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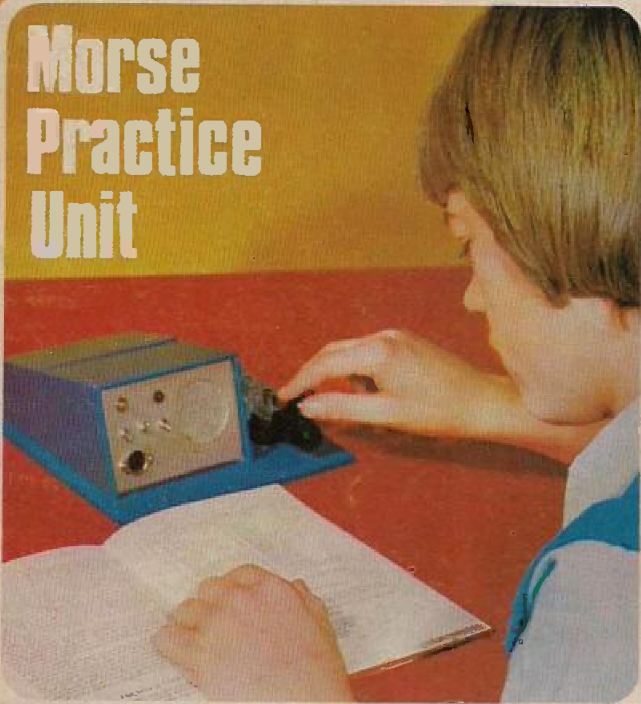

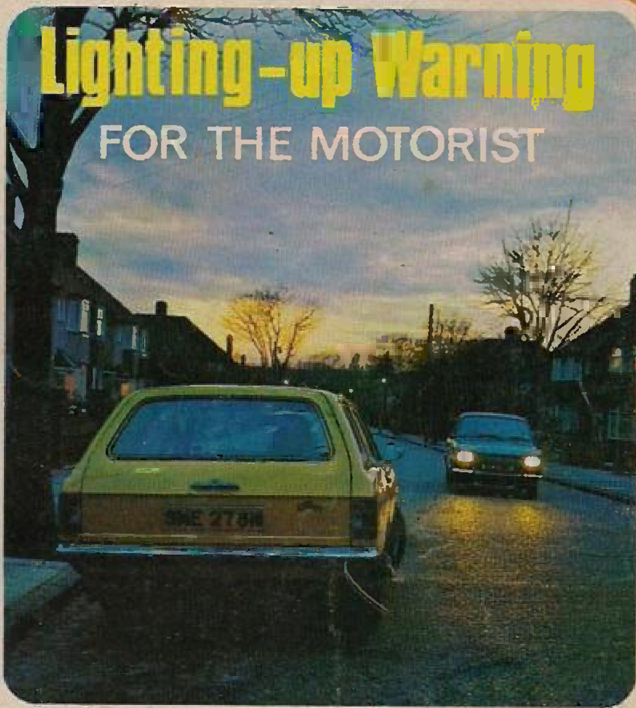

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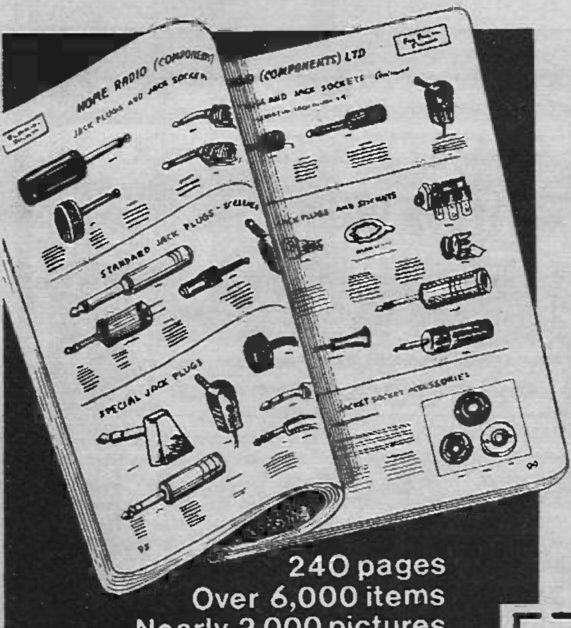

