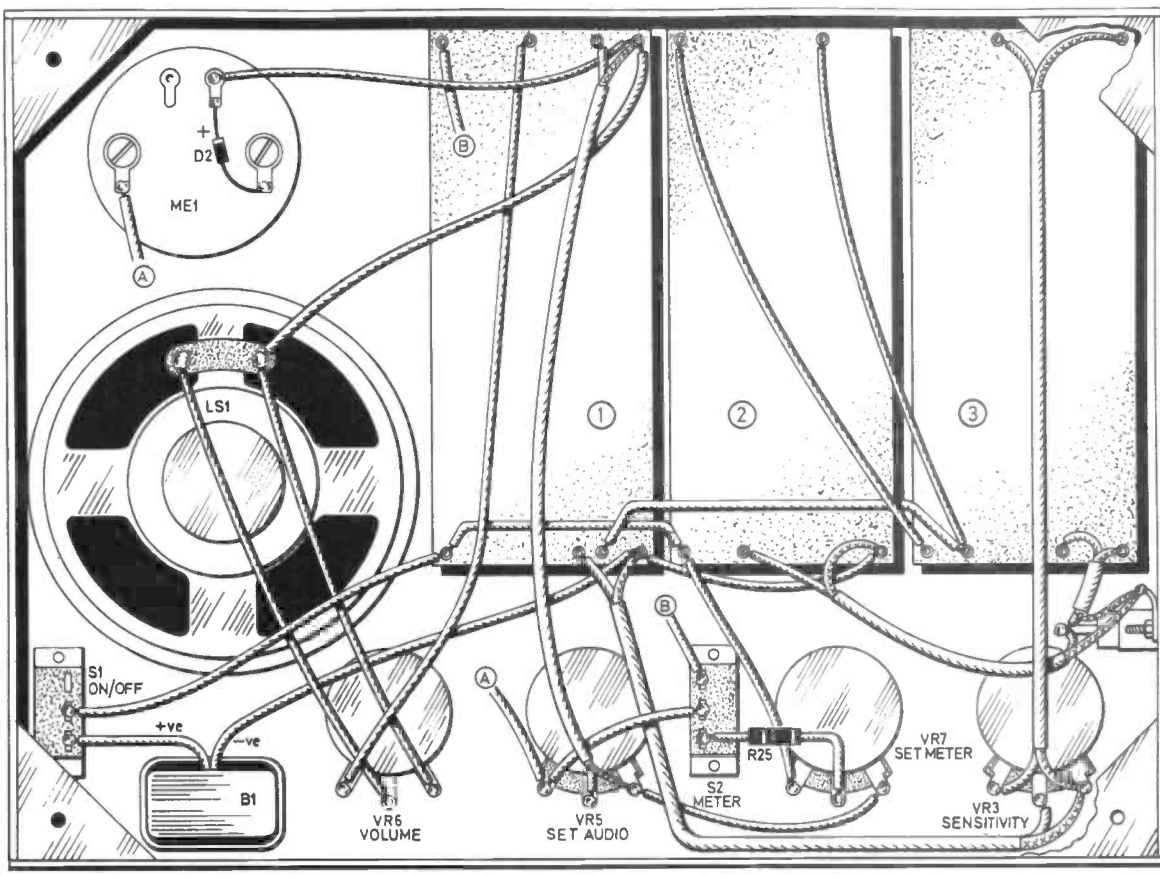


Fig. 7. Complete Clear Sky Indicator wiring.

SETTING UP

When the assembly has been completed, the preset potentiometers VR1, 2, 4, must be set to their correct positions. To set VR4 proceed as follows: Disconnect the negative end of C15 set the wiper of VR4 to its negative end, and switch on the unit. (The photocell need not be plugged in). Observe the meter, and gradually adjust VR4 until the needle, which initially is at zero, begins to move over. (If it does not respond, operate S2 and start again).

Now a point must be found where the meter will return to zero, but VR4 is set as closely as possible to the region where the meter reading begins to increase, as this will give the detector high sensitivity.

However, C16 has a delaying effect, so it will be necessary to wait a short while after each small adjustment of VR4 in order to find the best spot. Then switch off the unit, use a 100 ohm resistor to discharge C5, and reconnect C15.

To set VR1, 2 it is best to use an oscilloscope connected to the output of the tuned circuit, in order to time the circuit to 100Hz. Disconnect the photocell.

Connect the X input of the oscilloscope to the wiper of VR3 (if it is a d.c. coupled oscilloscope connection should be made using an $0 \cdot 1\mu F$ capacitor).

Connect the Y input of the oscilloscope to a 50Hz signal (which may be obtained from a low-voltage isolating transformer such as a bell transformer).

Set VR2 to minimum resistance. This should cause the tuned circuit to oscillate, and by adjusting VR3 and the gain-controls of the oscilloscope you should see a moving pattern on the screen.

If the circuit does not oscillate, adjust VR1 or reduce the value of R13 to 10 kilohms or less if necessary.

By adjusting VR1 you should be able to get a figure 8 on the screen, lying on its side, and this is a sign that the circuit is correctly tuned. As VR1 is adjusted the figure will rotate in one direction or the other. By increasing the resistance of VR2, it should be possible to stop the oscillation, and the trace will then collapse to give a horizontal line, and reappear as VR2 is once again decreased. Set VR2 to the point where the circuit only just ceases to oscillate.

OSCILLATION

Wire one end of a 100 kilohm resistor to the circuit negative, and tap the input terminal of the photocell socket momentarily with the other end of this resistor. Each time this is done the trace should appear and collapse slowly.

Adjust VR2 so that it takes about two seconds or maybe more to collapse. Adjust VR1 so that any rotation of the figure is as slow as possible. When these adjustments are complete, the circuit will be found to be timed to 100Hz, and on the verge of oscillation. In this condition it is very sensitive to any input at 100Hz, and this sensitivity will enable the instrument to detect very small inputs at this frequency.

If no oscilloscope is available then VR1 and VR2 can be set to give the best results. Do this with the photocell connected and with a remote artificial light source, e.g. internal lighting in another building. It is important that there is no source of artificial lighting near the cell. Set VR2 to mid resistance and adjust VR1 to give the highest possible reading on ME1 (backing off the sensitivity control to achieve this).

Next disconnect the photocell and adjust VR2 in the manner described above. Indication of oscillation can be achieved by setting the sensitivity control about $^1_3$ up and watching ME1 for full scale deflection. As oscillation dies away ME1 will return to zero.

Having achieved oscillation dieing away in about two seconds readjust VR1 as above.

Switch S2 to the position enabling the meter needle to be moved across the scale by means of VR7, and set a reading of $0 \cdot 5$mA (half full scale deflection). Turn up volume control VR6. Now by adjusting, VR5, you should be able to cause the audio tone to sound. By adjustment of VR5 and VR6, you should be able to cause the audio tone to sound at any chosen position of the meter needle. Leave VR5 set at the chosen position and switch back S2.

Allow a few seconds for the unit to "settle down", and the meter reading should move back to give a low reading, but its behaviour depends upon the setting of sensitivity control VR3. If VR3 is set high, noise from the components in the oscillator circuit may be expected to cause the needle to waver a little and may modulate the audio tone.

USE

Arrange the photocell to face towards any chosen part of the sky, but to be shielded from any direct rays from an artificial light. Now the photocell can only pick up 100Hz modulated light by reflection from cloud etc. in the sky.

Set VR3 to about half way, plug in the photocell and switch on. After a few preliminary excursions of the meter needle, lasting a few seconds, the unit should settle down and, as clouds pass over, reflected artificial light from them should be received by the photocell, causing the meter needle to swing over to a high current reading, and extinguishing the audio tone.

When the sky is clear, the meter reading should fall to a lower value and the audio tone should sound.

Whenever VR3 is adjusted, the unit will be upset for a few seconds, and then return to normal operation very quickly.

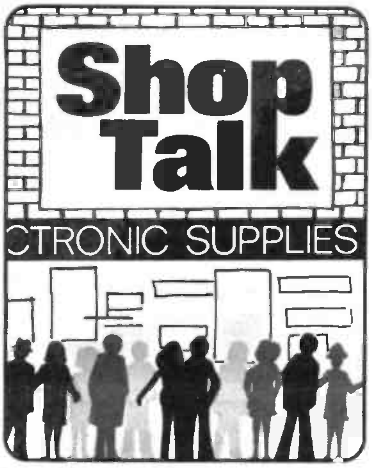
If you are using the detector in an area where there is a lot of artificial lighting, such as airport landing lights, it may be useful to reduce the sensitivity by increasing the value of R19 to 220 ohms or more.

If you find that it is necessary to increase the sensitivity beyond that which is provided with VR3 at its full setting, this may be done by reducing R19 to 10 ohms; however, it may result in a problem from increased "noise" and wavering of the meter needle.

This problem may be overcome by selecting lower-noise components for the oscillator board, especially R7, TR1, TR2, TR3 and the input capacitors.

REMOTE INDICATION

The audio signal may be heard in another room by switching over to another speaker, or if it is desired to leave the speaker in the unit connected and have simultaneous remote indication at more than one location, the speaker output of the unit may be connected to the input of a low-sensitivity audio amplifier. ⌑



By Mike Kenward

New products and component buying for constructional projects.

FROM the response we get whenever we publish anything remotely concerned with the pop music field we are sure many of our readers would be very interested in the Sound Design publication now available from our sister magazine *Practical Electronics.*

In addition to a couple of heavyweight articles—a synthesiser and electronic piano—there are six guitar and organ effects units (one which provides eight basic effects) which should be within the scope of many of our readers, plus the Orion hi fi amplifier design. The circuits used in the bigger items will no doubt find other applications and would be of interest to anyone who dabbles in this field.

The book costs £1·20 post paid and full ordering details are given on page 577.

Whilst on the subject of publications we have had two catalogues for some time now but have not had the space to bring them to your attention. The first one is from Vero Electronics and gives details of their range of boards, cases and tools, many of which will be familiar to regular constructors. The "catalogue" is worth having even if only for reference and is available direct from Vero Electronics Ltd., Industrial Estate, Chandler's Ford, Hampshire SO5 3ZR for 10p including postage and package, etc.

The second catalogue is one that looks very good but which we felt needed more than just a brief mention. This one comes from Marshall's. If you want semiconductors or i.c.s Marshall's probably carry more types in stock than any other supplier and their catalogue bears this out. In Mr. Marshall's introduction he states "we have tried to include some essential information which previously had been missing" by this we presume he means transistor and i.c. leadouts, data and Japanese equivalents.

Taking the above items in order the transistor types are each given a code number and a page of pin connection drawings are shown although originally this was almost useless, an amendment has now been printed which makes the information very worthwhile. The i.c. data and connections in most cases are good, but in some cases are pointless without a relevant circuit.

As far as the Japanese transistor equivalents go we feel this is a rather misleading title since the equivalent numbers given are all Marshall's own code numbers. Although this would enable one to buy a suitable replacement from Marshall's the information is otherwise useless and we see no point in its publication—they might as well simply say they can supply equivalents of the Japanese 2S type transistors. Or publish the type numbers with prices and say that equivalents will be supplied.

Well, as Mr. Marshall said, they "tried" and for doing that they get our praise, but if they can sort out the remaining points then at 30p this catalogue would become even more worthwhile. It also gives details of a good range of items for constructors other than semiconductors. Send 40p (including 10p postage) to A. Marshall, 42 Cricklewood Broadway, London NW2 3ET.

New Products

News of two burglar alarm systems intended for d.i.y. installation has recently come our way, both systems are interesting but it would take up far too much space to list all their points.

The first system is the simplest and contains everything for home installation in one of two kits. The AB10—door and window alarm—and the AFB15 burglar/fire alarm. These two come from Eagle International, are backed by a two year guarantee and cost £14·06 and £28·68 respectively, including VAT. The kits should be available from most electrical retailers but a list of your local stockists and a free catalogue can be obtained by writing to Eagle International, Heather Park Drive, Wembley, Middlesex HA0 1SU.

The second alarm is rather more comprehensive and in fact provides three basic systems with many options on alarms; shut down timers; magnetic, inertia and pressure contacts; window foil and personal attack buttons. The systems also incorporate facilities for heat detection and installation packs are available. Prices for the basic control units start at about £40 including VAT but to that must be added the cost of contacts, sounder etc. The simplest complete system costs £61·88 and an installation kit £9·72.

More details of the full range, which includes such items as a micro-wave radar detector and an ultrasonic motion detector, together with prices are available from Harley Security Systems Limited, 87 High Street, Alton, Hants GU34 1LG. Harley also run a free technical advice service for those fitting or considering fitting one of their systems.

P.C. Kit

Final new product this month is a d.i.y. printed circuit kit from Compstock Ltd. The kit has been aimed at development engineers but is equally suited to the home constructor because all chemicals are kept inside a sealed polythene bag while being used, thus reducing any risk of accidents. The kit comes with a p.c. etch resist pen, 10 strips of etch resist transfers, an abrasive block for cleaning boards and the etching system. Also included is a special neutraliser which, when mixed with the acid turns it into a semi-hard neutral mass which may be safely and easily disposed of.

Compstock say that the kit should etch about 10 average size boards (10 x 16 cm)—you would get many more smaller size boards. The cost is £8·25 including VAT post and packaging, but during the Internepcon Exhibition at Brighton (October 19, 20, 21) they are doing a special introductory offer of £5 per kit. Compstock Ltd., are at 42/44 Bowlers Croft, Basildon, Essex.

Constructional Projects

Although three of our projects this month contain a fair number of components· having looked through the lists carefully we doubt if any of them will provide any undue buying problems.

The semiconductors and i.c.s used should be available from the larger stockists, the most expensive being the LM3900N used in the *Enlarger Exposure Timer* and even that should only be about 60p.

One thing is worth mentioning; when buying a large number of items i.e. for the *Clear Sky Indicator*, it is as well to make sure your supplier's prices are reasonable because a small difference on a large number of items soon adds up.

D.I.D.

Doing It Digitally, or DID as we have come to know it, uses a fair number of parts for the construction of the wiring board this month and a components list for this, and for the other components used in the first few parts of the series, was given last month. We hope that a number of firms will be advertising kits of parts in this issue. If so, it should make buying that much more simple. Price—we estimate about £11·50 including the Vero case, on/off switch etc.

Try these for

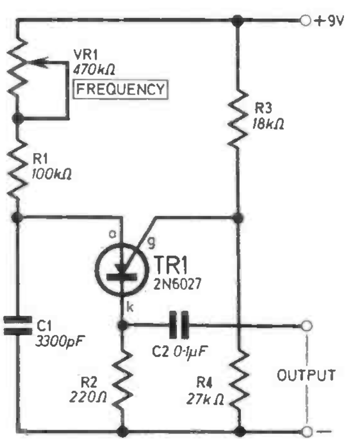
3 AUDIO OSCILLATOR

THE circuit shown in Fig. 1 is an oscillator, using only one active component—a PUT; or programmable unijunction transistor.

USES

There are several uses for audio oscillators. One is a practice oscillator for Morse Code. Another is as a "buzzer" for any unit or system requiring an audio output. An advantage of this type of oscillator as an alarm buzzer is that, by using separate switches from the positive supply to the anode of the PUT, each with a different amount of resistance in series, each alarm condition in a multiple system will give a different note—so you can easily tell which parameter should be checked.

While the oscillator will produce audible output from a 15 or 33 ohm loudspeaker, headphones (8 ohm hi-fi types) are preferred because of their high sensitivity. A further advantage in using headphones for Morse practice is that the dots and dashes will only be heard by you—maybe you think that hours of Morse sounds fine, but we doubt if your family would agree!



ESTIMATED COST OF COMPONENTS excluding V.A.T.

£0.85

For use as an alarm or door buzzer, the sound level into a speaker may not suffice, so an additional amplifier may be necessary.

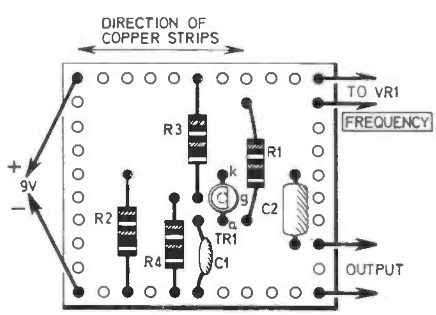
CIRCUIT

The circuit is a conventional one, the PUT being connected as a relaxation oscillator. A detailed explanation of how it works is not within the scope of this article. Suffice to say that a relaxation oscillator operates by charging a capacitor to some critical voltage the PUT then "triggers", discharging the capacitor, and the cycle is then repeated.

The frequency produced by the oscillator can be varied by means of a potentiometer included in the capacitor charging circuit. If a switch pot is used, this will save the expense of buying a separate switch for on/off.

Fig. 1. Circuit diagram of the oscillator.

Fig. 2. Layout and wiring of the oscillator.



Components

Resistors
R1 100kΩ
R2 220Ω
R3 18kΩ
R4 27kΩ
All ¼W +10% carbon

Potentiometer
VR1 470kΩ antilog carbon (see text)

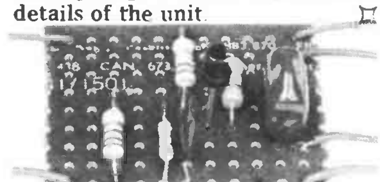
Capacitors
C1 3,300pF
C2 0·1µF

Transistor
TR1 2N6027 PUT

Miscellaneous
Veroboard 0·1 inch matrix 10 strips by 11 holes (half piece presented free with last months issue), connecting wire

The pot should ideally be an "anti-log" type—that is the opposite relationship to a conventional logarithmic type. Alternatively, you can use a log. pot. with connections reversed, the only disadvantage being that at minimum rotation, the frequency will be maximum. If you are not worried about linearity, an ordinary linear pot. will be quite acceptable.

As with other circuits in this series, the oscillator operates from a 9V supply. However, voltage is not critical, and other voltages, up to 18V, will be satisfactory. Fig. 2 shows construction details of the unit.



Starters...

4 CRYSTAL SET AMPLIFIER

THIS one stage audio amplifier should be of particular interest to those who have a simple crystal set and wish to hear stations with increased volume in the headphones.

ADVANTAGES

There are two advantages in adding an audio stage to a crystal set. The first, and most obvious, is the amplification of signals to a more comfortable listening level. The second, although not so obvious, is an improvement in selectivity; this may be obtained by reducing the aerial coupling, achieved by tapping the aerial further toward the earthy end of the coil.

This reduces the load on the tuning coil, enabling it to achieve a higher "Q", the major factor governing selectivity. Since the headphones also load the coil, a further improvement should result by reason of the higher input impedance of the amplifier, compared with most headphones, particularly the low impedance types.

The circuit uses a single BC108 or any similar small signal *npn* transistor. Output from the collector circuit may be into a set of "high impedance" headphones (2,000-5,000 ohms), or small valve-type output transformer. The transformer idea is useful, as it side-steps a supply problem with old-type 4,000 ohm headphones. It enables a set of modern "hi-fi" type phones to be used, with an added advantage of high sensitivity and better comfort.

ESTIMATED COST OF COMPONENTS excluding V.A.T.

£0.50 plus phones

CIRCUIT

Signal to the amplifier is applied to the input capacitor and earth. In exceptional signal areas, a 10 kilohm volume control could also be used. The transistor is biased by the two resistors connected to the base and by the bypass emitter resistor R3.

The input capacitor is shown on the circuit as a $0{\cdot}1\mu F$ type, mainly in the interests of economy. The circuit will work as it stands, but a higher value capacitor will give better low frequency response—particularly if good quality phones are used. A small tantalum capacitor, say $1\mu F$ 10V working, could be used, with its "positive" lead connected to the base of the transistor. ⌑

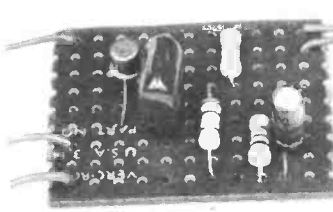
Components

Resistors
R1 68kΩ
R2 15kΩ
R3 1kΩ
All ¼W ±10% carbon

Capacitors
C1 $0{\cdot}1\mu F$
C2 $30\mu F$ elect. 12V

Transistor
TR1 BC108 silicon *npn*

Miscellaneous
TL1 2000–4000 ohm headphones (see text)
Veroboard 0·1 inch matrix 10 strips by 11 holes (half piece presented free with last months issue), connecting wire



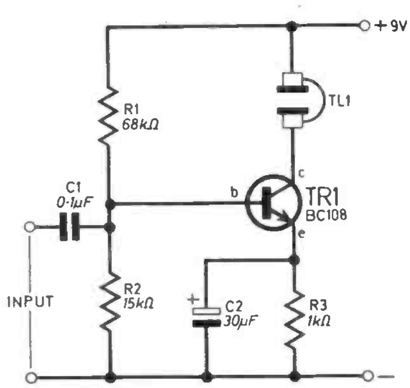


Fig. 1. Circuit diagram of the amplifier.

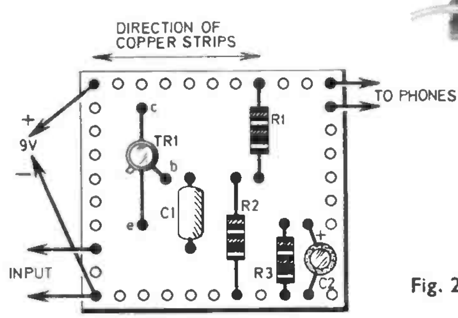


Fig. 2. Layout and wiring of the Crystal Set Amplifier.

TEACH-IN 76

By A. P. STEPHENSON

Part Fourteen

14.1 THE BISTABLE

An interesting example of a switching circuit is the **bistable** (which was invented many years ago when it was known as the Eccles-Jorden). The black-box is shown in Fig. 14.1a. It has two outputs, one called (by computer people) "Q" and the other $\bar{Q}$, called "not Q". These outputs are always in the opposite state to each other; when Q is high, $\bar{Q}$ is low and vice versa.

When the circuit is first connected the actual state is unpredictable but quite stable. The state can be changed over by a narrow trigger pulse to one of the bottom terminals. For example, the terminal marked **set** will cause Q to be high and $\bar{Q}$ low (if it is triggered); the **reset** terminal will cause $\bar{Q}$ to be high and Q low when triggered.

The title bistable is therefore very apt because the box rests in either one of two stable states called **set** and **reset.** Fig. 14.1b shows the circuit details—not a pretty sight.

Let us assume that on switching on, TR2 conducts first and is in deep saturation which of course makes the Q output voltage low. Because the base of TR1 is fed from Q there is no base current and therefore no collector current and $\bar{Q}$ is high. But because $\bar{Q}$ is high it pulls the base of TR2 upwards, which is why it is in saturation.

This very confusing chain of events can be easily summarised by stating that TR2 is held in saturation because TR1 is off. If TR1 happened to have conducted first, then it would have been held in saturation by TR2 being off.

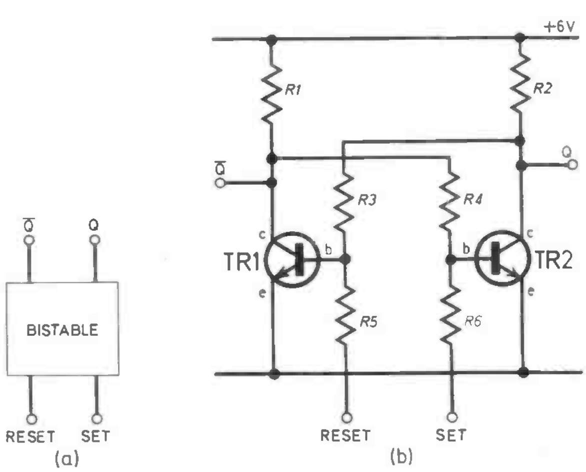


Fig. 14.1 (a) Black box bistable (b) Circuit of a bistable multivibrator.

Changing the State

Inspection of the circuit will reveal that a double positive-feedback loop exists. A change of voltage at one of the bases is inverted at the collector, passed to the opposite base, inverted for the second time and therefore arrives back at the original base in phase after being amplified twice. The circuit is therefore only stable if it is not disturbed, like a sleeping tiger. If we apply either, a negative going trigger to the transistor which is conducting, or a positive going trigger to the transistor which is off, a rapid change over action (called an **avalanche**) occurs, leaving the circuit stable again in the opposite state.

The *set* state is assured by a negative going trigger to the "*set*" terminal, (if the state was already set, nothing would have happened). *Reset* state can be assured by a negative trigger to the "*reset*" terminal. Such pulses can readily be obtained either electronically from other circuits or by switching manually from trigger terminal to ground. Bistables are in wide use in control circuitry and computers because they act as **memory cells,** i.e. they remain in (memorise) the state they were ordered to be in by a sudden pulse which could have been given months ago! They have infallible memories, providing the power is left on.

14.2 THE SCHMITT TRIGGER

The "black-box" shown in Fig. 14.2a shows a **Schmitt trigger** which is a device which converts any shape waveform to a straight-sided rectangular waveform at the output. For example if we have a sinewave and we wish to change to a rectangular wave then Schmitt is the chap for the job.

Seen in Fig. 14.2b is a typical Schmitt trigger circuit where in the resting state (no input) TR2 is conducting heavily so V_{out} is low; TR1 is non-conducting because the voltage drop across R_E is causing the emitter to be more positive than the base. Its collector is therefore high which holds TR2 on.

For example, if R_E is 2 kilohm and TR2 is drawing 2mA, both emitters are at 4 volts positive with respect to ground. The base of TR1 could be held by R1 and R2 at say 3 volts positive with respect to ground which means 1 volt reverse bias on the base.

Arrival of input

When the input waveform reaches a positive voltage sufficient to turn on TR1, a violent avalanche action causes the transistors to change state, i.e. TR1 turns on and TR2 turns off. The output therefore jumps almost instantaneously from a low voltage to $+V_{CC}$. This state is maintained until the input waveform falls again sufficient to cut-off TR1. A reverse avalanche then restores the Schmitt to its normal resting state.

To understand why an avalanche occurs, assume TR1 base rises, then its collector falls taking the base of TR2 with it. Thus the current in TR2 falls which causes TR1 to conduct harder still, which reinforces the original change. In other words we have another double amplified positive feedback loop.

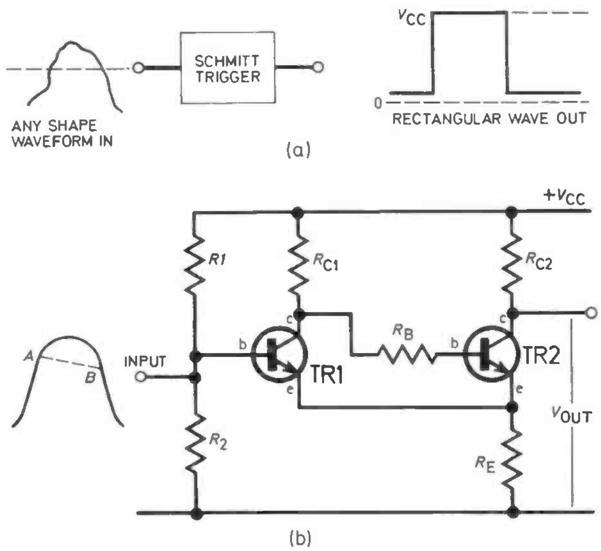


Fig. 14.2 (a) Schmitt black box (b) circuit diagram of a Schmitt trigger.

Hysterisis

The point on the input waveform which starts the avalanche, point *A* in Fig. 14.2b, and the point at which the reverse avalanche starts, point *B*, are never quite the same; the difference between these two voltages is called the **hysterisis** and can be decided by the designer.

14.3 THE ASTABLE MULTIVIBRATOR

Fig. 14.3a shows a "black box" which, you will notice, has two separate outputs available but requires no input and must therefore be an oscillator. The outputs are rectangular (but not quite so perfect as shown) and are opposite in phase to each other. A circuit capable of producing such an oscillation is shown in Fig. 14.3b and is obviously a kind of second cousin to the bistable. In fact the main difference is the capacitive coupling instead of resistive coupling between the stages.

To understand the theory of the astable we must delve a little deeper into the behaviour of capacitors to sudden changes of voltage on one of the plates. The rule is that capacitors cannot instantaneously change the voltage *across* their plates.

If for example, one side of a capacitor drops suddenly from plus 5 volts to zero volts then equally suddenly the other side must drop 5 volts downwards. i.e. if zero volts before, it will drop to minus 5 volts,

If one side of a capacitor suddenly changes voltage, the other side must instantaneously change in the same direction.

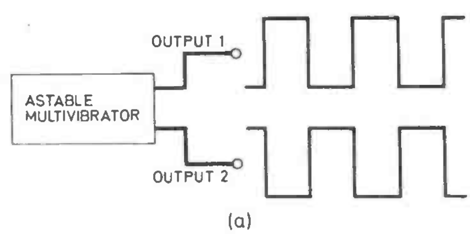


Fig. 14.3a. Black box of multivibrator and wave forms of the two outputs available.

A simple circuit and waveforms which illustrate this example are shown in Fig. 14.3c.

Resting conditions (switch open): Left hand plate of *C1* is +5 volts to ground. Base/emitter is in forward conduction which holds right hand plate of C1 at about 0·6V to ground.

Switch suddenly closed: Left hand plate of *C1* falls to ground, which must cause a corresponding

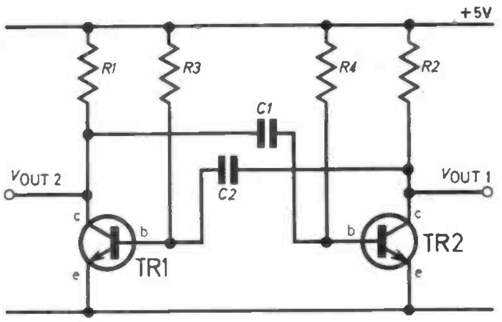


Fig. 14.3b. Circuit diagram of an astable multivibrator.

drop of 5 volts on the right hand plate, i.e. a drop to minus 4·4 volts. Thus closing the switch immediately cuts-off the transistor! How long will it remain cut-off? For as long as it takes the right hand plate of *C1* to reach its former resting state at +0·6V with respect to ground.

The time constant involved is *C1 times* R_b and it will be seen from the waveform that the capacitor has to climb about half-way up the total "aiming" point of +5 volts. Since it takes one *CR* to reach two-thirds of the total, it must take a bit less to reach half the total; in fact the actual time is about 0·7 *C1* R_b seconds—(according to rather abstruse mathematics which we shall skip). The term for this exponential return to cut-on is called **relaxation.**

Returning now to the astable multivibrator circuit in Fig. 14.2b, we notice that two relaxation circuits are in operation, *C1 R4* and *C2 R3* with transistor "switches" instead of real ones. When one transistor is on, the other one is relaxing towards cut-on—as soon as it does, the positive feedback action immediately cuts off the other. The circuit continuously oscillates backwards and forwards from TR1 to TR2.

The period of oscillation is T = (0·7*C1R4* + 0·7*C2R3*) so the frequency is given by

$$f = \frac{1}{0 \cdot 7(C1R4+C2R3)}$$

or if C1 = C2 = C and R3 = R4 = R, then:

$$\boxed{f \simeq \frac{1}{1 \cdot 4CR}}$$

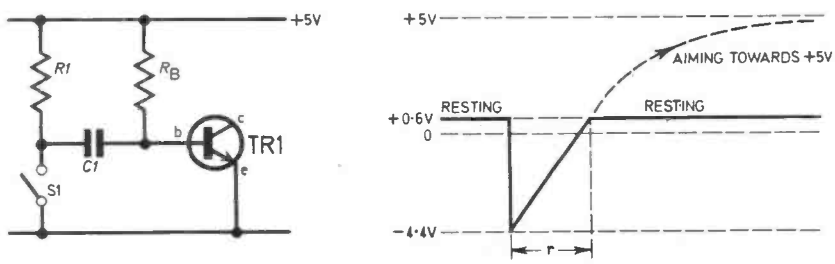


Fig. 14.3c. Circuit diagram to show relaxation principle and relaxation waveforms.

TEACH-IN '76 EXPERIMENTS

By now, you should be able to translate the theoretical circuit diagram onto the Circuit Deck yourselves, and therefore no physical layout is provided.

EXPERIMENT 14A

To demonstrate the Astable Multivibrator

PROCEDURE

Assemble the Components on the Circuit Deck according to the circuit diagram shown in Fig. 14A.1.

1. Measure the voltage across either transistor. If everything is in order, the meter needle should be rhythmically jerking up and down between 4·5 volts and nearly zero. The time of one complete up/down cycle should be about 1·4 CR_b = 1·2 x 100µF x 2·2kΩ = 0·3 seconds, although component tolerances will produce the usual errors.
2. Change the base resistors from 2·2 kilohms to 10 kilohms and note that the period increases to 1·4 seconds.
3. Replace the two 100 ohm resistors by 6 volt, 0·04 amp lamps. The two lamps should be winking on and off alternately indicating the antiphase relationship between the two outputs.

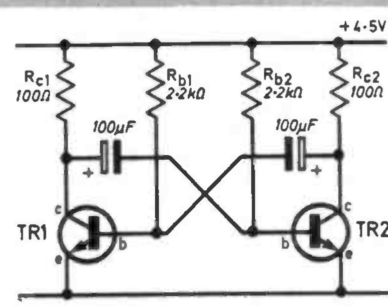


Fig. 14A.1. An astable multivibrator.

4. Change the base resistors so that one stage has 10 kilohms and the other has 2·2 kilohms. The lamp circuit with the larger base resistor should now be off for a longer period of time than the other. The circuit is now asymmetrical and has a "Mark to Space Ratio", "On-Off Ratio" or "Duty Cycle", larger than unity—actually about 4 to 1.
5. Repeat all these experiments with 1000 microfarad capacitors instead of 100 microfarad, and note that all times are increased by a factor of 10.

6. Modify the base circuit using the 25 kilohm potentiometer as shown in Fig. 14A.2. With VR1 set in the middle, the M/S ratio should be 1 : 1 and can be varied by the control to about an upper limit of 10 : 1 at either end.

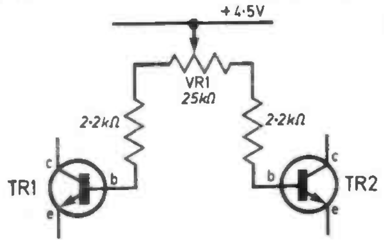


Fig. 14A.2. Circuit addition to obtain variable on/off ratio.

EXPERIMENT 14B

To demonstrate Bistable trigger action.

PROCEDURE

Assemble the components on the Circuit Deck according to Fig. 14B.1.

1. Measure the voltages across collector and emitter of both transistors in turn. You will find that one of them reads about 4·5 volts and the other nearly zero volts. This indicates that one is hard on in saturation and the other is off, although which way round is unpredictable.
2. Leave the voltmeter connected across the one which is reading 4·5 volts, i.e. the one which is off.
3. Perform the following trigger actions on points *A* or *B*. Momentarily touch either *A* or *B* with the probe which is at ground level. The voltmeter should instantly flick over from +4·5 to zero volts when your probe grounded the particular base which was conducting.

For example, if your meter was across TR2 and was initially reading 4·5 volts, then the point *A* would be vulnerable to the probe.

4. Touching point *A* then *B* then *A* again and so on will cause voltage to flick over to the other state each time.
5. Repeat the experiments using the other probe which is connected via the 4·7 kilohm resistor to the +4·5V line. The same effects can be produced as before but since the probe is "pulling" a base upwards this time, the change over takes place when the off transistor is touched.
6. Replace the 100 ohm resistors (or one of them) by 6V, 0·04A lamps. Repeat the experiments over again, using visual indication of state instead of the voltage readings.

Continued on page 578

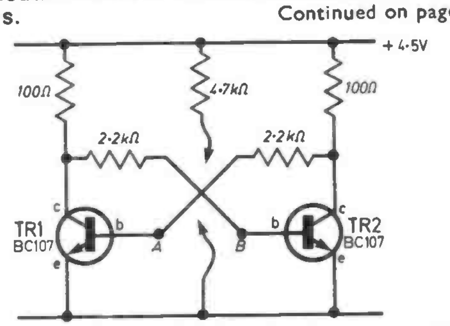


Fig. 14B.1. A simple bistable circuit showing trigger points.

Continued from page 577.

EXPERIMENT 14C

To demonstrate the triggering action and the hysterisis effect of a Schmitt circuit.

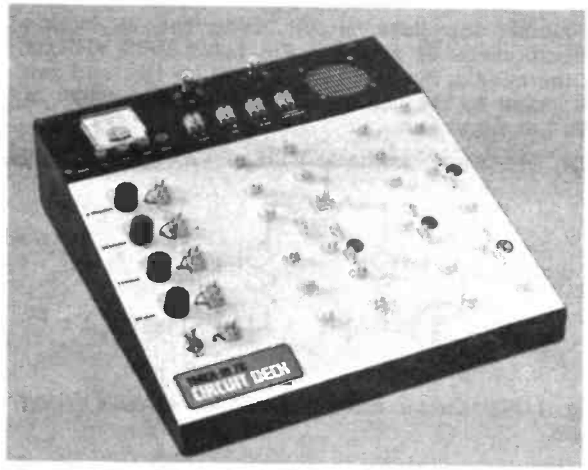
PROCEDURE

1. Assemble the components on the Circuit Deck according to circuit diagram Fig. 14C.1, leaving the slide control of VR1 down at the bottom end. The lamp should be on and TR1 off. Leave a voltmeter connected between point *A* and ground.

2. Slowly advance VR1 and observe the voltage rising. At some point the lamp will suddenly go out, indicating the circuit has flashed over. Note carefully the voltage at this point (which will probably be a little above 4 volts).

3. Now slowly reduce VR1 again towards the zero volts end. The lamp should remain off until the voltage nears 2 volts when the circuit should flash back to the lamp on state.

The difference in the on and off voltage points is the hysterisis—about 2 volts or so.



The Teach-In '76 series will terminate next month in Part 15.

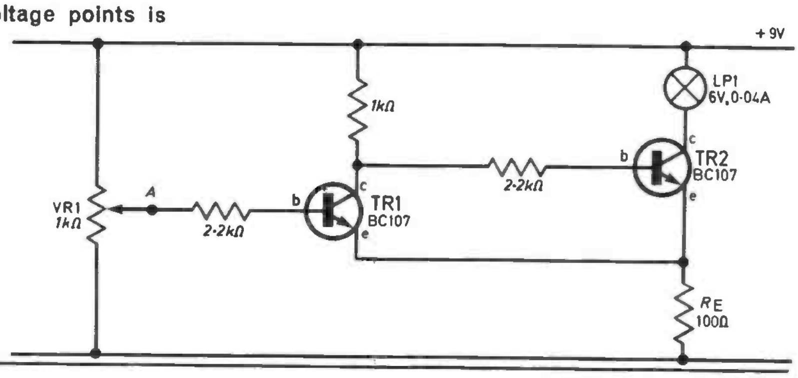
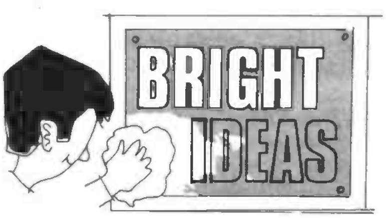


Fig. 14C.1. Circuit diagram of a Schmitt trigger.



When preparing printed circuit boards for etching, I find that Dalo etch resist pens are very expensive, and do not contain enough etch resist for filling in large areas.

Because of this I use an etch resist pen for the intricate areas, and I use pieces of PVC insulating tape, for covering the large areas of copper to be retained. Insulating tape is a very good etch resist, and can be just peeled off after etching.

D. J. Barfoot,
Bournemouth.

I, like many other readers like to construct my own printed circuit boards, from published designs, and make up my own for the more complex Veroboard projects. Often, after producing a shiny surface on copper clad board, one is frequently left with surplus material which is not going to be used for some time. The copper quickly tarnishes, and finger marks appear after a few days.

A very effective way of reducing this oxidation is to wrap the whole board in a very thin plastic sheet known as "cling film". This is available from supermarkets and grocers, and is sold to produce airtight coverings for foodstuffs.

It is very easily obtainable, and preferable to the use of sticky-backed plastic, which is an expensive alternative.

When covering the board, press and pull it tightly and firmly over the copper surface to ensure as much air as possible is expelled, and then fold over the edges so all four sides meet at the back with plenty of overlap. The adhesive properties of the plastic will be between the overlapping layers.

Care is needed to avoid puncturing of the plastic by the sharp corners and any rough edges, but if these are sanded smooth, the material is quite strong enough to be stretched over these edges gently.

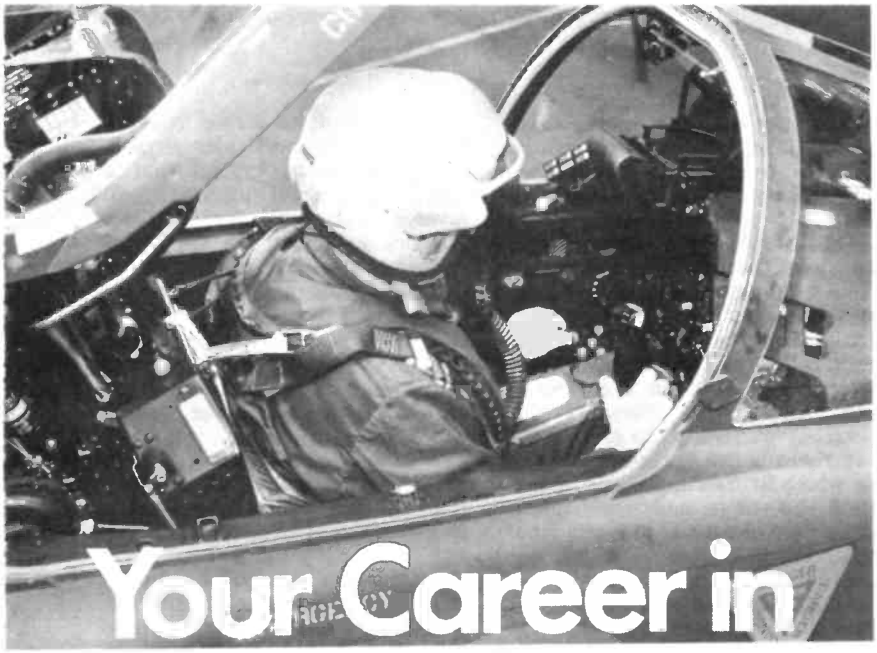
The material provides an almost perfect airtight enclosure for the copper and even after some months there is very little tarnishing.

Certainly there is no need for any abrasive cleaning after the board has been in storage for some time—just a light dab once over with a spot of organic solvent is all that is required—this will also keep a thick layer of copper on the board, there is no chance of cleaning it all away!

This method could apply equally well to Veroboard and double sided copper board, and provides a copper surface which is always ready for soldering.

Timothy C. Sheridan,
Bishop's Stortford.

"I expect the crystal set is vastly improved now to what it used to be."



Your Career in Electronics

By Peter Verwig

FOR a change, I am devoting all my space this month not to specific career opportunities but to an overview of the structure and importance of the aerospace industry to electronics and how electronics makes its contribution while also enjoying enormous spin-off in new technology.

CONTROVERSY

Today the aerospace industry is the subject of great controversy. Plenty of people think that great projects like Concorde are a waste of money, that landing men on the moon, however brilliant an achievement, was a rather silly exercise. That atmospheric pollution by jet aircraft is affecting the climate, that the noise nuisance is a hardly tolerable affront to civilisation, and that the heavy involvement by most aerospace companies in the design and supply of military aircraft and weapons systems is an even greater affront.

Nearly all these critics fly to overseas holiday resorts, enjoy TV programmes relayed to them by communications satellites, and sleep well in the knowledge that their homeland is reasonably well protected against aggression. In fact, despite all the loud noises they make, deprive them of the benefits of aerospace developments and they would be among the first to squeal.

On the other side of the coin there are folk who live and breathe aerospace as a complete end in itself. Nobody can deny that this young science which has prolificated into a huge industry in the course of a single lifetime is fascinating and appeals to the imagination. But, like all human activities, it can be used for both good and evil.

And, putting the military argument to one side, it cannot be denied that the bad effects of aerospace such as noise and atmospheric pollution are now well recognised, that huge sums of money are being spent on research to abate nuisance and that, on balance, aerospace has been of benefit to mankind.

If we look at the military argument, sensible and peace-loving people naturally prefer not to be involved in an arms race and even less in a possible future holocaust. Most accept that in an imperfect world they would prefer to be defended rather than defenceless, and even ardent pacifists, although perhaps unknowingly, daily enjoy amenities whose development, in the first instance, was stimulated by urgent military needs.

PROGRESS

It is no wonder that the general public remains bemused and uncertain on aerospace. First, the rate of progress has been so great that it numbs the senses. We have moved from man's first fumbling effort to fly a powered heavier-than-air machine (as distinct from airships and balloons) to passenger carrying supersonic flight on regular service in a mere 73 years.

Man-on-the-moon, already "old hat" has to be viewed within the context that the first ever manned space-flight took place only 15 years ago. Today we are getting pictures of Mars and the results of scientific experiments there, all remotely controlled at a distance of over 200,000 miles, an achievement considered by many to easily surpass the moon landings in technical excellence and even this, but for the excitement of finding out if there was life on the planet, would hardly have raised more than a riple of interest.

Incidentally, the tiny biological laboratory, occupying only one cubic foot of space in the Viking project, as well as its complement of mechanical engineering components, has the microelectronic equivalent of 22,000 transistors and 18,000 other electronic components and this is only one of the on-board electronic systems.

COST

Secondly, we all tend to become overwhelmed, not only with the spectacular nature of great achievement in aerospace, but also with its cost. Big passenger transports such as the long-range 1011-500 TriStars recently ordered by British Airways now cost some £20 million each. Aerospace people talk in millions all the time, while lesser mortals imagine they are on a big and useful deal when talking in tens of thousands.

Electronics and aerospace are now completely interdependent. One cannot get along without the other. You can't fly a TriStar or go to the Moon without electronics. And electronics could never have made such rapid progress had it not been for the ever-increasing demand for advanced technology products from the aerospace industry and the money to pay for their development. Aerospace has been, and still is, the forcing ground for electronic developments and, whether we like it or not, the primary source of cash funding comes from defence budgets.

It was a defence requirement

that spurred Britain into developing the world's first practical radar system in the 1930s, and the Americans into advanced microcircuit technology in the 1960s. But for heavy investment in defence, the general progress of electronics industry would have been much slower and we should all be the poorer for that in many other ways.

How is the aerospace industry organised and how does it work? The backbone is the airframe manufacturer who designs and builds the aircraft, the missile, the satellite and its launcher.