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AC154	0·22
AC155	0·22
AC156	0·22
AC157	0·27
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AC166	0·22
AC167	0·22
AC168	0·27
AC169	0·16
AC176	0·22
AC177	0·27
AC178	0·31
AC179	0·31
AC180	0·22
AC180K	0·32
AC181	0·22
AC181K	0·32
AC187	0·24
AC187K	0·25
AC188	0·24
AC188K	0·25
ACY17	0·28
ACY18	0·22
ACY19	0·22
ACY20	0·22
ACY21	0·22
ACY23	0·18
ACY27	0·20
ACY28	0·21
ACY29	0·39
ACY30	0·31
ACY31	0·31
ACY34	0·23
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AF139	0·33
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AL102	0·72
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ASY29	0·28
ASY50	0·28
ASY51	0·28
ASY52	0·28
ASY54	0·28
ASY55	0·28
ASY56	0·28
ASY57	0·28
ASY58	0·28
ASY73	0·28
ASZ21	0·44
BC107	0·9
BC108	0·9
BC109	0·9
BC113	0·11
BC114	0·17
BC115	0·17
BC116	0·17
BC117	0·20
BC118	0·11
BC119	0·33
BC120	0·88
BC125	0·13
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BC135	0·13
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BC183L	0·16
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BC184L	0·22
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BC209	0·13
BC212L	0·14
BC213L	0·14
BC214L	0·18
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BC226	0·39
BC301	0·30
BC302	0·27
BC303	0·35
BC304	0·40
BC440	0·34
BC460	0·40
BCY30	0·27
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BCY32	0·33
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BCY70	0·16
BCY71	0·22
BCY72	0·16
BCZ10	0·22
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BCZ12	0·28
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BD124	0·76
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BD132	0·66
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BD136	0·44
BD137	0·50
BD138	0·55
BD139	0·61
BD140	0·66
BD155	0·88
BD175	0·66
BD176	0·66
BD177	0·72
BD178	0·72
BD179	0·77
BD180	0·77
BD185	0·72
BD186	0·72
BD187	0·77
BD188	0·77
BD189	0·83
BD190	0·83
BD195	0·94
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BD197	0·99
BD198	0·99
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BF123	0·55
BF125	0·50
BF127	0·55
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BF153	0·50
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BF184	0·28
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BF194	0·13
BF195	0·13
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BF197	0·16
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BSY29	0·17
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OC22	0·52
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OC24	0·62
OC25	0·42
OC26	0·32
OC28	0·55
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OC41	0·22
OC42	0·27
OC44	0·17
OC45	0·14
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OC71	0·11
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OC74	0·16
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OC81D	0·17
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OC82D	0·17
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OC140	0·23
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OC170	0·28
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OC203	0·28
OC204	0·28
OC205	0·39
OC309	0·44
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ORP61	0·44
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2G373	0·19
2G374	0·19
2G377	0·33
2G378	0·18
2G381	0·18
2G382	0·18
2G401	0·33
2G414	0·33
2G417	0·28
2N388	0·39
2N388A	0·61
2N404	0·22
2N404A	0·31
2N524	0·46
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2N706A	0·10
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2N2147	0·79
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2N2160	0·66