There used to be dozens of airframe manufacturers in the days when you could buy a large passenger aircraft for a few hundred thousand pounds. But as aircraft became faster, higher flying, more comfortable to travel in as well as safer, costs rose to such a degree that the weaker companies were forced to join the strong so that there are just a few companies of world class left. In Britain the two remaining airframe companies, British Aircraft Corporation and Hawker Siddeley are about to come under public ownership and will eventually merge their activities.

The cost of high technology projects has now become so astronomically high that few single companies, however strong, can afford their full development costs and, indeed, this is also true of nations.

JOINT VENTURES

The days have long since passed when a small nation could afford a major aerospace development. Britain, with the largest aerospace industry in Europe and second in the Western world only to the United States, can now only afford joint ventures with partners overseas to share the cost and the risk of new development.

Thus we have in the military field joint projects like the Anglo-French Jaguar strike aircraft now in service with the French and British air forces, and the Tornado multi-role combat aircraft developed and built on a co-operative basis with partners in Germany and Italy. In civil aviation there is the European Airbus for which British Hawker Siddeley build the wings, and many more international projects too numerous to list here.

Even the mighty giants of Boeing, Lockheed and Douglas in the United States are seeking international partners for future projects. The trend is towards multinational participation, at least for the really big jobs.

The airframe manufacturers, however large, depend on hundreds of sub-contractors for the supply of component parts, sub-systems and systems. Principal subcontractors are specialist companies who make aircraft engines, landing gear and other major mechanical components and systems suppliers for items like automatic pilots, navigation systems or radio communications. In their turn, these subcontractors buy in component parts from specialist component manufacturers.

You can't put any old rubbish into aircraft. Every piece of alloy, every rivet, every electronic component, even the humble cable has to be "released" from the manufacturer to stringent approved specification. Otherwise the aircraft will not get a certificate of airworthiness and will not be allowed to fly.

It is difficult to arrive at exact figures for any particular aircraft but it might be typical that a large passenger aircraft will involve several hundred sub-contractors and that the supply of materials and other products from outside suppliers will account for at least half the cost.

An interesting statistic is that if you melted down an aircraft into its basic raw materials these account for only five per cent of the selling price. The other 95 per cent is nearly all in human skills, in designing, in machining and fabricating components, in assembly, in inspection, in testing.

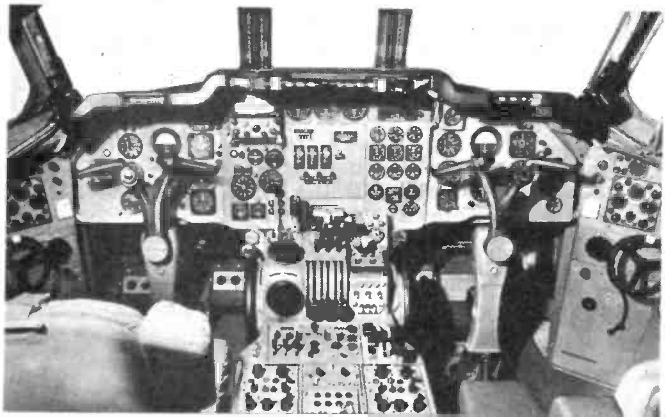
In modern passenger aircraft the electronics equipment can account for one third of the total aircraft cost and, in military aircraft like the Tornado, which is stuffed full of advanced electronics, the electronics content is even higher, approaching 50 per cent.

We can now begin to see why aerospace is so important to the electronics industry. It is not only the volume of trade that is important. It is the quality of the trade, too. The ability to build equipment to the most exacting standards and the opportunity to work on the very frontiers of technology, as all the major subcontractors are called in at the earliest design stages of every new project.

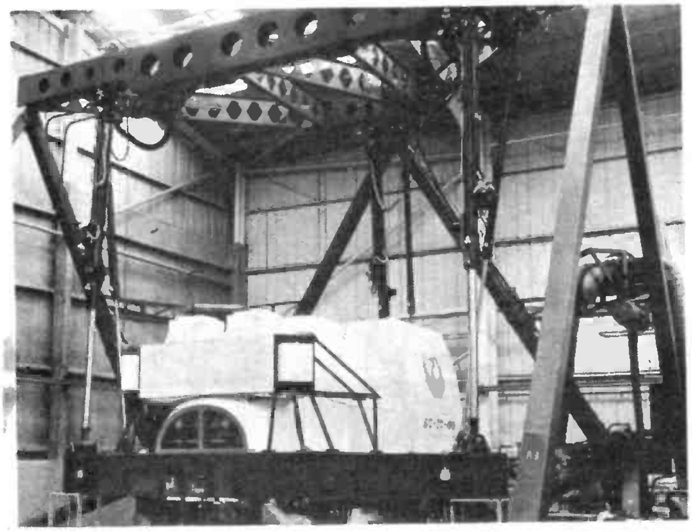
ATC

The aerospace industry, however, has ramifications far beyond those already discussed. However wonderful the flying machines they cannot operate in isolation. True, they have their basic navigation equipment and, in emergency,

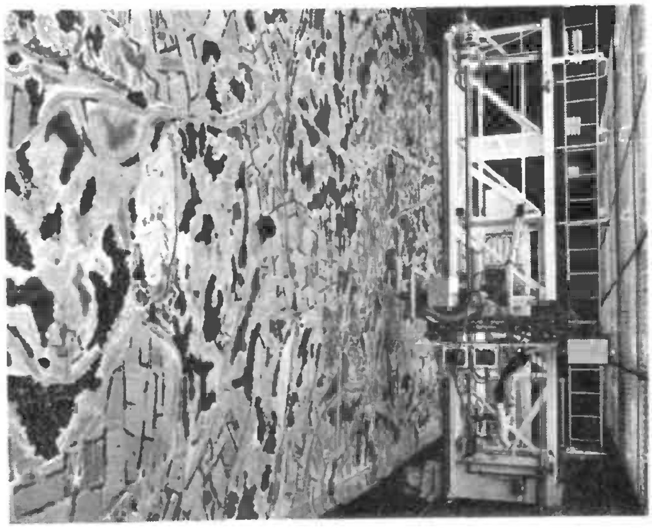
Flight deck of a Trident civil transport, the first commercial aircraft to be equipped for automatic landing using Smiths autopilot and autoland system, controls of which are on the central pedestal.



Latest air traffic control radar display by Marconi Radar. The control computer for distributing the radar data is centre background.



This large DC 10-40 flight simulator under final test at Redifon's Crawley factory helps Britain pay for Japanese imports.



Hand-made map mounted vertically is scanned by colour TV camera on the movable gantry. All part of the great illusion of flying in Redifon flight simulators.

can find their way around and make a safe landfall. But air traffic is now so dense that except in the remotest parts of the world it is rigidly controlled from the ground by air traffic controllers who direct aircraft to land or take off, or to "stack" while waiting clearance to land.

En route, aircraft fly in well defined "lanes" guided by radio navigation beacons. Here we find an enormous sector of aerospace electronics involving radio communication, radar and navigation beacons. All major airports are fitted with instrument landing systems, especially important in bad visibility, which guide the aircraft down to the threshold of the runway. With suitably equipped aircraft and the highest quality ILS systems it is possible to land entirely under automatic control, the pilot merely monitoring his instrument panel to check for abnormalities.

OTHER SYSTEMS

Air forces also have air traffic control at their airfields and, in addition, an air defence system which monitors airspace by radar to detect intruders and to direct interceptors on to targets. A complete integrated air defence system will have a number of radars at strategic points. Computers are used to evaluate threats and direct the activities of the defence forces by air interception, anti-aircraft guns or surface-to-air missiles.

An idea of the complexity of modern civil air traffic control systems can be gained from a recent order for modernisation of the existing system in Saudi Arabia. The contract is worth over £250 million, a large slice coming to Marconi Radar in Britain. This is additional to the £300 million up-date of Saudi Arabia's air defence system by British contractors.

We have dealt briefly and without any detail on the operational aspects of aircraft which involve huge quantities of electronic equipment in aircraft and on the ground. We have to remember, too, that aircraft and engine manufacturers are huge users of computers for design and for routine stock-control, production scheduling, pay-roll etc.

The manufacturers are also among the largest users of numerically controlled machine tools. The airlines who operate the aircraft are also dependent on computers for passenger seat reservation and similar tasks.

FLIGHT SIMULATORS

Nobody can now afford to fly big commercial jets or expensive military aircraft just for training so another important sector of aerospace electronics is concerned with flight simulators in which pilots on initial or conversion training can gain experience without ever leaving the ground. The best of these, costing over £1 million each, are completely realistic with the flight deck banking and pitching in response to the controls, with the outside world "moving" in vivid detail.

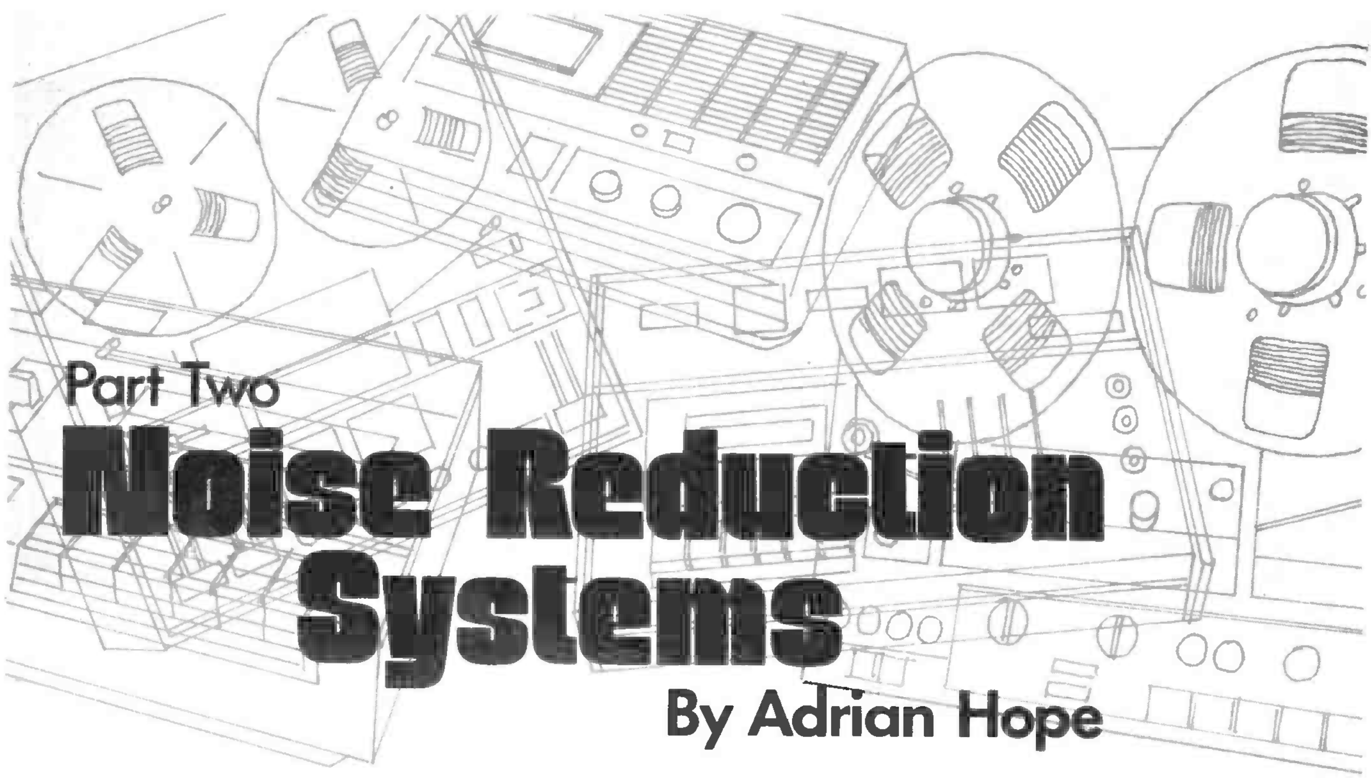
The beauty of flight simulation is that the instructor can introduce any flight hazard such as fire or engine failure at will to check trainee pilot reaction, and all in perfect safety. Last July, Britain imported over 17,000 monochrome TV sets from Japan at a landed cost of £570,000. The reaction was "ban these imports". But a single flight simulator built in Britain for Japan Air Lines pays for these sets more than twice over. Similarly our huge aerospace business with oil producing countries helps pay for imported oil.

The importance of aerospace is that we export high technology in exchange for goods we need and because aerospace means high technology, our engineers and designers are fully stretched on the newest developments.

I have hardly touched on the importance of defence equipment and its export potential. BAC's order book for the Rapier low-level surface-to-air missile is about £500 million, most of it for export, and this figure includes millions of pounds flowing in to the electronics industry.

FUTURE ARTICLES

In future articles I shall be returning from time to time to the aerospace industry and the participation of electronics companies. This area is perhaps the most exciting of all to work in. It is also among the most exacting, absorbing large numbers of graduate and technician engineers.



Part Two

Noise Reduction Systems

By Adrian Hope

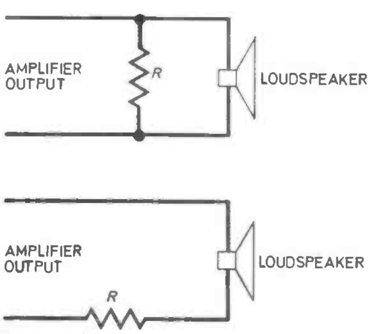
HAVING looked at various methods of noise reduction we now move on to actual systems.

SIMPLE COMPANDOR

So far I have deliberately omitted to mention any one brand of noise reduction system by name. We shall soon see how the various noise reduction systems available on the professional and amateur market rely on one or more of the basic principles described above, warts and all, and have refined them as far as possible to eliminate the warts.

First, however, it is instructive to look at the simplest practical form of compandor.

Figs. 2.1a and b. Wiring for a simple compandor system.



Compression and expansion may in theory, most simply be achieved by incorporating a resistance into an audio circuit which varies its characteristic in dependence on the signal passing through it; Fig. 2.1a shows such a resistor *R* across an audio connection between the output of an amplifier and a loudspeaker, and Fig. 2.1b shows a similar resistance *R* in series with such a connection. In each case the resistance *R* has a relatively low value when it is passing small currents and a relatively high value when it is passing high currents.

In the first case, therefore, a relatively high proportion of a low power signal from an amplifier output will be shunted through the resistance *R* and thus a relatively low proportion of the signal will reach the loudspeaker. However, because the resistance value increases as the signal strength increases, a relatively small amount of the signal will be shunted through *R* as the level of the amplifier output increases. Thus there will be an unnaturally wide range of power handled by the loudspeaker, starting from an unnaturally low level. In other words, in the circuit of Fig. 2.1a there will be expansion of the dynamic range of the signal fed out from the amplifier to the loudspeaker.

In the second circuit the reverse operation will take place. When the amplifier is supplying low power to the loudspeaker the resistance *R* in series will have little or no effect on the circuit, because it is of low value. When the power level increases, however, the resistance *R* will increase in value and thus place an unnatural limit on the power passing to the loudspeaker. It follows that the loudspeaker will handle an unnaturally reduced dynamic range, with an unnaturally low maximum power level. In other words, there will be compression in the circuit of Fig. 2.1b.

TORCH BULBS

By a happy coincidence, non-constant resistances are readily and cheaply available in the form of low voltage torch bulbs. When the filament of the torch bulb is cold (emitting no light) its resistance is low and when its filament is hot (emitting light) its resistance increases. This convenient phenomenon has been relied on over the years at various levels of sophistication.

Pre-war radio listeners sometimes strung a torch bulb in parallel with their loudspeaker to expand the sound signal, or in series, to compress it. But modern amplifiers with low impedance outputs will simply feed more power out as the load changes and there will be no audible effect.

Various simple circuits have been devised over the years to remedy this. Six years ago, the so-called Null-a-tron was briefly marketed by Audione and Co. The Null-a-tron used a stereo pair of resistance bridges incorporating both fixed value resistors and torch bulbs, the bridges being wired between the amplifier output and the loudspeakers. When the amplifier output was low, the torch bulb was cold and the bridge in balance, with a null or low output to the associated loudspeaker; when the power output from the amplifier increased, the torch bulb lit, the bridge went out of balance, and a disproportionate amount of power was fed to the loudspeakers.

Thus the signal was expanded with low levels pushed right down to zero and residual noise lost in the process. Although relatively cheap, the Null-a-tron was unfavourably reviewed, the expansion action of the various control settings being either inadequate or over-blown and intrusively audible. Such failings are virtually inevitable with light bulb expanders and compressors.

Thus, although sophisticated photoelectric sensor circuits have recently been proposed which detect the amount of light produced by a bulb and control an amplifier gain circuit accordingly, the use of a light bulb as a noise reduction tool, however cheap and convenient, is in many respects a non-starter.

MAIN NAMES

The current main names in noise reduction are Philips (with the Dynamic Noise Limiter or DNL), JVC (with the Automatic Noise Reduction System or ANRS) and Burwen, *dbx* and Dolby.

Most are available in both professional and domestic versions, but Burwen is so far available only to the professional user and DNL only to the amateur or domestic enthusiast. The availability of both professional and domestic versions of the other systems is a logical result of the fact that they started life professionally but were made available in domestic version as a market for them appeared, largely due to the advent of cassette tape.

Remember that, until the idea of cassettes as a hi-fi medium started to be taken seriously, there was little or no need for a noise reduction system on the domestic market. But as the frontiers of cassette quality were pushed further and further forward, the need for a good noise reduction system to cut down on lowspeed tape hiss was generated. Then, once a domestic system was available for cassette use, eyes were opened to the possibility of using the system also for domestic reel-to-reel recording and for receiving radio transmissions.

BURWEN SYSTEM

It is convenient to start with the Burwen 2000 compandor system from the USA.

Burwen sought to encode with compression on "record" and decode with expansion on "playback", using a constant or straight slope (sometimes confusingly called a linear slope) compandor and a cubic or 3:1 ratio. Thus an audio signal fed into the Burwen processor at the record stage emerged compressed in amplitude range by the ratio 3:1.

To be more specific a 3dB change is recorded as 1dB and an input signal range of 90dB will be compressed into a 30dB range by the compressor. This 30dB range will then be mirror-expanded again by the processor on playback, to restore it to its full 90dB range. Simple subtraction shows that there can, in theory, be a 600dB improvement in signal to noise ratio, with consequent virtual elimination of process noise such as hiss.

Unfortunately, nothing in this world is for nothing, and the very substantial compression and expansion adopted to achieve such dramatic noise reductions lays the system wide open to the problems of modulation, overshoot and tendency to exaggerate frequency response errors discussed in general terms last month. In an effort to avoid these problems, Burwen's system incorporated equalisation techniques, to boost and cut different frequencies by different amounts, and the pros and cons of the resulting compromise were argued in the pages of erudite technical journals a few years ago. But almost inevitably the very high price tag (even in 1974 it would have cost £27,000 to equip a 16-track recording studio) wrote the system off in the eyes of most European studios.

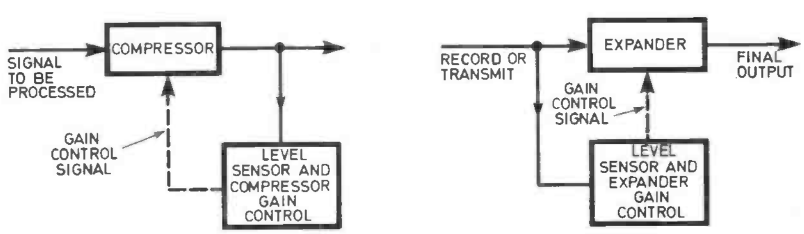
Burwen equipment, of modified form, was briefly handled in this country by Ampex (the tape and tape recorder firm) but currently there is no UK agent or availability. The new Burwen range includes a "noise gate" which can be described as a highly sophisticated professional version of the Philips DNL, to be discussed later.

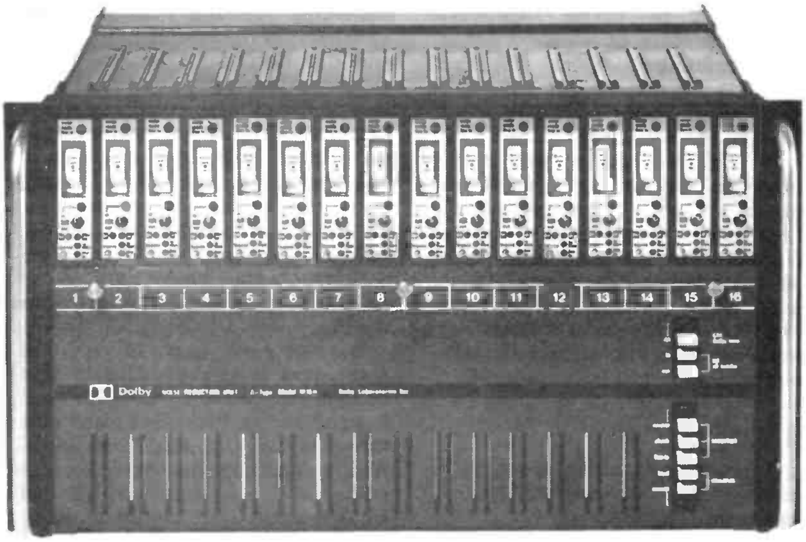
dbx SYSTEM

Another system of American origin is *dbx*, and closely resembles the original Burwen compandor system in that both systems process substantially the whole of the audio signal, rather than part of it. The basic idea behind such overall processing as practised by Burwen and *dbx* is shown schematically in Fig. 2.2. In each case the signal level is sensed and used to control the compressor or expander accordingly.

But *dbx* differs from Burwen in that, whereas Burwen used a 3:1 or cubic compression and expansion ratio, the basic *dbx* systems use a 2:1 or square law for compression and expansion. Thus a 2dB programme change is recorded as 1dB and an input signal having a 90dB range fed into a *dbx* compressor emerges with a 45dB range. When it is restored to its 90dB range by the expander on playback there is in theory a 45dB improvement in signal to noise ratio. In practice the theoretical levels of noise reduction are not sought in full by

Fig. 2.2. Basic overall processing system.




The Dolby A professional 16 channel system.

out above the programme. Put another way, if the programme (eg. the music being recorded and played back) is quiet, any hum and hiss present will be noticeable; but if the programme music is loud it will drown out the hum and hiss. In fact, the preceding sentence is over-simplification, because a high pitched note will not mask a softer low-pitched note, or *vice-versa*. Indeed, the whole philosophy of the Dolby system centres around the fact that the human ear will not hear or be disturbed by a low level sound at around the same frequency as a high level sound.

either Burwen or *dbx*. But clearly *dbx* offers relatively less potential noise reduction than Burwen. By the same token, however, *dbx* is less susceptible to the basic problems inherent in compandors.

As with Burwen, the signals fed into the *dbx* system are equalised, with high and low frequencies relatively boosted or cut (pre- and de-emphasis) to minimise those problems that do exist. But with *dbx* the signal level is sensed in r.m.s., rather than peak, values. It is incidentally important to note for future context that neither Burwen nor *dbx* needs elaborate calibration to ensure that the signal level encoded exactly matches the signal level decoded. But at a somewhat elevated technical level, arguments on this point persist, and critics of *dbx* point to the problems which can arise if *dbx* tapes recorded at different levels are spliced together.