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2N2925	0·16
2N2926(G)	14
2N2926(Y)	12
2N2926(O)	11
2N2926(R)	11
2N2926(B)	11
2N3010	0·77
2N3011	0·16
2N3053	0·19
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2N3391	0·16
2N3391A	0·18
2N3392	0·16
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2N5458	0·25
2N5459	0·44
2N6221	0·75
2S301	0·56
2S302A	0·46
2S302	0·46
2S303	0·62
2S304	0·77
2S305	0·86
2S306	0·86
2S307	0·86
2S321	0·62
2S322	0·46
2S322A	0·46
2S323	0·62
2S324	0·77
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AAZ13	0·11	BY164	0·55	OA85	0·10
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BA116	0·23	BYZ10	0·39	OA91	0·07
BA126	0·24	BYZ11	0·33	OA95	0·08
BA148	0·16	BYZ12	0·33	OA200	0·07
BA154	0·13	BYZ13	0·28	OA202	0·08
BA155	0·16	BYZ16	0·44	SD10	0·06
BA156	0·15	BYZ17	0·39	SD19	0·06
BA173	0·16	BYZ18	0·39	1N34	0·08
BY100	0·17	BYZ19	0·31	1N34A	0·08
BY101	0·13	CG62	0·06	1N914	0·06
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72741C	0·28	0·27	0·26
72741P	0·30	0·29	0·28
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72748P	0·38	0·36	0·34
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7402	0·15	0·14	0·13	7451	0·15	0·14	0·13	74141	0·85	0·82	0·79
7403	0·15	0·14	0·13	7453	0·15	0·14	0·13	74145	1·30	1·25	1·20
7404	0·15	0·14	0·13	7454	0·15	0·14	0·13	74150	1·60	1·40	1·30
7405	0·15	0·14	0·13	7460	0·15	0·14	0·13	74151	1·10	1·05	1·00
7406	0·39	0·34	0·31	7470	0·32	0·29	0·27	74153	1·00	0·95	0·90
7407	0·39	0·34	0·31	7472	0·32	0·29	0·27	74154	1·70	1·65	1·60
7408	0·25	0·24	0·23	7473	0·41	0·39	0·35	74155	1·20	1·15	1·10
7409	0·25	0·24	0·23	7474	0·41	0·39	0·35	74156	1·20	1·15	1·10
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7413	0·32	0·31	0·30	7481	1·10	1·05	1·00	74162	1·40	1·35	1·30
7416	0·30	0·29	0·28	7482	0·90	0·85	0·80	74163	1·40	1·35	1·30
7417	0·30	0·29	0·28	7483	1·20	1·15	1·05	74164	1·82	1·75	1·70
7420	0·15	0·14	0·13	7484	1·00	0·97	0·95	74165	1·82	1·75	1·70
7422	0·30	0·29	0·28	7485	1·10	1·55	1·50	74166	1·60	1·55	1·50
7423	0·40	0·39	0·38	7486	0·35	0·34	0·33	74174	1·60	1·55	1·50
7425	0·40	0·39	0·38	7489	4·00	3·75	3·50	74175	1·40	1·35	1·00
7426	0·40	0·38	0·36	7490	0·65	0·63	0·60	74176	1·25	1·20	1·15
7427	0·40	0·38	0·36	7491	1·10	1·05	1·00	74177	1·25	1·20	1·15
7428	0·45	0·42	0·40	7492	0·74	0·71	0·64	74180	1·25	1·20	1·15
7430	0·15	0·14	0·13	7493	0·74	0·71	0·64	74181	3·95	3·85	3·75
7432	0·40	0·38	0·36	7494	0·85	0·82	0·75	74182	1·25	1·20	1·15
7433	0·42	0·40	0·38	7495	0·85	0·82	0·75	74184	1·80	1·75	1·70
7437	0·35	0·32	0·30	7496	0·96	0·93	0·88	74190	1·95	1·90	1·85
7438	0·35	0·32	0·30	74100	1·50	1·45	1·40	74191	1·95	1·90	1·85
7440	0·15	0·14	0·13	74104	0·60	0·58	0·55	74192	1·95	1·90	1·85
7441	0·74	0·71	0·64	74105	0·60	0·58	0·55	74193	1·95	1·90	1·85
7442	0·74	0·71	0·64	74107	0·44	0·42	0·40	74194	1·30	1·25	1·20
7443	1·20	1·15	1·10	74110	0·60	0·55	0·50	74195	1·10	1·05	1·00
7444	1·20	1·15	1·10	74111	0·90	0·88	0·85	74196	1·20	1·15	1·10
7445	1·60	1·55	1·50	74118	1·00	0·95	0·90	74197	1·20	1·15	1·10
7446	1·20	1·15	1·10	74119	1·50	1·40	1·30	74198	3·75	3·70	2·65
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200	0·06	0·10	1N4003	0·07	0·12	0·22	0·25	1·00
400	0·08	0·15	1N4004	0·08	0·15	0·30	0·38	1·35
600	0·09	0·17	1N4005	0·10	0·18	0·36	0·45	1·90
800	0·12	0·19	1N4006	0·11	0·20	0·38	0·55	2·10
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100	0·28	0·37	0·52	0·52	0·55	0·64	0·70	1·54
200	0·39	0·41	0·54	0·54	0·63	0·67	0·83	1·76
400	0·48	0·52	0·62	0·62	0·74	0·83	1·03	1·93
600	0·59	0·63	0·75	0·75	0·85	1·07	1·38	—
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UIC04 = 12×7404	0·54	UIC53 = 12×7453	0·54	UIC94 = 5×7494	0·54
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UIC10 = 12×7410	0·54	UIC72 = 8×7472	0·54	UIC121 = 5×74121	0·54
UIC20 = 12×7420	0·54	UIC73 = 8×7473	0·54	UIC141 = 5×74141	0·54
UIC30 = 12×7430	0·54	UIC74 = 8×7474	0·54	UIC151 = 5×74151	0·54
UIC40 = 12×7440	0·54	UIC76 = 8×7476	0·54	UIC154 = 5×74154	0·54
UIC41 = 5×7441	0·54	UIC80 = 5×7480	0·54	UIC193 = 5×74193	0·54
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PROJECTS. THEORY....