The range of *dbx* equipment commercially available is somewhat confusing and is also best discussed in a later context.

DOLBY

The Dolby system is another compandor-based system which offers less noise reduction (10dB or 12dB) than Burwen (in practice up to 50dB) or *dbx* (in practice up to 30dB), but is less prone to the modulation, overshoot and accentuation of frequency non-linearity problems previously mentioned. On the debit side (along with the comparatively low degree of noise reduction available) the Dolby system requires accurate calibration of the input and output levels for correct working results.

The main difference between Dolby, on the one hand and Burwen and *dbx* on the other, is that, whereas the latter two systems process substantially the whole of the signal according to a generally constant slope, the Dolby system processes only a part of the signal. As shown in Fig. 2.3 the signal to be processed is split by Dolby between a main and a side chain, the main chain handling all high level signals and the side chain handling only low level signals.

The main chain (handling the high level or loud signals) does not affect them or process them in any way. The side chain (handling the low level or quiet signals) is the active compandor link. It thus follows that if only a loud signal is passed through a Dolby processor it remains unprocessed.

This is in practice perfectly acceptable because noise (such as hiss or hum) is only noticeable if it is of sufficient level to stand

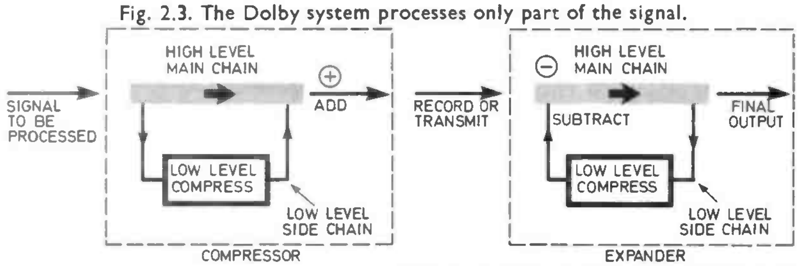
DOLBY A

To pursue the previous musical analogy, reasonably loud violins (with plenty of meaty high frequency content) will mask the sound of tape hiss (with quiet high frequency content), and a string bass (plenty of low frequency content) will mask the presence of quiet mains hum (also of low frequency content). But the violins will not mask hum, and the bass will not mask hiss.

Accordingly, in the professional (A) Dolby system the low level side chain is divided into four separate parallel channels each of which handles a separate frequency band (see Fig. 2.4). What is more, each of these channels works independently of the others, so that a low level, high pitched signal (such as quiet violins) will be routed through only the high frequency side chain channel and low level, low frequency signals (such as quiet basses) will be routed through only the low frequency channel of the side chain.

Each of the side chain channels acts on the signal passing through it, in manner generally similar to that in which the *dbx* system acts on the whole frequency range. In other words, in each of the Dolby A side chain channels there will

Fig. 2.3. The Dolby system processes only part of the signal.



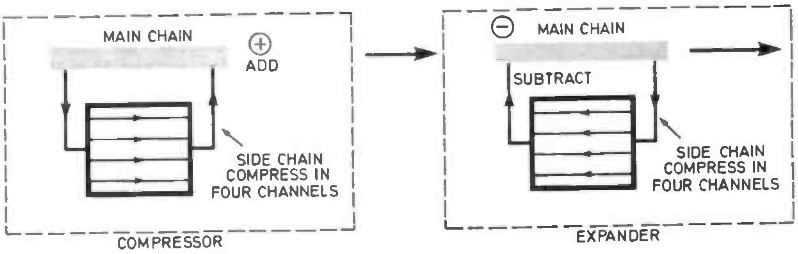


Fig. 2.4. Basic Dolby A system.

be over some of the slope 2:1 or square law compression on encoding and expansion on playback.

Thus the Dolby A system senses in which frequency area there are low level (quiet) signals and in that area *and that area only* boosts them on "record" and reduces them on "playback". If there are low level signals in only one frequency band, then there is processing in only that channel of the side chain; if there are low level signals in more or all of the bands, then there is processing in the appropriate side chain channels; if there no low level signals, and all the programme being fed to the compressor is at high level (loud), then there is no processing and no boosting on "record" and reduction on "playback".

However, no compression or expansion is effected on the lowest levels. This avoids the risk of the expander on playback mistaking noise for quiet useful signal and boosting it. Two important points follow from all this. First, the deliberate failure to process loud signals means that there is less risk of overshoot. In practice, the fact that only low level signals are boosted means that only around 1dB overshoot is obtained on a correctly set up compressor. This is small enough not to overload the recording or transmission medium. The other advantage of the band splitting technique is that there is less risk of noise modulation.

Clearly, if the presence, or absence of low frequencies only affects the low frequency performance of the processor, then there is no risk of high frequency breathing sounds.

But all this follows from the fact that the system is level-conscious. Whereas Burwen and *dbx* treat all signals according to the same law, in the Dolby system all the high level signals remain unaffected. Obviously therefore the system must have a point of level reference to decide what is low and what is high (soft or loud). It is for this reason that the Dolby circuitry must be set up using a fixed level set tone as its point of reference. Indeed, correct calibration is essential to successful use of Dolby.

Later in the series we shall examine the calibration technique and how it can present practical pitfalls, especially for the user who does not realise that even the use of different tape types can throw out the calibration of his Dolby circuitry.

DOLBY B

So far the description of Dolby has related to the professional (A) system. The B system, for domestic use, resembles the A system in all respects except one. Instead of side chain being divided into four sub-channels, each with its own frequency of operation, in the domestic, B system, there is only one side chain. This simplified procedure can be adopted in the interests of economy because, in domestic low speed tape recording, the most troublesome noise is always hiss.

Although at first sight it would seem sufficient simply to provide a side chain acting only in the upper frequency range (where the hiss makes its presence felt) this single band approach has been found satisfactory in practice only if the **width of the band is automatically** varied in response to the amplitude and frequency content of the signal being treated.

The Dolby B circuit is shown schematically in Fig. 2.5. When loud signals are fed to the processor the cut-off frequency of the side chain is pushed upwards, so that it becomes able to act on an increasingly narrow band of high frequencies. As the signals quieten, so the cut-off frequency of the side chain band comes downwards again, enabling it to treat not only high frequencies but also some lower frequencies as well.

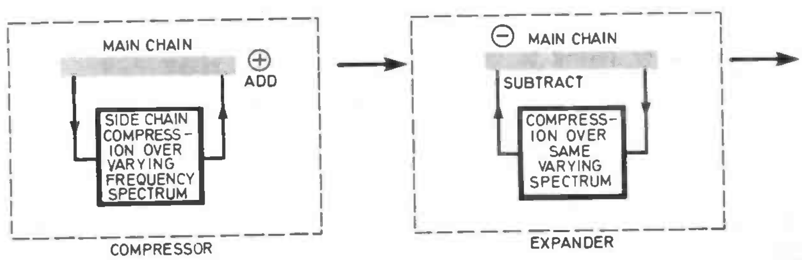
The result of this automatic adjustment of the side chain is that there is processing over a fairly wide range of frequencies (but always above 500Hz) for most of the time, because most programme material is not loud enough to push the filter cut-off up too high. But for some of the time the processor works over a much narrower band. At no time is there any audible change in that portion of the noise which remains unmasked.

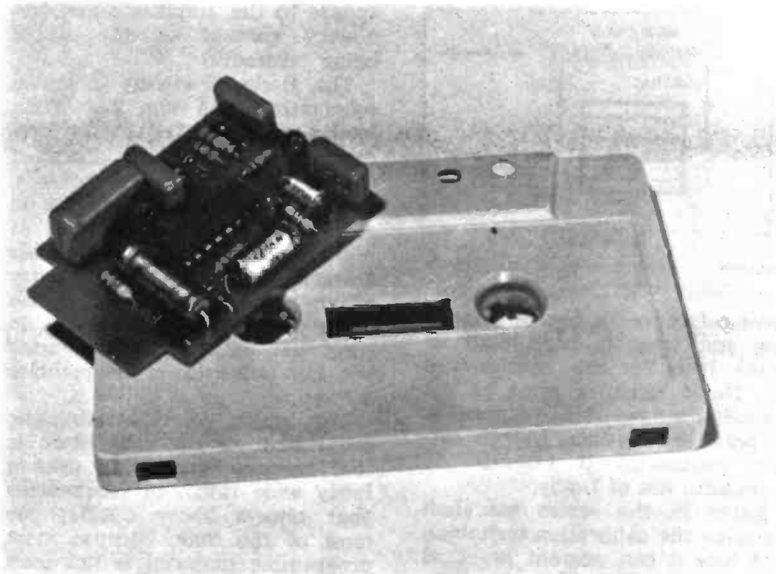
Over the years, there have been various authorities who have claimed to be able to hear both Dolby A and B systems "working", but usually this has been the result of a wrongly calibrated system.

dbx RANGE

Before discussing the JVC-ANRS system, which in many respects resembles the Dolby B system, it is opportune first to return as promised and look more closely at the *dbx* range of equipment which is now commercially available. Like Dolby, *dbx* started as a professional system for use with tape in recording studios, but (again like Dolby) has spread to other professional areas, such as film and broadcasting technology, and in a modified form, to the semi-professional

Fig. 2.5. Basic operation of Dolby B system.





The Dolby B chip showing relative size to a cassette.

and domestic markets. However, unlike Dolby, *dbx* has also moved into the area of disc recording, and it is now possible (although not easy) to buy a *dbx*-encoded disc for playback on domestic equipment linked to a *dbx* decoder.

Although the *dbx* and Dolby systems are in all respects incompatible (*dbx* encoded tape cannot be decoded on Dolby equipment and vice versa), the marketing philosophy adopted by the two firms is very similar.

Dolby Laboratories manufacture all their own professional (A type) equipment and sell it to studios and radio stations around the world. But Dolby Labs do not produce any domestic Dolby equipment (B type) and instead license the manufacturers around the world to produce it for themselves. Thus professional Dolby A equipment never finds its way into the consumer shops, and the only Dolby equipment that you are ever likely even to see, is domestic, Dolby B equipment.

It does not, therefore, matter that Dolby B equipment is incompatible with Dolby A equipment—the normal consumer will never have the opportunity of making the mistake of trying to decode an A tape on B equipment or vice versa.

By exactly the same token, *dbx* market their professional equipment through one distributor (Scenic Sounds Equipment) and their domestic equipment through an entirely separate agent (Acoustic Research International). Thus, just as with Dolby, the domestic consumer never has an opportunity to see, let alone buy professional *dbx* equipment, so again there is no risk that the incompatibility between the professional and domestic types will trap a consumer into using the wrong equipment for the job in hand.

BASIC FORMATS

However, whereas there is only one Dolby A format and one Dolby B format (for use on domestic cassette and reel-to-reel recorders or broadcast receivers), there are more than two basic *dbx* formats. And not only are there more *dbx* formats, there has also so far been less successful education of the audio fraternity in the UK over the differences between the different formats. It is important therefore to set the matter straight, and the situation is as follows:

In the professional and semi-professional area (handled by Scenic Sounds Equipment) there are four different professional and semi-professional units, which are compatible with each other. (216; 177; 187; 150.) These are all used for recording on tape in professional or semi-professional recording studios.

Also falling into the professional and semi-professional area is the 140 broadcast series, which can also be used to produce *dbx*-encoded discs (and tapes) of the type which are gradually becoming available on the domestic market. These can be reproduced using some (but not all) domestic *dbx* equipment. However, tapes made on the other professional equipment (216; 177; 187; 150) cannot be replayed on domestic equipment, and for this reason will never be made available on the domestic market.

Anyone wishing to replay *dbx* encoded discs (or tapes) produced for domestic use on the professional 140 equipment will need to use a 120 series domestic *dbx* unit. As well as decoding professionally made discs and tapes, the 120 series can also be used as a compandor for amateur recordings (just like Dolby B). A recording made on a reel-to-reel or cassette machine, using a 120 series unit to encode the recording, and decode on playback produces more dramatic loss of process noise than Dolby. However, the *dbx* 120 series units cost more than Dolby B.

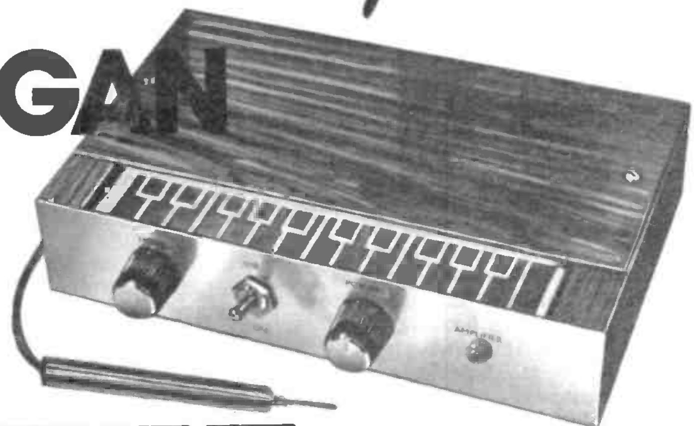
Continued next month

The *dbx* 124 four-channel system.

Next Month....

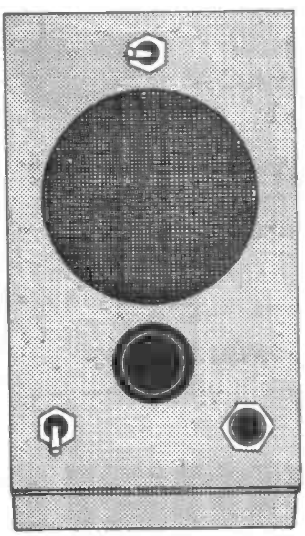
Party time Projects!

MINI ORGAN

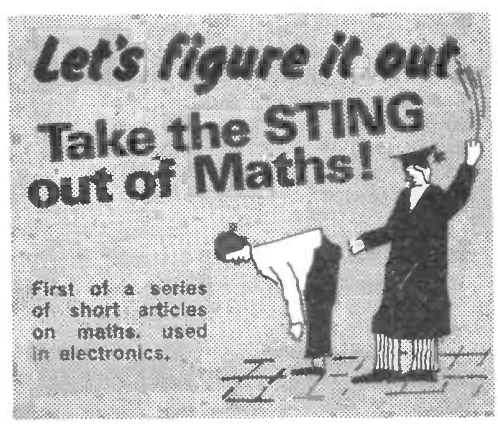


A simple musical instrument which can provide hours of amusement for all the family.

SCRABBLE TIMER



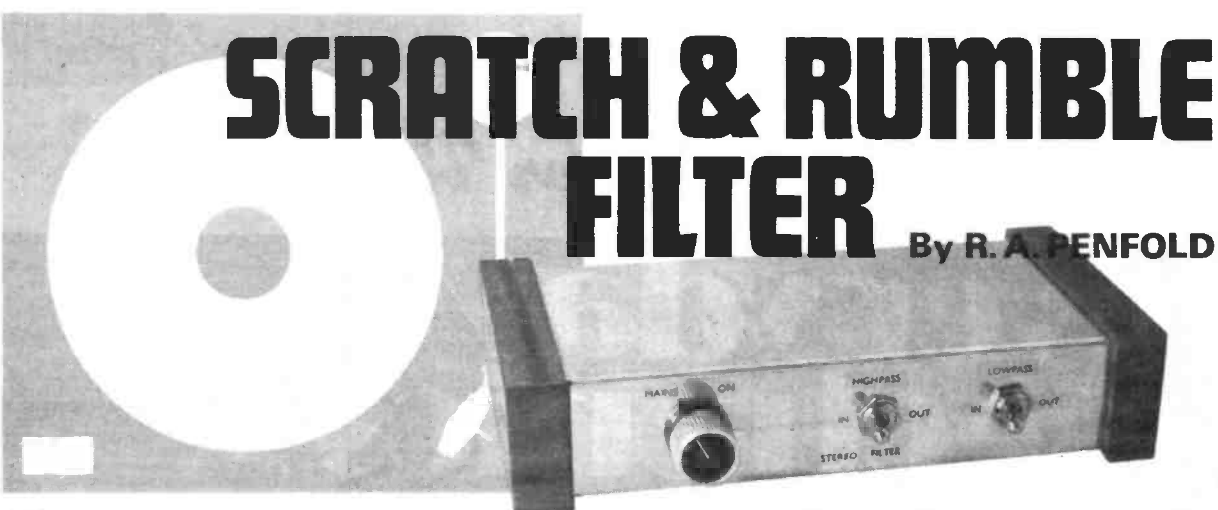
Another reader's suggested idea: this timer takes the waiting out of Scrabble and has a "panic" facility to add a new dimension to the game.



Plus Index for Volume 5

SCRATCH & RUMBLE FILTER

By R. A. PENFOLD



PROBABLY the main limiting factor on the reproduction quality of most modern record playing systems is the mechanical part of the equipment. For instance, the noise level of most amplifiers is negligible, with most of the noise in the system coming from the record deck and from the record itself.

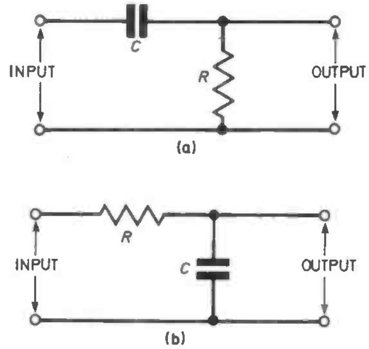
Noise from the record deck is mainly in the form of a very low frequency sound, or "rumble" as it is usually termed. Much of this signal is below the lower limits of human hearing, but it can still produce audible effects as the result of intermodulation distortion between this noise and the desired signal. Some record decks produce a noticeable amount of rumble just within the lower limits of human hearing, and this can be especially annoying.

Rumble is sometimes present on records to a significant degree, but surface noise is the most usual cause of trouble here. Even well cared for records will eventually show signs of wear in the form of a continuous crackle of small scratches.

It is possible to incorporate circuits in the amplifier which will minimise the inconvenience caused by rumble and small surface scratches, and a number of amplifiers incorporate scratch and rumble filters. This article describes a simple scratch and rumble filter which can be used as an add-on unit to a system which does not already have these features.

Basic Operation

As the signals produced by



Figs. 1a and 1b. Basic high and low pass filters.

rumble are at very low frequencies, if one rolls off the low frequency response of the amplifier, the rumble will be greatly reduced. Similarly, rolling off the high frequency response of the amplifier will reduce the level at which the scratches are reproduced. This is simply because most of the signals produced by small scratches are at very high audio frequencies.

It should be borne in mind that deep scratches have a large middle and even bass frequency content. These cannot usually be effectively reduced by simple filtering. Also some of the cheaper record decks produce a significant level of rumble at comparatively high frequencies, and again only a limited improvement in reproduction quality can be made by the use of a filter.

Simple Filters

The circuit of a basic passive high pass filter is shown in Fig. 1a and Fig. 1b shows the circuit of a basic low pass filter. These work by virtue of the fact that the impedance of a capacitor (its resistance to an alternating current flow) varies with frequency.

In fact the impedance of a capacitor rises with decreasing frequency. Halving the frequency doubles the impedance of a capacitor.

The two circuits shown in Fig. 1 are forms of potential divider. In Fig. 1a the capacitor is chosen to have a value which has a negligible impedance at high and middle frequencies, compared to the value of the resistor. Signals at these frequencies can pass through the filter virtually unhindered. At bass frequencies the capacitor will have a high enough impedance to cause severe losses through the circuit.

In the circuit of Fig. 1b the capacitor has a value which will only cause small circuit losses at bass and middle frequencies. At higher frequencies where the capacitor has a lower impedance,

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the potential divider action will result in severe losses in the circuit.

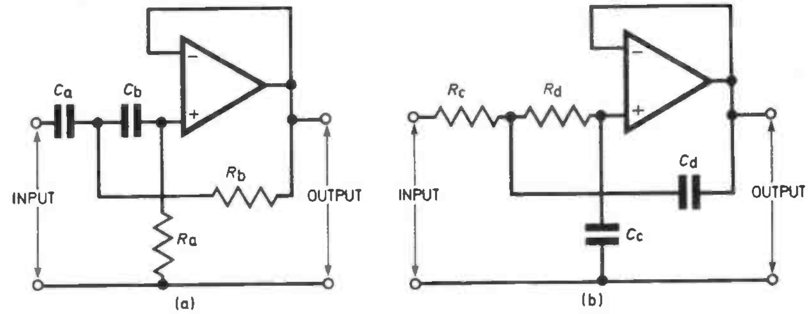
Active Filters

These simple passive circuits provide only a gradual roll off of the high and low frequencies, with some of the desired middle frequencies being somewhat attenuated as a result. The extent of the roll off is about 6dB per octave (doubling the frequency causing a reduction by half of the output amplitude), and this can usually be obtained using the amplifier's tone controls. A roll off of about double this rate is desirable, and can easily be obtained using an active filter; Figs. 2a and b show the circuits of a basic active high pass filter and low pass filter respectively.

The amplifier has 100 per cent negative feedback between its output and inverting (−) input, and it therefore has a voltage gain of only unity.

The combined capacitance of C_a and C_b together with R_a form a high pass filter. Thus at high and middle frequencies the overall gain of the circuit is about unity.

Resistor R_b thus has no effect on the circuit as any variation in the potential at the junction of C_a and C_b will be exactly matched by an equal change at the output.



Figs. 2a and 2b. Basic active high and low pass filters.

The voltage across R_b remains constant, and so none of the input current will flow through it; R_b has an apparent infinite impedance at high and middle frequencies.

At bass frequencies losses through C_a and C_b give the circuit less than unity gain, and changes in the potential at the input end of R_b will not be fully matched by similar changes at the other end. Some of the input current will thus flow through R_b, and the level of this current increases as frequency decreases, because the gain of the circuit is less at low frequencies. This gives the circuit a roll off rate of about 12dB per octave with C_a and R_b forming a second high pass filter network.

Note that this is not simply two high pass filters connected in series, and that a combination of the first filter network and the positive feedback via R_b (known as bootstrapping) is used to give the second filter a fast roll off rate. The circuit as a whole thus has a very fast roll off rate.

The low pass circuit operates in a similar manner: R_c, R_d, and C_c form a passive low pass filter, and C_d will appear to have an infinite impedance at bass and middle frequencies, but not at treble ones. This again provides a 12dB per octave roll off with R_c and C_d forming a second filter network.

Practical Circuit

A practical scratch and rumble filter circuit appears in Fig. 3. This only shows one channel, the two channels being identical. Four inexpensive 741C operational amplifier I.C.s provide the basis of the unit. When used as unity gain buffers, as they are here,

Fig. 3. One channel of the Scratch and Rumble Filter circuit.