GETTING BIG IDEAS

From time to time we receive requests for projects that would be too complex to include in this magazine if we are to remain true to our declared policy. Our advice, generally, is that those interested in more advanced and more complicated electronic designs should consult our companion PRACTICAL ELECTRONICS—long ago christened "Big Brother" (but with only friendly implications, we are sure) by some correspondents.

However, rules can sometimes be "bent", if not actually broken, to some advantage. So just once in a while we may bow to popular demand, forget Big Brother, and allow something rather more ambitious than would be strictly in accord with our general policy to enter our pages. Only once in a while, though. That's a promise.

MODULES MAKE IT EASY

A hifi stereo amplifier seems to be high on many an enquirer's list. So here now in this issue is our first reckless venture, embarked upon regardless of all cost—well not entirely!

Certainly by any previous standards, the Modula 3 is a large and unusual project for EE. Yet things aren't always quite what they appear to be. In this case, the actual constructional work involved is far less than one might expect. The secret lies in the use of circuit modules—factory assembled units containing the more complex parts of the whole design.

Even so, this is not a project for the absolute beginner. But those with some modest experience in building electronic circuits need not shrink from the task involved here.

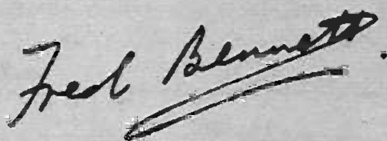
AMAZE YOUR FRIENDS

The cost of the Modula 3 is, necessarily, high in comparison with our usual run of projects. But it represents good value, since the modules ensure a top class performance that will compare favourably with commercial amplifiers costing rather more to buy.

A good quality audio system is nowadays regarded as a vital piece of furniture for the home. What better way to show off one's abilities in electronics than to build an amplifier that could form the heart of a home entertainment system. An excellent way to amaze friends. After all, one doesn't have to let them into the full secret, does one?

VERY SORRY, BUT—

As from next month the price of EVERYDAY ELECTRONICS will be 25p. We regret the need for this increase, but believe our readers will agree that our contents represent good value at this new price.