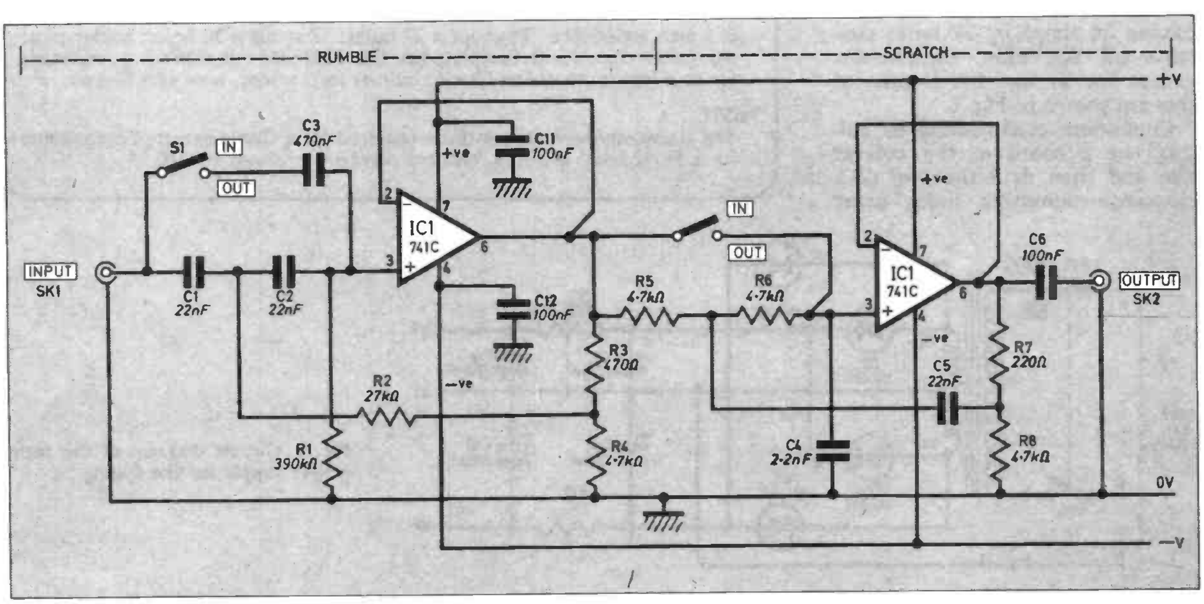
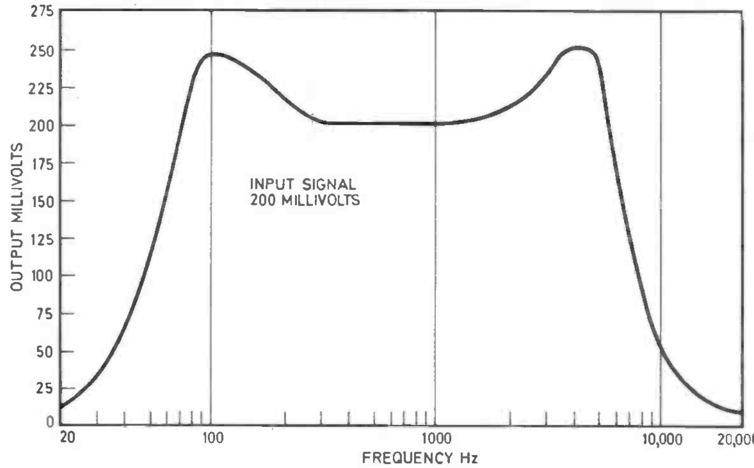


Fig. 4 (right). Response curve of the filter.



these devices have insignificant levels of noise and distortion. The similarities between the skeleton and practical circuits should be obvious, and only the differences will be discussed.

Components C3 and S1 can be used to bypass C1 and C2, and thus cut the rumble filtering out of circuit; C3 maintains d.c. blocking at the input and S2 provides "in" and "out" switching for the scratch filter.

Resistors R3 and R4 form a potential divider which reduces the gain of the feedback circuit of the rumble filter, as otherwise an undesirable excessive peak appears in the frequency response of the unit; R7 and R8 provide a similar function in the scratch filter. Capacitor C6 provides d.c. blocking at the output, and C11 and C12 are supply decoupling capacitors.

With S1 and S2 in the "out" positions the unit has a flat response over the audio frequency spectrum. With these switched in, the response shown in the graph (Fig. 4) is obtained.

Power Supply

The prototype filter is powered from a simple conventional mains p.s.u., as can be seen in Fig. 5. This provides dual loaded outputs of about plus and minus 7 volts, and has a smoothed output.

Components Panel

A 0·1 inch piece of stripboard having 34 strips by 27 holes contains all the filter components except for S1 and S2. Details of this are shown in Fig. 6.

Commence construction by cutting out a board of the correct size and then drill the two 6BA clearance mounting holes using

Components

See Shop Talk Page 571

Resistors
- R1, 101 390kΩ (2 off)
- R2, 102 27kΩ (2 off)
- R3, 103 470Ω (2 off)
- R4, 104 4·7kΩ (2 off)
- R5, 105 4·7kΩ (2 off)
- R6, 106 4·7kΩ (2 off)
- R7, 107 220Ω (2 off)
- R8, 108 4·7kΩ (2 off)
- R9 56Ω
- R10 56Ω
- All ¼W carbon ±5%

Capacitors
- C1, 101 22nF type C280 (2 off)
- C2, 102 22nF type C280 (2 off)
- C3, 103 470nF type C280 (2 off)
- C4, 104 2·2nF polystyrene (2 off)
- C5, 105 22nF type C280 (2 off)
- C6, 106 100nF type C280 (2 off)
- C7 400μF 16V elect.
- C8 400μF 16V elect.
- C9 220μF 10V elect.
- C10 220μF 10V elect.
- C11, 100nF type C280
- C12, 100nF Type C280

Semiconductors
- IC1, 101 741 operational amplifier 8 pin d.i.l. (2 off)
- IC2, 102 741 operational amplifier 8 pin d.i.l. (2 off)
- D1-D4 1N4001 or similar silicon diode (4 off)

Miscellaneous
- T1 mains primary 6–0–6V 100mA secondary transformer
- S1, 2 d.p.d.t. toggle switch (2 off)
- S3 d.p.s.t. rotary mains type switch
- SK1, 2 3 pin DIN socket (2 off)
- 0·1 inch stripboard: 34 strips x 27 holes; 17 strips x 30 holes; solder pins; aluminium chassis with baseplate size 178 x 102 x 63 mm x 16 s.w.g., materials for case (see text); control knob: cabinet feet; solder, wire 6BA fixings.

NOTE
The above components are those required for a stereo set-up. Components for L.H. channel are R.H. channel numbers prefixed by 100.

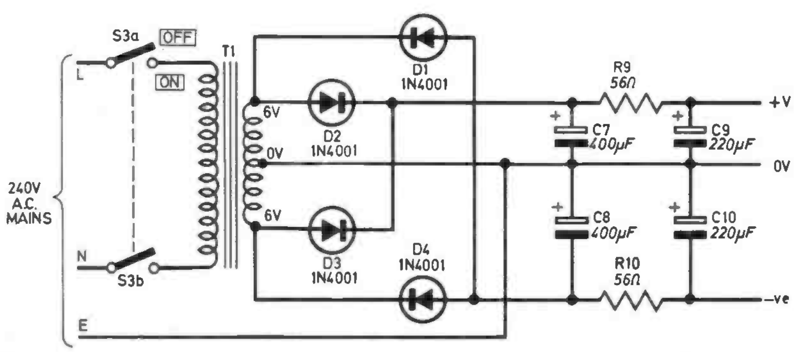
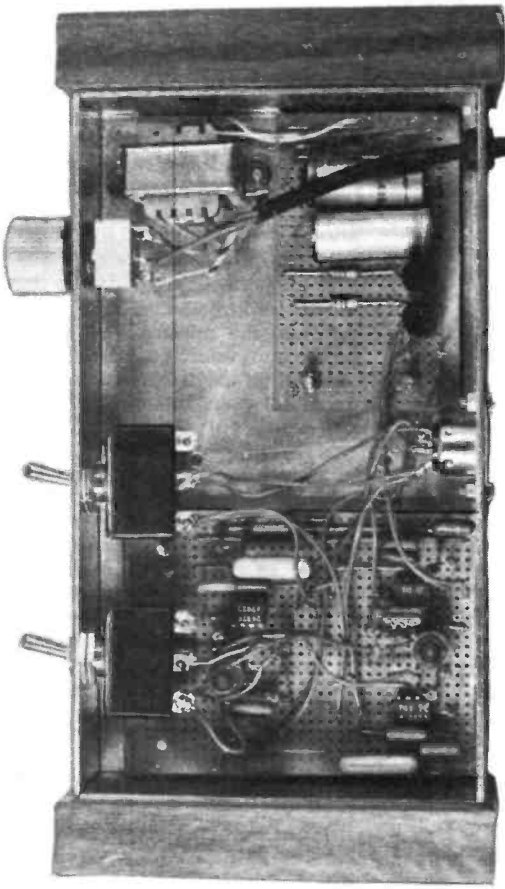


Fig. 5. Circuit diagram of the mains power supply for the filter.

SCRATCH & RUMBLE FILTER



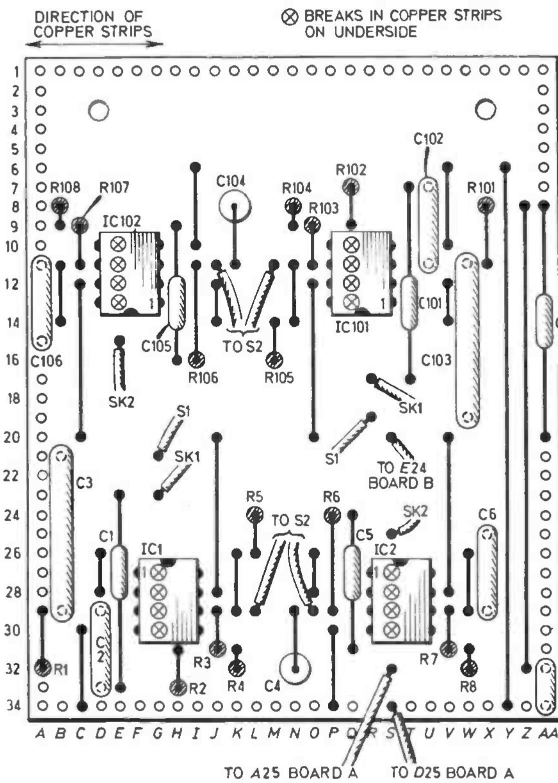


Fig. 6. Wiring details of the filter circuit board.

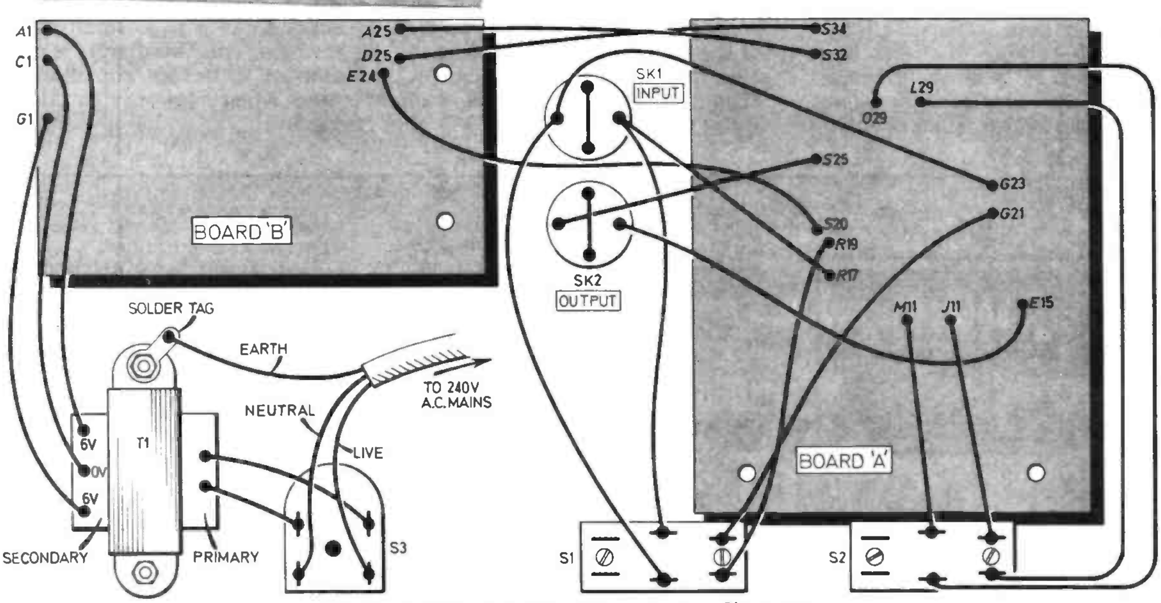


Fig. 8. Layout and wiring of the complete filter unit.

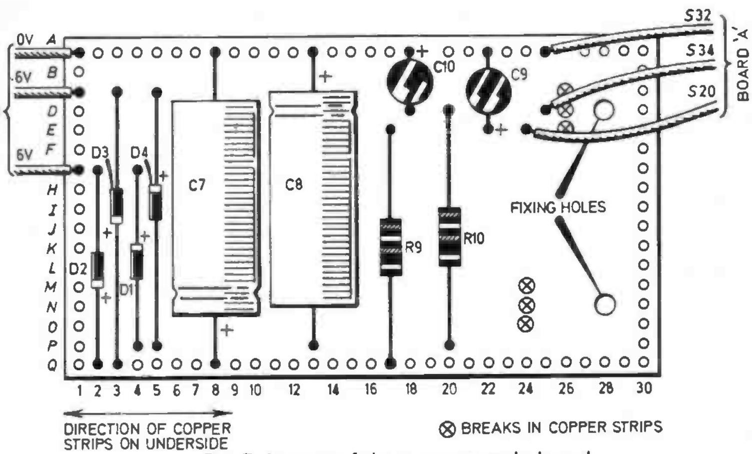


Fig. 7. Layout of the power supply board.

a 3·2mm twist drill. Then make the numerous breaks in the copper strips on the underside as indicated. The board is then wired up, starting with the link wires, and then progressing to the resistors and capacitors, and finally in the i.c.s. At the points where leads from S1, etc. will eventually connect to the panel, use of solder pins is recommended.

The small power supply components are wired up on a second 0·1 inch matrix strip board panel, and details of this are shown in Fig. 7. The panel has 17 strips by 30 holes, and is constructed along the same lines as the main panel.

Case Layout

It is important that the components are sensibly layed out inside the case, otherwise problems with pick-up of mains hum may result. It is strongly recommended that the general layout used by the author is adhered to.

The prototype was housed in a 178 x 102 x 63mm 16 s.w.g. aluminium chassis. This is fitted with a baseplate which in this particular application becomes the lid of the case.

Two 6BA self tapping screws are used to hold the lid in place, and these pass through the rear panel of the case and into the rear flange of the lid. Drill the holes in the panel using a No. 31 drill, and those in the flange using a No. 42 drill.

An attractive finish can be given to the case by cutting out two 110 x 145 x 18mm pieces of chipboard, and finishing these with a woodgrain patterned self adhesive plastic material. These are glued to the ends of the case to produce a bookends type cabinet. Extra nuts or short spacers are used to hold the component panels clear of the bottom of the case. A notch is filed in the rear flange of the lid so that SK1 does not prevent the lid from being pushed into position.

When the components and panels have been mounted, the unit should be wired up as shown in Fig. 6, using insulated connecting wire. Keep all leads as short as possible.

Using the Filter

If the unit is used in conjunction with a record deck fitted with a crystal or ceramic cartridge, it is interposed between the deck and the amplifier. The filter has been designed to have a high input impedance (250 kilohms) so that it will match such a cartridge satisfactorily.

If a magnetic cartridge is used, it will be best if the unit is fitted between the preamplifier and the power amplifier, but this will not always be feasible. It could be used between the deck and the amplifier, but to do this it will be necessary to connect at 47 kilohm resistor across each input in order to obtain the correct input impedance for a magnetic cartridge.

Due to the lower output from a magnetic cartridge, problems with excessive mains hum may result unless the main circuitry is screened from the power supply components. A better alternative would be to simply power the unit from a couple of 9 volt batteries (type PP6 for example).

Input and output leads must both use screened cables.

When using the rumble filter results will probably be best if the amplifiers tone controls are adjusted to give a small amount of bass cut. Similarly, a small amount of treble cut should be used when the scratch filter is used.

A simple but effective way of making test probes is to make a hole in the back of an empty cartridge pen refill case and push a piece of wire through it to the front. Next join the wire on to the head of a pop rivet, pull back slack wire, and push the end of the rivet back into refill case. You will find that it makes a tight fit and makes an ideal test probe.

Mr. L. A. Marks,
Dagenham.

I am sending you the following construction idea as it may be of interest to your readers.

It is often useful when testing the output capability of amplifiers, power supplies etc., to use a low value resistor with high power rating as a dummy load. Unfortunately, these resistors are quite expensive even at power ratings of 5 watts, and in experimental work, one invariably ends up wanting to use a different value resistor from the ones purchased.

A useful way out of this problem is to use a replacement spiral element for an electric fire. This is a 35 ohm resistor when cold rising to 60 ohm when red hot and dissipating 1,000 watts. This can easily be cut into lengths to give any required resistance (the resistance being proportional to length) and the last few turns straightened out for connection into breadboards, printed circuits etc.

The above information was discovered using a Wellco 230/250 volt 1,000 watt spiral element costing 32p, but other makes of replacement element should yield similar results.

F. Harris,
Whitland, Dyfed.

Physics is FUN!

By DERRICK DAINES

Induction Coil

THE induction coil also has the name of spark coil and with its aid one may manufacture fat sparks across a terminal gap. This in turn can lead us to study the phenomena of radio waves and related subjects, so a spark coil is well worth constructing.

First make a spark-gap support out of wood as shown in Fig. 1. It is very simply made by glueing together, and the banana plugs that form the actual spark gap are a tight fit in drilled holes.

For the induction coil itself we can use a small bell transformer. These are made with the intention that the primary is to be connected to the mains, giving a step-down on the secondary of 3 volts, but we will use the transformer the other way round.

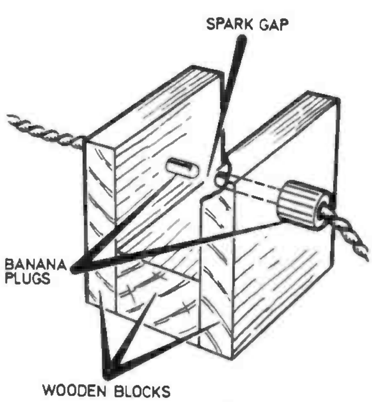


Fig. 1. Making a spark gap with banana plugs.

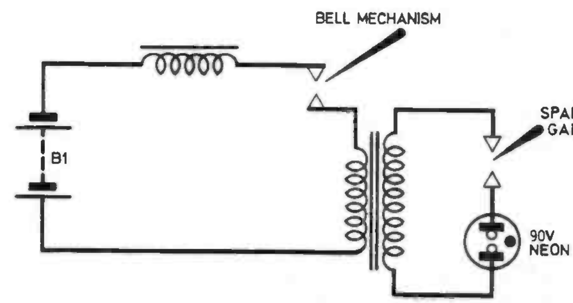


Fig. 2. The circuit diagram of an induction coil.

Connect the high-tension leads so that the current flows through a neon lamp (optional) and across the spark gap, as in the diagram of Fig. 2.

If we now connect a battery to the low-tension primary, nothing will happen because the battery supplies direct current and the transformer will work only on alternating current. We need some method of chopping up the d.c. from the battery and this can be done in either of two very simple ways. The usual way is to remove the bell from a low-voltage door bell such as we have made earlier in this series (July '76). The action of the clapper arm switches the d.c. on and off very rapidly, see Fig. 3.

The other way is to use a small electric motor, as was pointed out by a young reader earlier this year. The very high speed of a motor will make the switch on and off by the brushes and commutator ring that much faster, and the overall effect will be to make the sparking more efficient. The battery supply should suit the motor, but with the very high voltages produced at the high-tension side of the transformer, I would recommend a battery of not more than 9 volts.

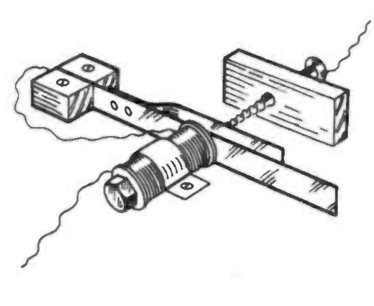


Fig. 3. Using a simple bell clapper mechanism to chop up the d.c.

The arrangement is shown in Fig. 2. Connect up the battery with the ends of the banana plugs touching. The neon lamp will glow, showing that high voltage is being produced. Now slowly move one plug backwards so that a tiny gap appears between them with a stream of sparks leaping across it. This gap can slowly be increased with the sparks getting longer and longer until they finally cease and the neon lamp goes out indicating a break in the circuit.

Depending upon the battery supply voltage, general efficiency and so on, this gap can be anything up to 5mm across with a bell transformer.

Radio Interference

While the sparking is taking place, switch on a nearby television or radio and observe the interference, particularly on long wave. This noisy interference can be broadcast by the spark over quite a surprising distance. For this reason creating such a nuisance is (strictly) illegal and if one has a social conscience, one will keep it to a minimum—perhaps by conducting such experiments outside normal broadcasting hours. Placing a large tin over the spark equipment will reduce this interference or remove it altogether, recalling our experiments with shielding earlier (September, '74). Be careful not to short out anything when positioning this tin.

It will be obvious that induction coils can be used to produce very high voltages indeed. Industry finds a ready application for them in radio transmitters and in X-ray equipment, while smaller coils are used in the treatment of some nervous disorders. As proof of this, one has only to touch the terminals producing the spark to observe that the high-voltage low-amperage current stimulates the nerves of the hand!

ENLARGER EXPOSURE TIMER

By S.R. LEWIS B.Sc.

To make consistently good enlargements, it is necessary to have accurately timed exposures. It is relatively easy to count the ticks of a clock for short exposure times but for anything over about ten seconds it becomes tedious, time-wasting and liable to error.

The Enlarger Exposure Timer described here controls the enlarger lamp directly and will produce exposure times of one second to 99 seconds, the time being continuously variable by means of a ten-way switch and a potentiometer. A focus switch is provided so that the enlarger can be adjusted before the actual exposure is carried out.

THE SYSTEM

A block diagram of the Enlarger Exposure Timer is shown in Fig. 1. It will be seen to consist of three main blocks: a bistable; a constant current sink; and a comparator.

The heart of the timer is the large electrolytic capacitor, C_A. When the unit is first switched on the bistable will be in its reset state—output Q will be at a low voltage and output $\bar{Q}$ will be at a high voltage.

Capacitor C_A will charge up to a high voltage via D_B. Since the Q output is low the buffer will not switch on the relay and the enlarger lamp will be unlit.

When the TIME button is pressed momentarily, the bistable will change state—Q will be high and $\bar{Q}$ low. This means that now the relay will be energised and the lamp will be on.

Both diodes D_A and D_B are reverse biased, so the only way that charge can leak away is through the constant current sink, which is an electronic circuit which allows current to flow to ground at a rate determined by the value of the resistor VR_A. No matter what the voltage across the constant current sink, the current through it will always be the same.

As charge leaks away from C_A the voltage across it falls linearly. The voltage comparator detects when the voltage has fallen to about 5·5 volts. As soon as this happens its output V_O goes high and immediately resets the bistable thus extinguishing the lamp.

It can be seen that varying the rate of discharge of the capacitor varies the time it will take to reach the threshold voltage. If V_C is the initial voltage across C_A, V_{ref} the threshold voltage of the comparator, I the current into the constant current sink and C_A the value of the capacitor then the time it will take to discharge from V_C to V_{ref} is given by:

$$T = \frac{I}{C_A \times (V_C - V_{ref})}$$

where T is in seconds, C_A in farads, V_C and V_{ref} in volts and I in amps.

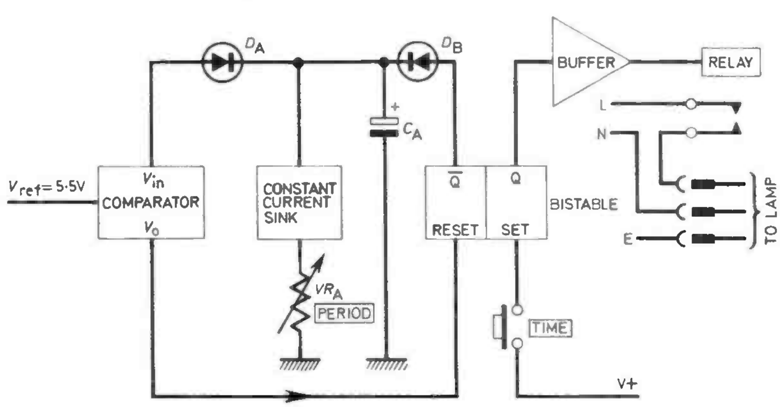
Large capacitors are bulky and expensive so it is wise to keep them as small as is practicable. In the actual unit a 150 microfarad capacitor has been used; V_C and V_{ref} are limited by the supply voltages. In the circuit used there is also the limitation that the constant current source will not function if the voltage across it falls below 5 volts so V_{ref} was set at 5·5 volts to allow a good margin of safety and V_C at the supply voltage minus a diode voltage drop giving about 14·5 volts.

We require T to be between one and 99 seconds so we can now calculate the value of I in these limiting cases.

For $T = 1$ second

$$I = \frac{1}{150 \times 10^{-6} \times (14{\cdot}5 - 5{\cdot}5)} = 1{\cdot}3\text{mA}$$

Fig.1. Block diagram of the timer.



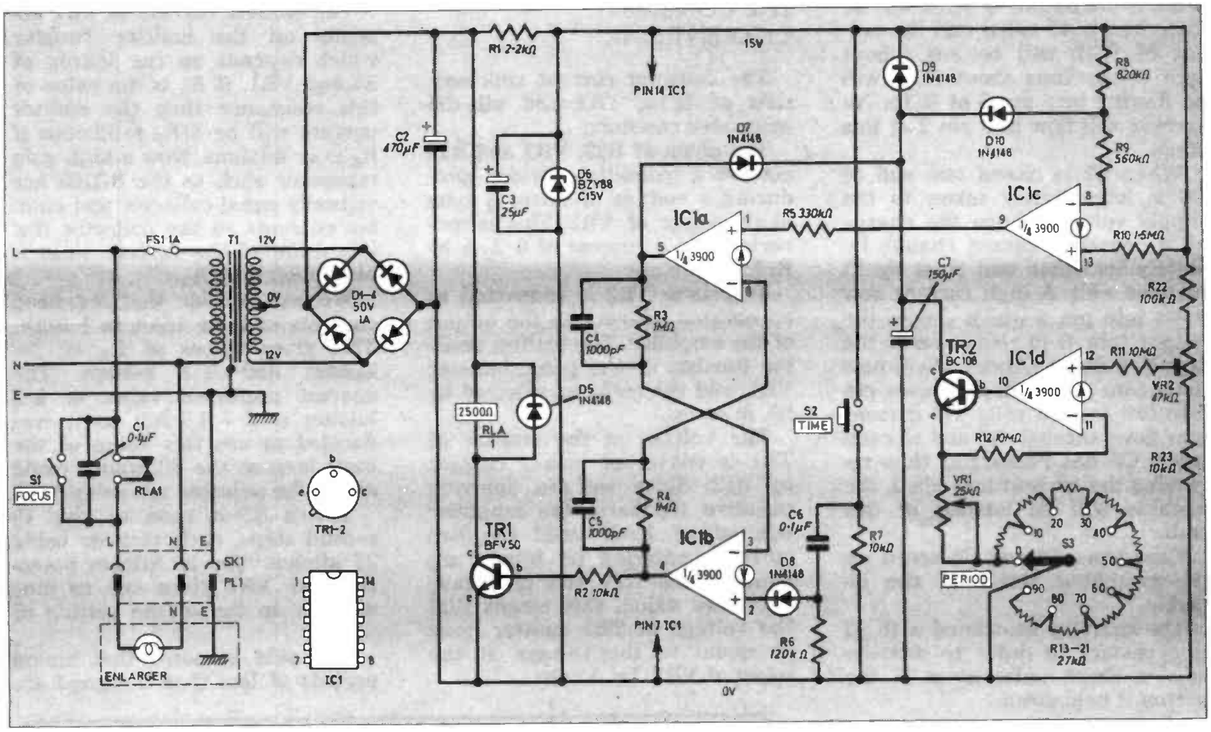


Fig. 2. Complete circuit diagram of the Enlarger Exposure Tuner

For $T = 100$ seconds

$$I = \frac{150 \times 10^{-6} \times (14 \cdot 5 - 5 \cdot 5)}{100} = 13\mu A$$

This gives us all the design parameters for the unit.

CIRCUIT DESCRIPTION

The complete circuit of the Enlarger Exposure Timer is shown in Fig. 2. The three main blocks of Fig. 1 have been translated into actual circuitry using a single four-amplifier package type LM3900. The blocks may be identified thus: IC1a and IC1b form the bistable; IC1c is the comparator; IC1d is the constant current sink.

Transformer T1 is a 12-0-12 volt 100mA type which is used to give 24 volts a.c. This is rectified and smoothed by D1 to 4 and C2 to give about 30 volts with quite a bit of ripple. This is used to supply the relay RLA.

The 30 volts is then dropped to 15 volts by R1 and stabilised by C3 and D6. This 15 volt line is used to power the actual timer circuit.

The relay controlled lamp supply is fed to an output socket SK1 into which the enlarger is plugged.

THE 3900 INTEGRATED CIRCUIT

The 3900 is probably not a familiar device to most readers so a short summary of its capabilities may be useful.

The LM3900 (or its equivalents the CA3900 or the MC1314) contains four identical *current differencing amplifiers*. Current differencing or *Norton* amplifiers are different from ordinary operational amplifiers such as the 741 in quite a number of ways.

The voltage at the inputs of a 741 can vary over a range of several volts but the voltage at both the inputs of the Norton amplifier is clamped by diodes to approximately 0·5 volt. In order to use the Norton amplifier in conventional op amp applications it is necessary to convert input voltages to currents by means of input resistors.

The output voltage of the Norton amplifier depends on the difference between the currents entering its non-inverting (+) and inverting (−) inputs.

Only a single power supply line is required for the 3900 unlike the 741 which requires both negative and positive supply lines.

The symbol for the Norton amplifier can be seen in Fig. 2. The arrow between the two inputs indicates that current flows between the inputs—a fact which can be put to use in some novel circuits.

The 3900 is extremely cheap making it ideal for use in low cost systems.

THE BISTABLE

Now we have looked briefly at the properties of the 3900 we can return to the circuit diagram to see how the various sections operate.

The bistable consists of two cross-coupled amplifiers IC1a and IC1b. Before the TIME button is

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£7.40
excluding case

pressed the output of IC1a will be high (nearly 15 volts) and the output of IC1b will be low (about zero volts). Thus about 15µA will be flowing into pin 3 of IC1b. No current will flow into pin 2 at this stage.

When S2 is closed one end of C6 is immediately taken to the supply voltage. Since the charge on a capacitor cannot change instantly its other end rises by 15 volts as well. A high current now flows into pin 2 which causes the output (pin 4) to rise towards the supply voltage. About 15µA now flows into pin 6 which causes pin 5 to fall to zero volts. No current now flows through R3 and so even when C6 has recharged thus removing the current into pin 2, the bistable will be latched in this state.

Capacitors C4 and C5 speed up the switching action of the bistable.

The circuitry associated with S2 is necessary in order to produce only a short pulse even if the button is held down.

THE COMPARATOR

The comparator consists of IC1c, R8, R9, R10 and D10.

If we imagine D10 as an open circuit for the moment we can see that current will be flowing into both inputs of the amplifier.

About 11µA will be flowing into pin 8 via R8 and R9 and about 10µA into pin 13 via R10. Since more current is flowing into the inverting input (pin 8) the output (pin 9) will be at zero volts.

The voltage at the junction of R8 and R9 will be approximately 6·3 volts. Now in calculating these figures we assumed that D10 was an open circuit and, in fact, unless the voltage on the capacitor is one diode voltage drop (i.e. 0·6 volts) less than 6·3 volts D10 will be reversed biased and will be virtually an open circuit.

As soon as the voltage on C7 reaches this threshold of 5·7 volts, D10 will be forward biased and current that was flowing into pin 8 will be diverted into C7. Soon this current will become less than the 10µA flowing into pin 13 and the output of the amplifier will rise to the supply voltage thus applying a reset pulse to IC1a via R5.

As soon as the bistable is reset C7 will charge up and the output of IC1c will fall back to zero volts, thus preparing the circuit for another timing period.

THE CONSTANT CURRENT SINK

The constant current sink consists of IC1d, TR2 and all the associated resistors.

The chain of R22, VR2 and R23 act as a potential divider producing a voltage of about 3 volts at the wiper of VR2. This is converted into a current of 0·3µA by R11.

Transistor TR2 is connected as an emitter follower to the output of the amplifier. The emitter resistor consists of the potentiometer VR1, and the resistors selected by S3, in series.

The voltage at the emitter of TR1 is converted into a current by R12. Since we are applying negative feedback, the amplifier will adjust itself until the two currents entering its inputs are equal. Since R11 and R12 have the same value, this means that the voltage at TR2 emitter must be equal to the voltage at the wiper of VR2, i.e. 3 volts.

The emitter current of TR2 depends on the emitter resistor which depends on the setting of S3 and VR1. If R_E is the value of this resistance then the emitter current will be $3/R_E$ milliamps if R_E is in kilohms. Now a high gain transistor such as the BC108 has virtually equal collector and emitter currents so the collector (i.e. the value of the current sink) is also given by $3/R_E$.

We saw earlier that we need currents of from 13µA to 1·3mA. This gives values of R_E of 230 kilohm and 2·3 kilohm. The nearest preferred value to 2·3 kilohm is 2·7 kilohm so it was decided to use this value as the basic step as the difference could always be adjusted out using VR2.

Switch S3 is used to give 10 second steps, each resistor being 27 kilohm. The 25 kilohm potentiometer VR1 gives one to nine seconds on top of the setting of S3.

It should be noted that timing periods of less than a second are

Components

Resistors

R1 2·2kΩ ½W
R2 10kΩ
R3 1MΩ
R4 1MΩ
R5 330kΩ
R6 120kΩ
R7 10kΩ
R8 820kΩ
R9 560kΩ
R10 1·5MΩ
R11 10MΩ
R12 10MΩ
R13 to R21 27kΩ ± 2 per cent (10 off)
R22 100kΩ
R23 10kΩ
All ±5% ¼W unless otherwise stated

Capacitors

C1 0·1µF polyester
C2 470µF 63V elect.
C3 25µF 25V elect.
C4 1000pF polystyrene
C5 1000pF polystyrene
C6 0·1µF polyester
C7 150µF 25V elect.

Semiconductors

D1–D4 50V 1A bridge rectifier
D5 1N4148 or similar silicon diode
D6 BZY88 C15V 15V 400mW Zener diode
D7–D10 1N4148 (4 off) or similar silicon diode
TR1 BFY 50 *npn* silicon
TR2 BC108 *npn* silicon
IC1 CA3900 (or LM3900)

Miscellaneous

VR1 25kΩ linear potentiometer
VR2 47kΩ subminiature horizontal skeleton preset
S1 on/off toggle switch
S2 on/off pushbutton switch
S3 1 pole 10 way rotary switch (see text)
T1 mains primary, 24V 100mA secondary
FS1 1A fuse and panel mounted holder
RLA 24V 2500 relay with at least one make contact (see text)
SK1, PL1 Mains plug and socket
0·1 inch matrix stripboard, 33 strips x 44 holes; solder pins; mains cable; pointer knobs (2 off); connecting wire.

See **Shop Talk** page 571

not feasible as the current required is too high for the circuit to cope.

Potentiometer VR2 allows the voltage to be varied from about 0·9 volts to about 5·5 volts. This variation is necessary in order to allow for all possible values of C7. A capacitor which is marked "150μF" may in fact have any value between 75μF and 300μF.

Thus the voltage at the wiper of VR2 must be variable over a similar four to one range to compensate for these variations.

There must always be a voltage between the collector and emitter of TR2 for it to operate properly; with VR2 at maximum the voltage on the emitter will be 5·5 volts so the threshold voltage of the comparator must be higher.

Although there is no "lower end stop" on the potentiometer, it is not possible to time for periods of less than a second as the constant current sink will not operate if the emitter resistor of TR2 is reduced to a low value.

RELAY OUTPUT

One side of the main bistable is used to drive transistor TR1 through the base resistor R2. The relay is connected between the collector of the transistor and the 30 volt line. The relay used in the prototype was a 24 volt 2500 ohm type. In fact any relay with a voltage rating of less than 30 volts and a current requirement of less than 50 milliamps can be used providing an appropriate resistor is placed in series.

A 24 volt or 30 volt relay will need no series resistor but if the voltage rating is V_r and the current I_r, then the series resistor R_s should have a value given by

$$R_s = \frac{30 - V_r}{I_r}$$

If only the resistance of the relay R_r and its voltage ratings are known, then use

$$R_s = \frac{(30 - V_r) \times R_r}{V_r}$$

Two "make" contacts of the relay are used to switch the enlarger lamp current so these contacts must be capable of carrying the required current. A capacitor C1 is placed across the contacts to absorb some of the energy of the spark thus extending contact life.

A FOCUS switch S1 is placed in parallel with the relay contacts so that the enlarger lamp can be switched on for adjustments.

DISCHARGE PATH

The only component not described so far is the diode D9 from the positive plate of C7 to the 15 volt supply line. The purpose of this diode is to provide a discharge path for C7 when the power supply is switched off.

If this diode were not provided then C7 would retain its charge for a very long time since D7, D10 and TR2 would all be reverse biased.

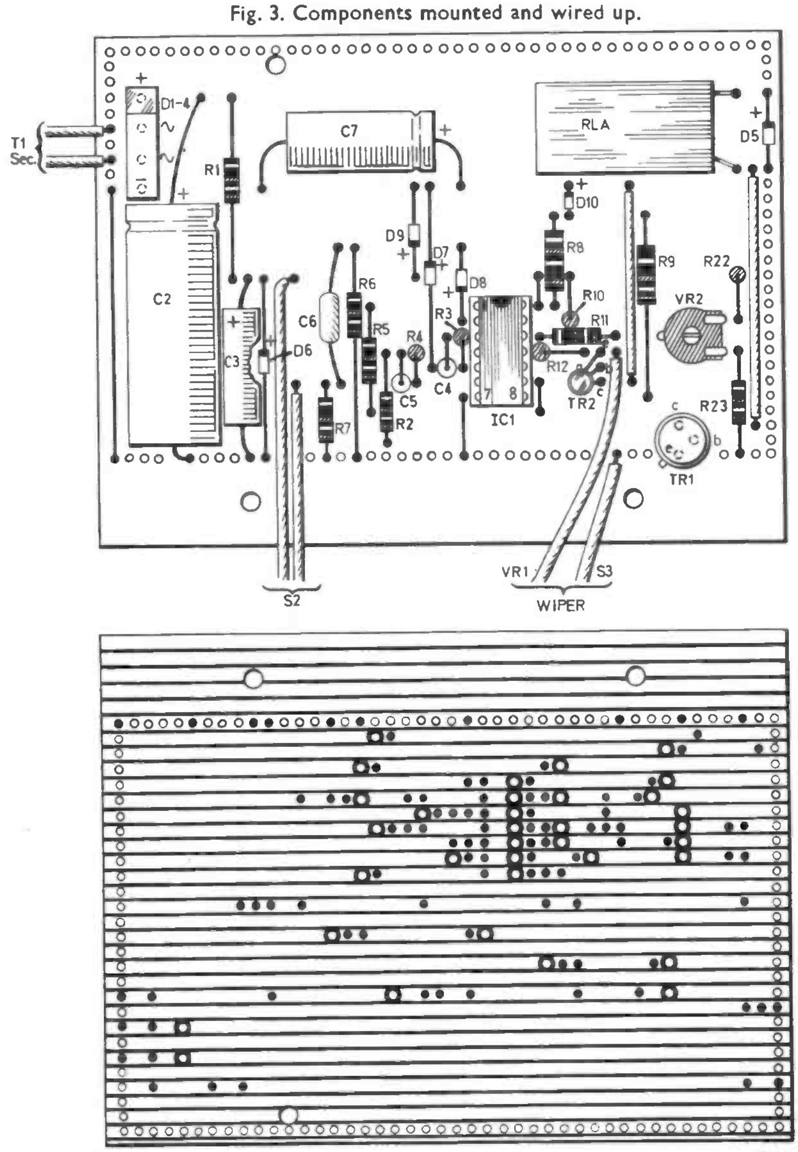
The reason that it is necessary to discharge C7 is to make sure that on applying power to the circuit, the bistable is in its reset state. If this were not ensured then it is possible that the enlarger lamp would come on when power was applied.

To see how discharging C7 ensures that the bistable resets, note that with zero volts across C7 the comparator output (pin 9) will be high. This will cause pin 1 of IC1a to be high which resets the bistable. Of course, as soon as the bistable is reset C7 will charge up to nearly supply voltage, thus sending the output of the comparator low, but this will not change the state of the bistable as it will be latched as described earlier.

CONSTRUCTION

Most of the components are mounted on a piece of strip board as shown in Fig. 3. A socket was used for the i.c. and, while

Fig. 3. Components mounted and wired up.



ENLARGER EXPOSURE TIMER

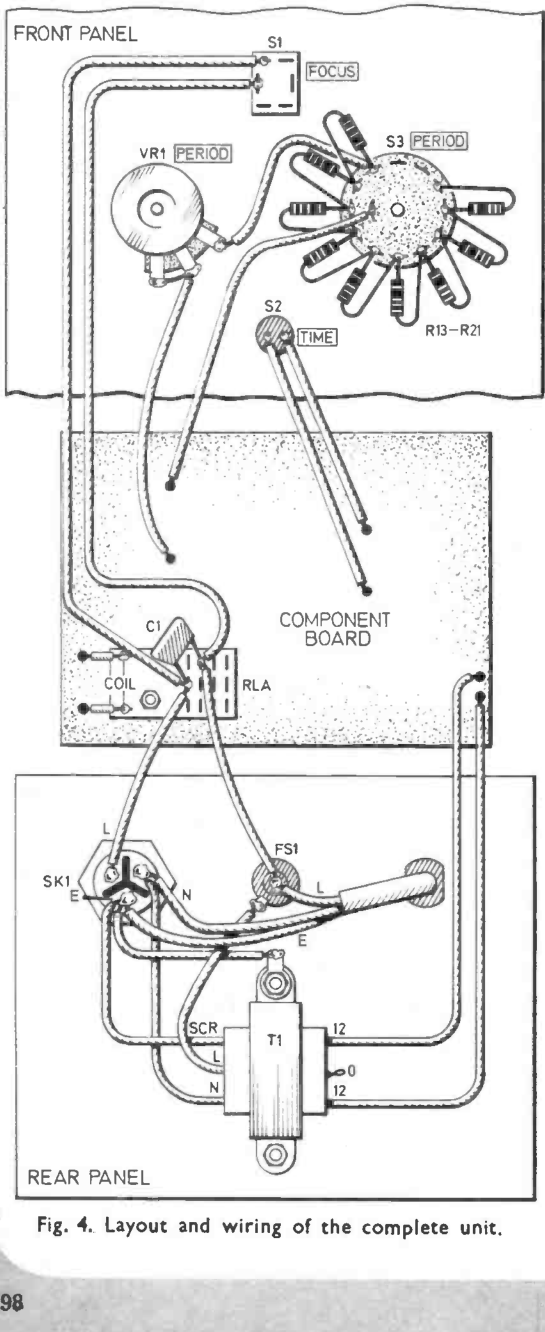
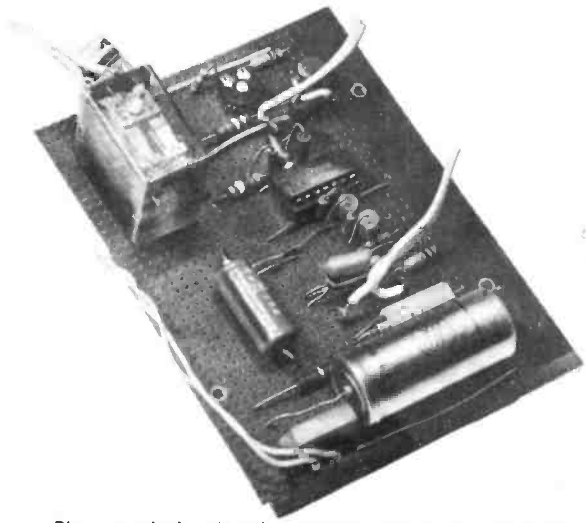
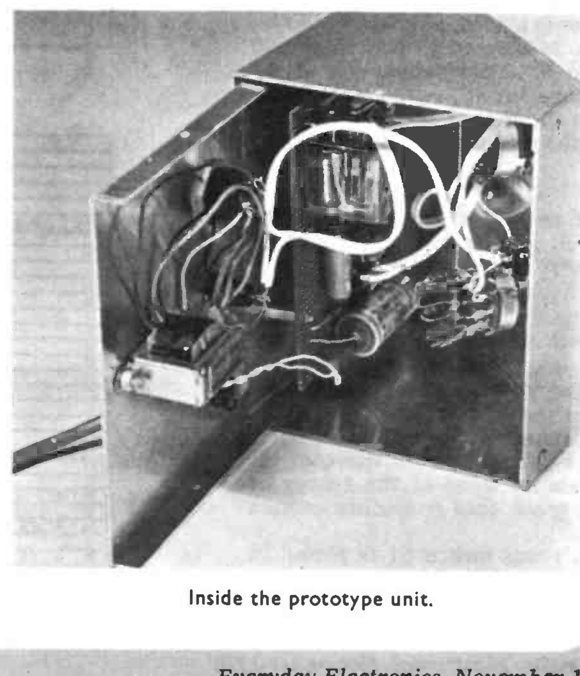


Fig. 4. Layout and wiring of the complete unit.



Photograph showing the prototype component board.



Inside the prototype unit.

this is not essential, it does make testing easier.

Pins have been used to carry wires which leave the board. Two pins have also been used to mount the relay which is held quite firmly by soldering its coil contacts to these pins.

Bridge rectifiers vary in packaging and the contact arrangement may not be as shown. Check carefully and make any changes necessary to accommodate the type used. Four 1 amp diodes could be used if required.

The whole unit was built into a sloping front case with a removable back. This back was used to mount all the mains components so as to keep them separate from the low voltage board (see Fig. 4).

Switch S3 and potentiometer VR1 are mounted on the sloping panel together with S1 and S2. All the resistors should be attached to S3 before mounting it in the box. In the prototype a one-pole 12-way switch with an adjustable end stop was used to give a 10-way switch.

Before mounting the board in the box it is necessary to test it and to set VR2 to give the correct timing periods.

SETTING UP

Connect the secondary of T1 to the board and connect S3 and VR1 in series to the pins on the board and also S2 to its pins. There is no need to connect anything to the relay at this stage. Apply power.

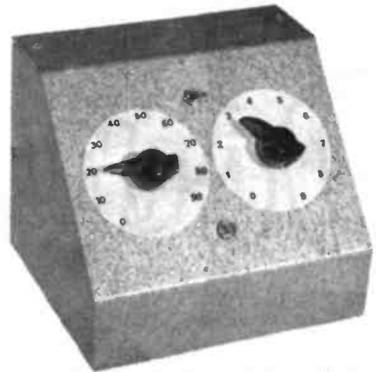
Check the voltage of the power line before inserting the i.c. It should be very close to 15 volts. If not check the power supply wiring. Insert the i.c. (correctly oriented) into the socket.

Press S2 with VR1 at minimum setting and S3 at the 10 second position. The relay should click in immediately and click open again after about 5 to 15 seconds. If this does not happen the operation of the circuit can be checked by connecting a high impedance meter across C7.

Before S2 is pressed it should have about 14·4 volts across it—if it does not then check the wiring of the bistable. Monitor pin 5 then pin 4 of the i.c. these should go from high to low, and low to high respectively as S2 is pressed.

Assuming the bistable is working, check that the voltage across the capacitor is falling when S2 is pressed. If it stays at 14·4 volts suspect the wiring of the constant current sink. There should be a voltage of about 3 volts at the emitter of TR2. Do not try to measure the voltage at the inputs to the i.c. as these will always be about 0·5 volt.

Assuming these sections are not at fault check the wiring of the comparator.



When the unit is working satisfactorily it may be calibrated. Set both S3 and VR1 to their maximum settings i.e. 99 seconds and press S2. Measure the time against a clock with a second hand and adjust VR2 to give exactly 99 seconds. This is all the calibration that is needed because all other ranges are now set up.

Mount the board in the bottom of the case and then fix the switches and potentiometer to the front panel. Finally affix the back panel into the case.

Two paper scales are then glued to the front panel. The ten positions of S3 are marker 0, 10, 20, etc. up to 90. The scale of VR1 is divided into nine equal segments and these are marked 1, 2, 3, etc. up to 9.

The unit is now ready for use. ☐

I frequently get customers who say, "Oh! you remember that amplifier that appeared in Everyday Electronics in 1974, might have been May or June, have you got the parts for it?" At one time we kept every copy of every magazine and even had them bound. In the end we were defeated by space and pace. The space to store them, and the pace of business which gives us no time for such niceties.

It was while I was pondering over this situation that the following idea occurred to me. If only all the constructional articles published in the last three years were grouped together in similar types, for example, amplifiers, radios, test gear, burglar alarms. Each one could be published as a separate book, or if there were not enough to make a reasonable sized publication, several groups, together.

I would like to see not only Everyday Electronics and *Practical Electronics*, but *Practical Wireless* come in on it as well. However, this might be treasonable talk.

Everyone I have mentioned the idea to has been most enthusiastic. If you like the sound of it, please drop a line to the editor or myself.

By the time this appears in print an old friend of mine Mr. Fred Chaston a Director of Jackson Bros. will have retired after 50 years of service with his firm. Of course you all know what they make, variable capacitors. I asked Mr. Chaston how business was and he told me it was booming. I told him not many firms could say that today, but added that they have almost a monopoly in their product. I went on to say that their only danger might be from the Japanese, and he surprised me by saying that they export large quantities to Japan. Bravo!

I was even more astonished to learn that Mr. Chaston has driven every day from Palmers Green (which is North London) to Croydon (which is South London) a dreadful journey at any time. When he told me, I said, "You must leave at about 6.30 a.m. to miss the traffic?"

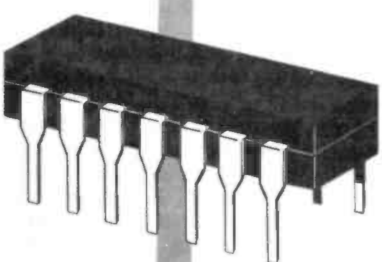
He said, "No I am at my desk by 6.30 a.m." I gave an incredulous gasp and replied, "What ever time do you finish for mercy's sake?" Back came the reply "6.30 p.m.!"

Well it all goes to show how hard we component chaps work on your behalf! Meanwhile a long and happy retirement Fred.

Doing it Digitally...

New Series Part 2

By O.N. Bishop



A new series providing an introduction to, or revision of, digital techniques.

WE CONTINUE this month with two more gates, the INVERTER and NOR.

Details are given for making the i.c. board and experiments described.

THE INVERTER

The output of the circuit shown in Fig. 1.5 is the same as the input so this is not a useful logic circuit on its own. What happens if it is slightly altered to the circuit of Fig. 2.1?

When the 10 kilohm resistor is touched to negative the lamp lights but when to positive the lamp goes out—the output is now the opposite of the input.

This is easily explained. When the transistor is off (10 kilohm to negative or disconnected) current can easily flow through the 560 ohm resistor and l.e.d. so the l.e.d. lights.

When the transistor is on (10 kilohm to positive) the current flows more easily through the transistor than the l.e.d. so less current goes through the l.e.d. which does not light.

This could be a useful circuit for solving problems for its output is opposite to its input—it is called an INVERT gate or simply an INVERTER.

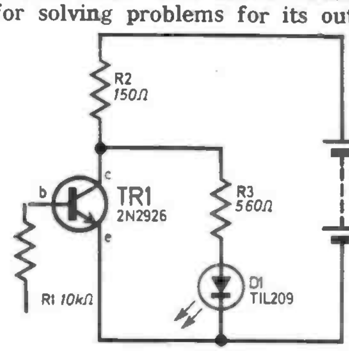


Fig. 2.1. Connecting the l.e.d. across the transistor rather than its collector lead produces an inverter.

It could be used to solve the following problem: "a person goes to the cinema if it is not raining. It is raining, what does he do?"

Connect the resistor to positive (high) whenever it is raining and the lamp will indicate what he should do.

Rather a simple problem on its own, but used in connection with other gates, the INVERTER can help sort things out.

Try connecting the INVERTER to the OR gate of Fig. 1.5. The circuit is shown in Fig. 2.2.

Try connecting no diodes, one diode, the other diode, and both diodes to the positive terminal and record the results in a truth table. A connected diode is recorded as high (H) and a disconnected diode which has the same effect as a diode connected to negative is recorded as low (L). If the l.e.d. lights record this output as H, if not record as L.

The completed table is shown in Table 1.4. On comparing this with Table 2.1, it will be found that the circuit has behaved just as expected. The input columns are the same, but each entry in the output column is inverted (H instead of L and vice versa).

This inverted OR (sometimes called negative OR or NOR for short) is used fairly often in computer circuits and is used later in the series. It is used to solve problems involving a negative such as: "A person will NOT go to the cinema if it is raining OR if a western is showing".

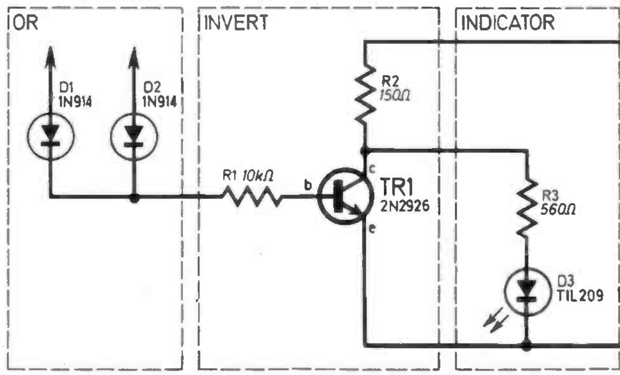


Fig. 2.2. Connecting an OR gate and an INVERTER in series produces a NOR gate.

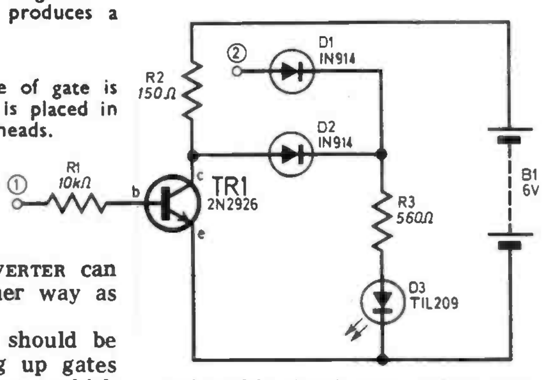


Fig. 2.3. A different type of gate is produced if the inverter is placed in one of the OR gate input heads.

ANOTHER GATE

The OR and the INVERTER can be put together another way as shown in Fig. 2.3.

By now the reader should be getting used to wiring up gates and simply wants to know which gates to connect to which, rather than every single component. Symbols are used for the various gates, some of which are shown in Fig. 2.4. Fig. 2.4e shows the symbolic form of Fig. 2.3.

The symbolic form shows that one of the inputs to the OR gate goes through the INVERTER first, the other goes directly to the OR gate.

The reader might like to try predicting the truth table for this circuit before building it.

The solution is shown in Table 2.2.

Problems which can be solved using this circuit are: (a) "A person goes to the cinema if there is a western showing OR if it is NOT raining. A western is showing and it is raining, does he go?" (Make sure to use the correct inputs for western and raining.) (b) "We will beat the enemy if they delay their attack OR if we do NOT get caught by the rainy season. The rainy season is not due for a long time, but the enemy is attacking. Shall we win?"

These problems are still pretty simple once the method of converting them into circuits becomes familiar. To solve complex problems a lot of gates are needed which means a lot of components and complicated wiring which leads to potential errors.

INTEGRATED CIRCUITS

Fortunately it is not necessary to wire up hundreds of resistors, transistors and diodes—electronic engineers have invented special components in which dozens of components are already wired together to make gates. A gate can be taken as a unit and plugged in ready for use.

It might be expected that these complicated components (or integrated circuits) would be very expensive but this is far from true. The mass manufacture makes many of them no more than the price of a single transistor, so both time and money can be saved by using i.c.s.

MAKING AN I.C. BOARD

The layout of the board which is to be used for the construction of experiments is shown in Fig. 2.5. In fact, there is no need to make up the whole board at once—only one "i.c. socket" and one lamp can be used and the additional components added at a later date.

The board, when complete, has enough space for all the experiments in this series and for many other projects which can be thought up.

COMPONENTS

When obtaining the parts for the board it would be wise to also purchase the integrated circuits necessary for the first experiments. Those used are from the widely advertised "7400" series of transistor transistor logic (TTL) i.c.s. Be careful not to buy the low power (e.g. 74L00) types or high speed (e.g. 74H00) versions as these are not suitable for the beginner and are much more expensive.

The construction of the board is quite straightforward. Start by cutting the board to size and make the cuts in the copper

Table 2.1. Truth Table for Fig. 2.2

Inputs		Output
L	L	H
L	H	L
H	L	L
H	H	L

Table 2.2. Truth Table of Fig. 2.3

Inputs 1	Inputs 2	Output
L	L	H
L	H	H
H	L	L
H	H	H

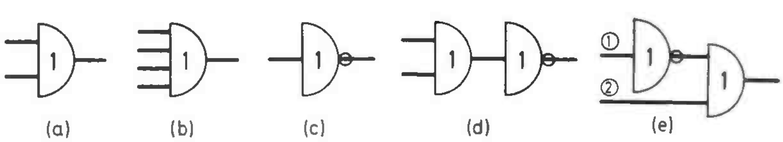


Fig. 2.4. Symbols for some typical gates:
(a) Shows a 2-input OR gate (b) a 4-input OR gate (c) an inverter (d) the circuit of Fig. 2.2. (e) the circuit of Fig. 2.3.

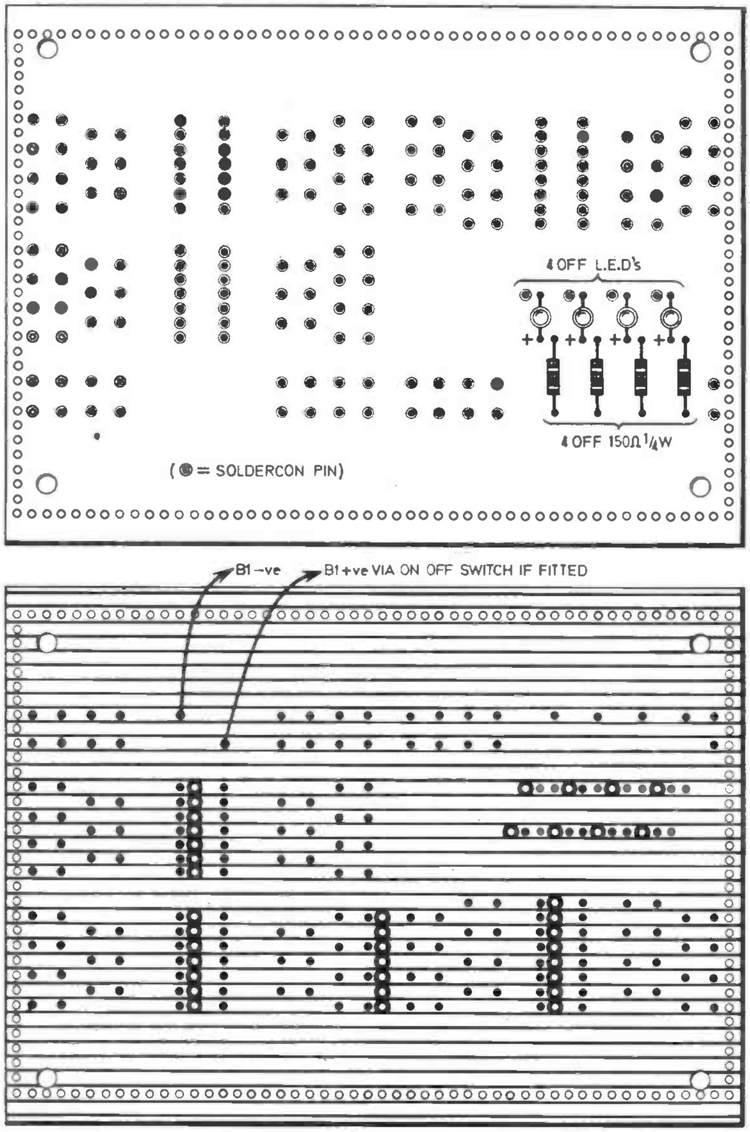


Fig. 2.5. The i.c. breadboard showing the layout of the components and pins on the top side and the breaks to be made on the underside of the strip board.

strips. Insert the four resistors, cut the leads short and solder.

Insert the Soldercon pins; these are used to hold the i.c.s and make connections to the i.c.s.

Next the l.e.d.s must be fitted. Spread the leads carefully and make sure that the leads are the correct way round—cathode to the lower ground rail. Do not overheat when soldering.

Finally connect the two wires for connection to the battery and mount the board on two wooden blocks. If required the complete board can be fixed in a suitable case and an on/off switch inserted as shown in the photographs.

After thoroughly checking the back of the board all is ready for the first experiment with an integrated circuit.

WORKING WITH AN INTEGRATED CIRCUIT

The first i.c. to be used is the 7402. This is described as a "quadruple two-input NOR gate" which means that the device contains not just one two-input NOR gate like the one constructed in part 1, but four of them.

Actually, the circuit of each gate is not the same as the circuit of the gate in part 1. In fact, it is a lot more complicated in order to make it more reliable, faster switching and to improve its performance in other ways.

The function of each of the i.c. pins is shown in Fig. 2.6. The diagram is drawn with the i.c. viewed from above—just as the i.c. is viewed when it is in its socket.

Only the pin connections are shown in the diagram—the gates are really all together on a tiny chip of silicon about 1mm square.

The power supply is connected to pins 7 ("ground" or negative) and 14 (positive) and these connections run to all four gates. Apart from these, each gate has its own pins for its two inputs and one output.

Carefully insert the i.c. into the top 14-pin "socket". Make sure that none of the pins gets bent so avoiding contact with the socket pins. If any are bent remove the i.c., straighten the pin and re-insert.

Using short pieces of insulated wire, make connections from pin 7 to the ground or negative rail at the lower edge of the board and from pin 14 to the positive rail.

Connect the output of one of the gates (pin 1) to a lamp pin. Attach a wire to each of the inputs to the gate (pins 2 and 3) but leave these free. The board should appear as shown in Fig. 2.7.

Re-check for correct orientation of the i.c. (cut-out groove or semi circle or dot towards the top). If the battery is connected when the i.c. is the wrong way round the i.c. may be damaged and at the very least some odd results will be obtained from the experiments.

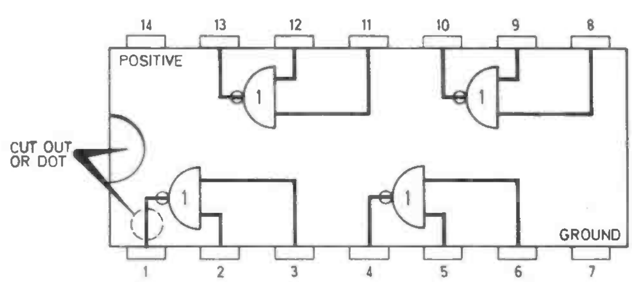


Fig. 2.6. The internal connections of the 7402 integrated circuit.

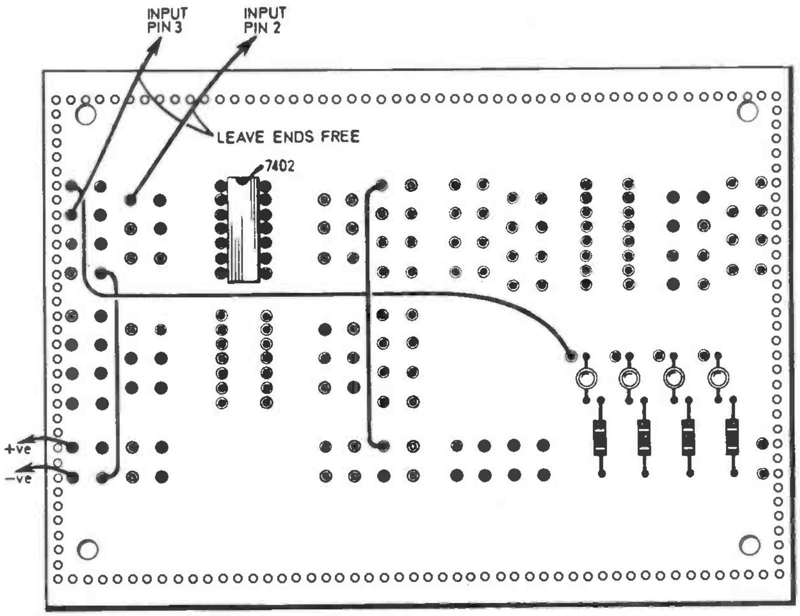


Fig. 2.7. Wiring up of the gates of the 7402.

Remember that the 7400 series work at between five and six volts—the absolute maximum is seven volts. Never connect to a nine volt supply or anything greater.

The battery leads can now be connected, again making sure positive goes to the positive rail and negative to the negative rail.

Try touching the wires from pins 2 and 3 against the pins on the positive and negative rails. Work through the usual sequence: Both to negative, one to negative one to positive; then the other way round; finally both to positive. Make out a truth table to show what happens to the lamp with each input.

Check the results against Table 2.3. Now compare this with Table 2.2. This was the table for an OR gate followed by an INVERTER, which we later said was called NOR for short. Usually there is a simpler way of drawing it too as shown in Fig. 2.8 (and, incidentally in Fig. 2.6).

Check the other NOR gates in the i.c. using the truth table method to see if they are working

Table 2.3 Truth Table for one 7402 NOR gate

Inputs		Output
Pin 1	Pin 2	
L	L	H
L	H	L
H	L	L
H	H	L

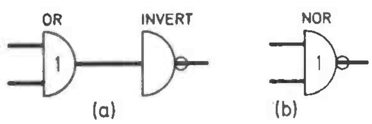


Fig. 2.8. Shows a 2-input OR gate followed by an inverter. These symbols are usually combined into the NOR gate symbol at (b).

properly. Try not to leave the battery connected when not actually testing the gates as unused gates take more power than used ones and this might overheat the i.c. This can be overcome by connecting unused inputs to ground but the extra wiring is hardly worth while for the short time that testing requires.

Table 2.4. Truth Table for Fig. 2.9.

Input	Output
L	H
H	L

USING SEVERAL GATES

Now that so many NOR gates are available, with only two wires going into each and one wire coming out, it is easy to try wiring several gates together to see what can be built from them.

In part 1 gates were built from resistors, diodes and transistors: now whole gates are used as building blocks and complicated circuits can be made from them.

Some suggestions are given in Figs. 2.9 to 2.12. Connect them up and work out the truth tables. Check against those given.

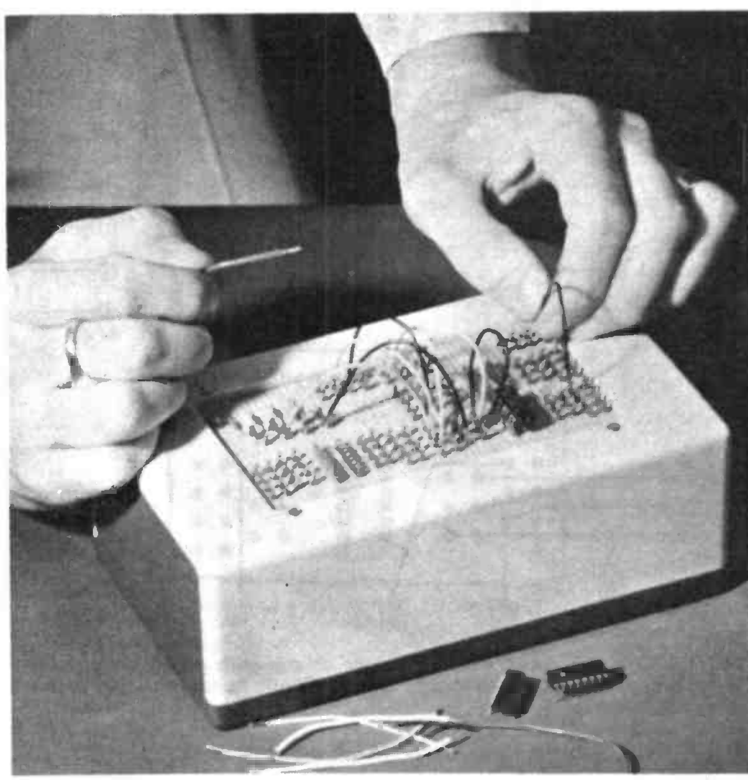


Table 2.5. Truth Table for Fig. 2.10

Inputs 1	2	Output
L	L	L
L	H	H
H	L	H
H	H	H

Table 2.6. Truth Table for Fig. 2.11

Inputs 1	2	3	Output
L	L	L	L
L	L	H	L
L	H	L	H
H	L	L	H
L	H	H	L
H	L	H	L
H	H	L	H
H	H	H	L

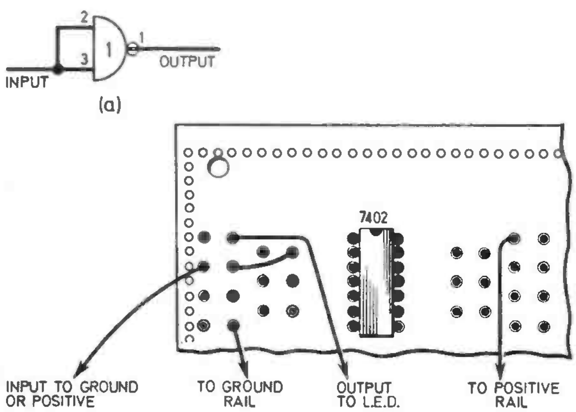


FIG. 2.9 (b)

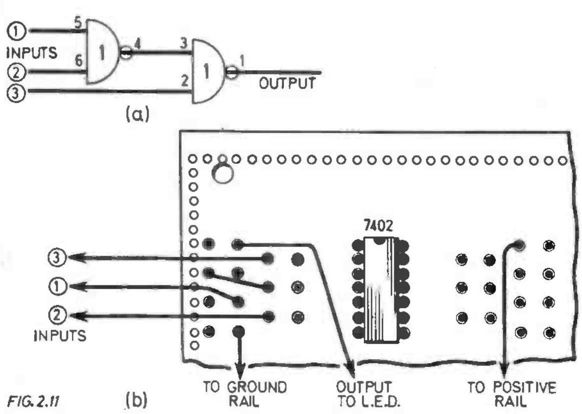


FIG. 2.11 (b)

Fig. 2.9. Connecting two inputs together on one gate produces a type of gate we have met before. Check its truth table and name it.

Fig. 2.11. This gate has three inputs. Check the truth table.

Table 2.7. Truth Table for Fig. 2.12

Inputs 1	2	3	4	Output
L	L	L	L	L
L	L	L	H	L
L	L	H	L	L
L	H	L	L	L
H	L	L	L	L
L	L	H	H	L
L	H	L	L	L
H	L	L	H	H
L	H	H	L	H
H	L	H	L	H
H	H	L	L	L
L	H	H	H	H
H	L	H	H	H
H	H	L	H	H
H	H	H	L	H
H	H	H	H	H

There are plenty more combinations of NOR gates that can be tried. Work out some more, find their truth tables and try to write out some problems that the circuits would solve.

To be continued

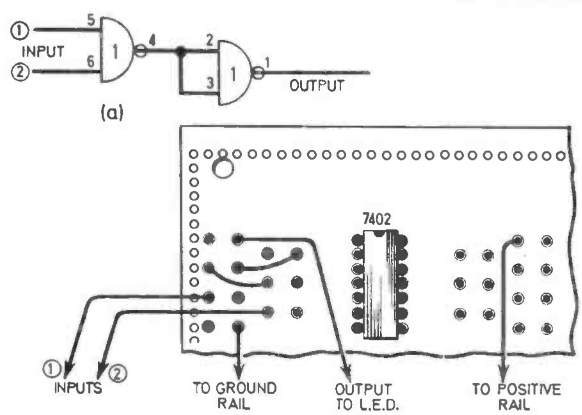


FIG. 2.10 (b)

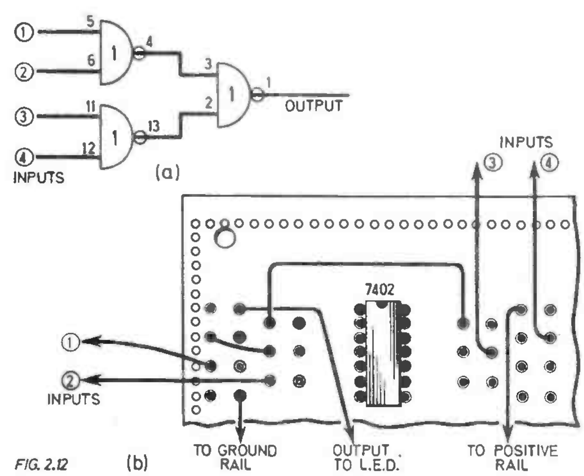


FIG. 2.12 (b)

Fig. 2.10. Here two gates are used in this experiment and again they produce the same truth table as a gate discussed earlier.

Fig. 2.12. Here a four input gate has been made from three NOR gates.

READERS LETTERS

Retirement Hobby

First, may I say how much I am enjoying your present series of "Teach In" but have now reached the point where I can only follow the practical side, the theoretical part is now beyond my mathematical learning. However, this does not deter me as I can follow the workings if not the whole of the reason why.

I appreciate this opportunity to learn because although I have always had a leaning towards radio, but never had the time to follow it through due to my employment etc., I have decided to make it a hobby for my retirement years and it may surprise you that I am now 60 years old and played about with crystal sets and cats whiskers.

I recently completed your *Matchbox Receiver* but reception in these multi story flats was not too good due I suppose to the steel reinforced concrete; however, I put the set into a slightly larger box and fitted a telescopic aerial and am pleased to say it works well. In the evening I can get numerous foreign stations plus one I have not heard for some time, Radio Caroline.

T. E. Flint,
Liverpool

Helping Hand

My main reason for writing is to tell you that last September, I began a course in Radio, T.V. and Electronics (City & Guilds) at Bradford College. In that same month I bought my second copy of E.E. and found to my delight, part one of a series for beginners which was to become a useful aid to my course.

I have recently obtained the results and found that I have passed both the Mechanics & Technicians exams with credit. I would therefore like to thank you and Mr. A. P. Stephenson for *Teach In* 76. I am not saying I couldn't have passed without your aid, but it most certainly was a great help.

Malcolm P. Crann.
Bradford,

Objection

I have just read *For Your Entertainment* in the August '76 issue of EE and I feel I ought to point out to Adrian Hope that the 27MHz band is already being used for radio controlled modelling and is not in fact "spare" as he appears to assume and I am sure that most radio modellers would object to being turfed out of our allotted band.

Graham Thomas,
Fife.

We are not amused

Adrian Hope's remarks (*For Your Entertainment* August 1976) concerning the Citizens band on 27MHz deserves some comment as he completely ignores the existing users of the band, and in particular the many thousands of modellers, legally using this band for the purposes of remote control of vehicles, boats, and aircraft.

The radio control of models is a fast growing hobby and its governing bodies were instrumental in making illegal the use of this band for CB purposes. To suggest that 27MHz should be used for CB on the American style would create many safety hazards especially those operating flying aircraft where injury and loss of life could and would result through interference.

American modellers have foresaken their 27MHz band due to CB Interference in favour of 72MHz, which is not available to modellers in the U.K. The only alternative is 458MHz which at this time is completely impractical for the purpose due to transmitter power limitations, complexity, reflection problems and high costs.

Mr. Hope should consult the CB association who know our problems are lobbying for a v.h.f. frequency modulated allocation. It would however seem likely that f.m. will be used increasingly by modellers to resolve existing interference problems on 27MHz.

In our modelling club we have about 140 members and about 110 of these are remote control flyers. We can fly six models only at one time on six frequencies. Can you imagine six models weighing 8 lbs a piece travelling at speed between 40 and 150 m.p.h. careering round the sky due to interference.

John and Peter Pearson,
Peterlee, Co. Durham.

Simple Root!

I should like to correct an error in the construction article *C-L Resonance Tester* in EVERYDAY ELECTRONICS, September, 1976, which otherwise may confuse some of your readers. On page 482, item (7) dealing with the calibration of the variable capacitor it is stated that if 100pF resonated with the coil at 6.1MHz then 110pF will resonate at $\frac{100}{110} \times 6.1\text{MHz} = 5.81\text{MHz}$. This should of course be $\sqrt{\frac{100}{110}} \times 6.1 = 5.81$ MHz. Just above this the error is compounded with the statement $\frac{\text{C original}}{\text{C unknown}} \times$ original frequency $=$ new resonant frequency. Here again the square root sign is omitted. It might help some readers with their calibrations if they remember that for small additions of capacitance the frequency decreases by half the amount of the change. This should be sufficiently accurate as a rough and ready guide.

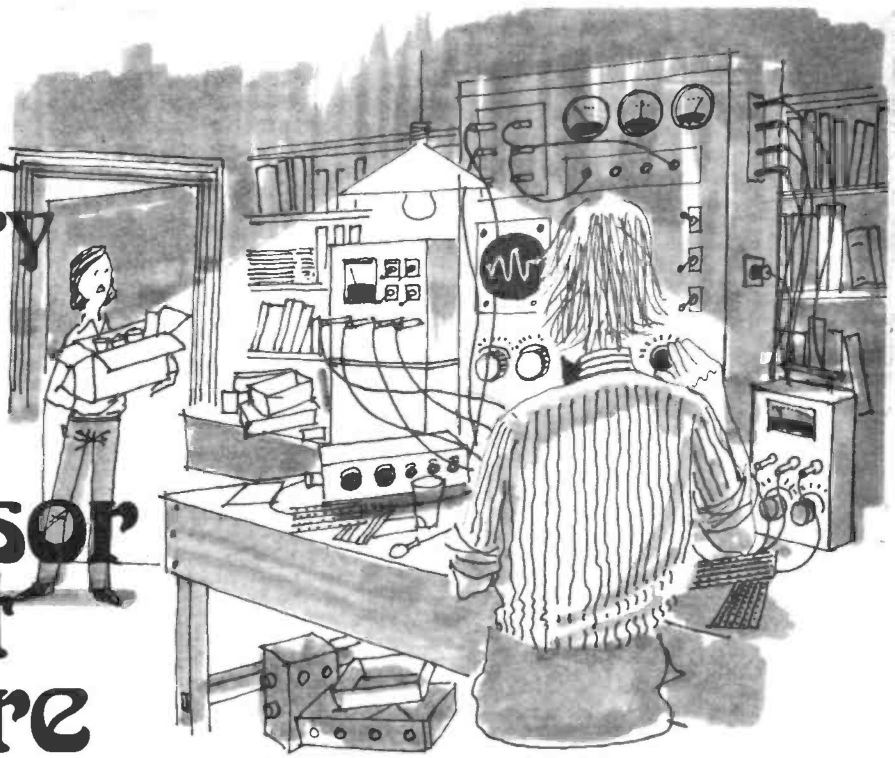
i.e. 10 per cent increase of capacitance = approx 5 per cent decrease in frequency. The same rule applies to inductance.

A. Ferriman
Wimbledon

PLEASE TAKE NOTE

In Fig. 1.3 of Doing It Digitally (October 76) dioges D1 to D4 are shown with the incorrect polarity. They should be reversed for correct operation.

We apologise to students of Teach-In '76 for an error in part 13. In Fig. 13. 2a, a resistor R_b should be connected between TR1 base and $+V_{cc}$. Also, capacitor C2 should be labelled C3 and a capacitor C2 inserted in series with TR1 base. Consequently, section 13.2, column 2, line 21 should read ..... the time constant C2 $\times$ R_b.



The Extraordinary Experiments of Professor Ernest Eversure

by Anthony John Bassett

THE Prof's discourse on the use of transistors to reduce the current flowing through delicate sets of contacts was interrupted by the arrival of two more visitors, both young men in their teens, who appeared to be having a peaceful but vigorous argument.

"The tall one is Tom," Bob informed the Prof., "From one of the upper forms at my school."

"Yes, and his companion is Maurice, another of my friends; Hello, Maurice!" the Prof. continued, "what seems to be the problem today?" "Well, Prof." began Maurice, "it is a problem which is usually solved for us by a local public address engineer. But this time—and the last time also, he has been unable to help us."

"Yes", said Tom, "I wish I knew enough about electronics to be a public address engineer—it is a terrific job—really great! This chap has been hired by a famous band to supervise their sound system during a tour of the States. So he's getting a tour of the States and being paid a fortune for it!

This is the second time he's done it, and unfortunately each time has coincided with an event when we really need his help. The last time, we tried to do without him it was nearly disastrous, and Maurice and I have been racking our brains for the last few days to try to solve the problem—so we've decided to consult you.

CHARITY EVENT

The problem is this, Prof.: We've been asked once again to help organise a charity event, with stalls, sideshows and amusements and a dance.

Now our friend usually helps out by loaning his equipment, as we need a sound system during the afternoon for announcements, background music, knockout competitions and performances by local folk singers, and during the evening we need it for the dance.

Last time, when he wasn't available to help, we used a 50 watt per channel stereo amplifier with 8 ohm output, and to each channel we connected two 8 ohm 20 watt hi fi speakers in parallel. Now, Maurice advised at the time that this was not a wise way to do it, as it would result in a 4 ohm load on the amplifier, which is designed for 8 ohms, and this might damage the amplifier. Also, the speakers were only capable of handling 40 watts and the output of the amplifier might be too much for them if the volume were too high.

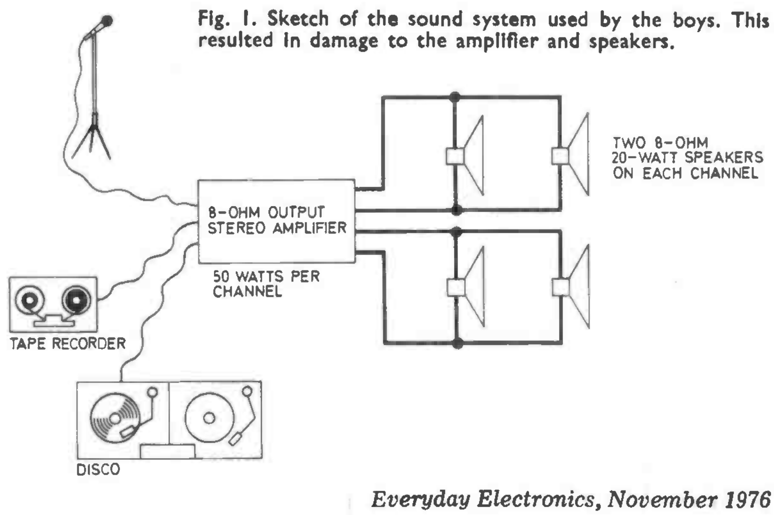


Fig. 1. Sketch of the sound system used by the boys. This resulted in damage to the amplifier and speakers.

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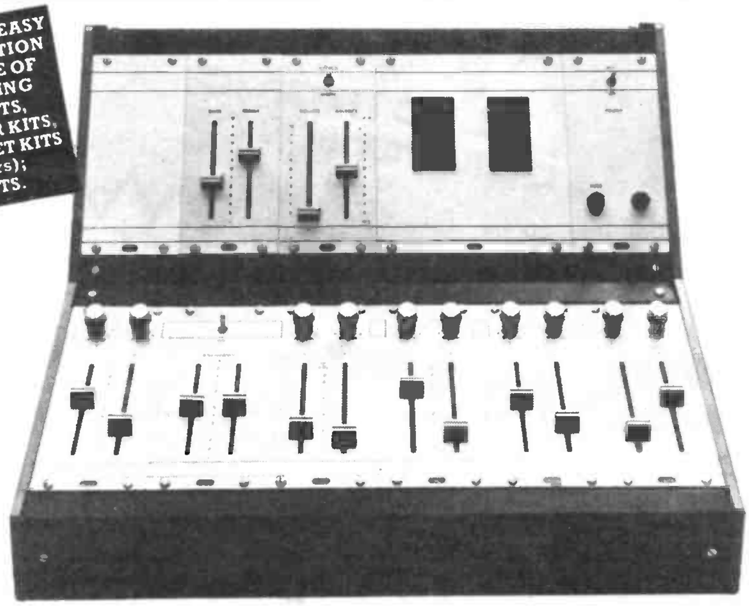

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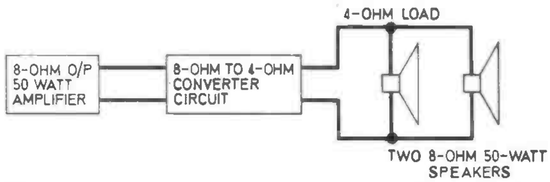
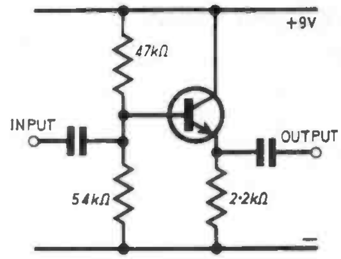
Fig. 2. The block diagram and circuit of an impedance converter drawn by Bob.





DAMAGE

Someone advised us that it would be O.K. to use the 20 watt speakers, and to run the amplifier with 4 ohms instead of 8, as long as we kept the volume control setting low, and this is what we did. It was O.K. all through the afternoon and for most of the evening, but just near the end of the evening someone got a little over excited and put on some very loud music.

The loudspeakers on one channel suddenly began to sound distorted — but before anyone could do anything about it, one channel of the amplifier blew with a loud hum and a crackle, and the whole sound system became silent.

We got the amplifier mended, and we had to buy two replacement speakers. Now if we want to use that amplifier again, we would like to know how to do it properly. This time I've managed to get two 50 watt 8 ohm speakers.

"So have I," broke in Maurice, "which means that the speakers we now have at our disposal have sufficient power handling capability not to be damaged by the power of the amplifier, and we also have four speakers, which is the minimum number we need to cover the event.

But if we connect two of these in parallel to each channel of the amplifier, this will once again mean a mismatch, because the two 8 ohm speakers in parallel would give 4 ohms, which is wrong as the amplifier needs an 8 ohm load. So, Prof., we still need your help, it seems."

Maurice fished a much-used notebook from his duffel-bag and thumbing through it he showed a diagram to Bob and the Prof. (Fig. 1).

"This is a sketch of the sound system we used last time, Prof." he said, "and eventually it caused damage to both amplifier and speakers. Now, if we used 50 watt speakers instead of 20 watt ones, the speakers would be safe—but not the amplifier."

IMPEDANCE CONVERTER

"I've got an idea!" exclaimed Bob. Maurice, too deep in thought to speak, offered Bob his pencil and, indicated that Bob should go ahead and use his notepad.

Maurice had drawn a sketch of an amplifier (8 ohm output) and two 8 ohm speakers in parallel (4 ohm load). Now Bob drew, in between these, a box which he labelled '8 ohm to 4 ohm converter' (Fig. 2), and next to this he drew a circuit diagram of an impedance converter.

"Prof.," he asked, "I have been reading about impedance converters which convert a signal to a lower impedance without the problems of using an audio transformer. Can a circuit like this be used for matching loudspeakers to power amplifiers?"

HIGH POWER

"Yes", replied the Prof. "Though the circuit which you have drawn is not suitable for use with high-power amplifiers and loudspeakers. It is a very handy circuit for use with low level signals of a few millivolts. But what Tom and Maurice need for matching these speakers to the amplifier, is a special kind of impedance converter. It is a very simple and effective circuit, by means of which you can match a larger number of loudspeakers to one audio amplifier."

To be continued

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IMPEDANCE MATCHING

THE literature of electronics abounds with references to impedance matching. One reads about matching a loudspeaker to an amplifier, for instance. What does it mean?

Matching, in these cases, is about the transfer of signals from one place to another; e.g. the transfer of audio signals from amplifier to speaker, or of the output of a radio transmitter to its aerial.

Often the object of matching is to transfer as much *power* as possible from a source of power to a load. But sometimes (this is especially true of amplifiers with class B output stages) it is more a question of drawing the correct amount of power rather than the maximum possible. The maximum might overload the amplifier.

Most signal sources can be represented accurately, for the purpose of studying matching, by a voltage generator in series with a resistance. In Fig. 1 these are labelled V_s and R_s ("s" for source). The load is R_L and the voltage across it V_L. The current, I, being the same for source and load, needs no other letter to identify it.

In practical cases you are usually stuck with a particular value of R_s but you can vary R_L. The condition for maximising I is then obvious from the circuit. Reduce R_L as much as possible. In the limit, when $R_L=0$, I is as large as it can be.

Looking now at the voltage, with an unalterable R_s, the way to maximise V_L is to increase R_L. (This is why, in general, voltage-driven amplifiers are designed to have a high input impedance: it maximises the transfer of voltage from the source to the amplifier.)

Power, however, is voltage *times* current. The power in R_L is $I \times V_L$. So in cases where the amount of *power* transferred from source to load has to be maximised, we must somehow maximise I *times* V_L. Maximising I alone (by reducing R_L) doesn't help, because as R_L is reduced, V_L is reduced, until finally R_L is a short circuit, with maximum current through it, but no voltage across it. The power is zero, so that's no good. Maximising R_L raises V_L, but in the limit, when R_L is infinite, V_L is maximum (equal to V_s) but I is zero. No power again.

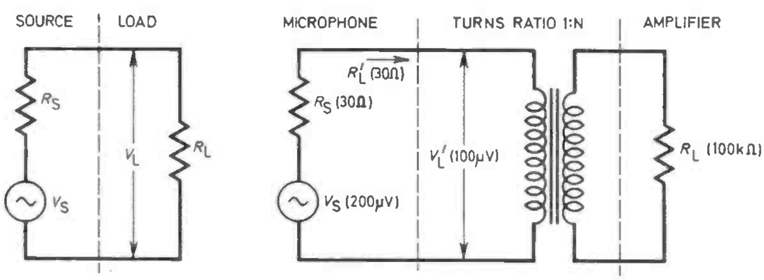

Fig. 1. Signal source and lead.

Where is the happy medium between these extremes? There must be some value of R_L which allows, simultaneously, enough I and V_L to maximise the power. (That is the *load power*, the power in R_L itself.)

The solution is to make $R_L=R_s$. Then half the voltage appears across R_L and the current I is half its maximum (short circuit load) value. Under these circumstances the greatest possible amount of power is transferred from source to load.

EFFICIENCY

There is however a penalty. Just as much power is now spent in R_s as in R_L. So, although the load *power* is maximised, the *efficiency* is not. The efficiency is only 50 per cent. In many cases, it is just not possible to operate a power source at 50 per cent efficiency, because the waste of power inside the source itself (in R_s) raises the temperature of the source to a dangerous level. It "burns out". For this reason, the "optimum load" for many power sources is not the value of R_L which maximises the power but the one which just raises the internal temperature of the source to its safe limit.

In cases like this, R_L is greater than R_s and the efficiency is greater than 50 per cent. So, although you get less power, you also waste less. As a general rule, it is safe to operate a power source into a load resistance *greater* than the optimum load.

EXAMPLE

If, for example, an audio amplifier is rated to deliver 100 watts into 4 ohms, it is generally safe to substitute a load of 8 ohms. The power output will be reduced but the dissipation inside the amplifier will probably also be reduced and certainly won't be increased. (But be careful with multiple speakers drive through crossover networks. Both the network and the speaker impedances must be changed.)

Using a load resistance *less* than the rated 4 ohms may increase the dissipation inside the amplifier and damage it. You can see from Fig. 1 why a short-circuit can damage an amplifier. If you make $R_L=0$, all the power is then spent in R_s. Class B amplifiers are very vulnerable to this kind of overload, class A much less so.

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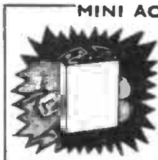

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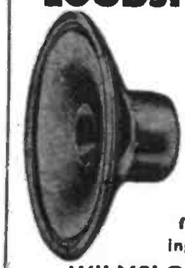

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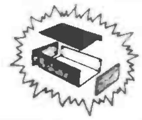

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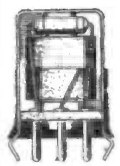

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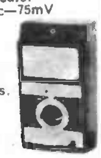

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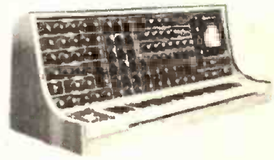

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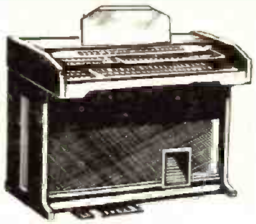

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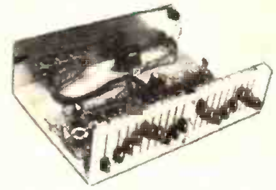

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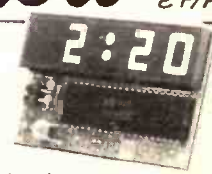

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