Our March issue will be published on Friday, February 21

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. EASY TO CONSTRUCT
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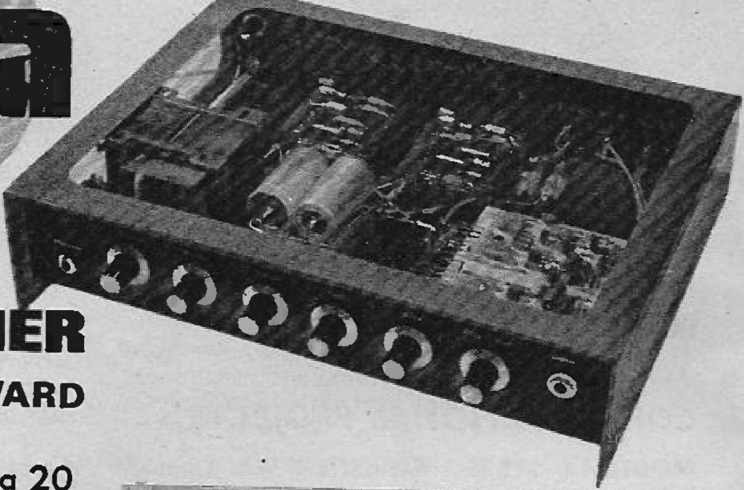
LOOK TO THE FUTURE!

Our younger readers will learn something greatly to their advantage in a new unique series starting soon. Further details next month.

PART ONE

modula 3
STEREO AMPLIFIER

By MIKE KENWARD



A hi fi stereo amplifier providing 20 watts output per channel at low cost

THE construction of a high power stereo amplifier of the quality of this design is normally a complex and substantial undertaking; however, with the use of some of the many audio modules now available this task has been drastically reduced. The use of modules also helps to guarantee "first time" results, however this does not imply that this project is a suitable first construction for the novice.

We do not advise any reader who has not constructed electronic units previously, to undertake this design. A reasonably high standard of soldering and mechanical workmanship is required to successfully complete the amplifier. However, if the design is carefully followed and the correct materials used, an amplifier can be produced that compares very favourably with similar commercial units costing considerably more. The design employs two Sanyo thick-film power amplifiers and a printed circuit Mullard preamplifier module.

PERFORMANCE

The basic specification of the Modula 3 is given in Table 1 this, together with the graphs if Figs. 1 and 2 show the typical performance that can be expected from the completed unit.

The output has been conservatively rated at 20 watts per channel and the amplifier will provide this output on both channels (continuous r.m.s.) without trouble. The modules are in fact rated by Sanyo at 25 watts each into 8 ohms.

However, at the higher power levels, above 20 watts, the distortion rises, at 28 watts it is approximately 0·8 per cent. Thus, although the amplifier is capable of providing a maximum total output of 56 watts, this increase is at the expense of the distortion figure.

TABLE 1

MODULA 3 PERFORMANCE

OUTPUT POWER
35W continuous one channel driven
28W continuous per channel, both channels driven

POWER BANDWIDTH
−3dB at 20Hz and 20 kHz

FREQUENCY RESPONSE
−1dB at 30Hz and 20kHz } see Fig. 1
−3dB at 15Hz and 27kHz }

TONE CONTROLS
Bass ± 14dB at 20Hz } see Fig. 2
Treble ± 15dB at 20kHz }

INPUTS
For 20W r.m.s. per channel output
Magnetic 2·5mV at 40kΩ RIAA equalised (within ± 1dB between 20Hz and 20kHz) Dynamic range 30dB
Radio 80mV at 1·2MΩ flat response
Guitar 12mV at 50kΩ flat response

TAPE OUTPUT
80mV at 5·6kΩ

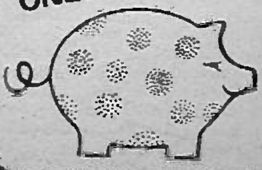
SIGNAL TO NOISE RATIOS
Measured at an output of 20W. Unweighted figures
Magnetic −52dB
Radio and Guitar −60dB

INTERCHANNEL CROSSTALK
−43dB measured with one channel driven at 20W

DISTORTION
Total harmonic distortion.
Less than 0·2% up to 20W
Less than 0·8% up to 28W.

FOR GUIDANCE ONLY

ESTIMATED COST* **OF COMPONENTS** including V.A.T.



£28 excluding case

*Based on prices prevailing at time of going to press

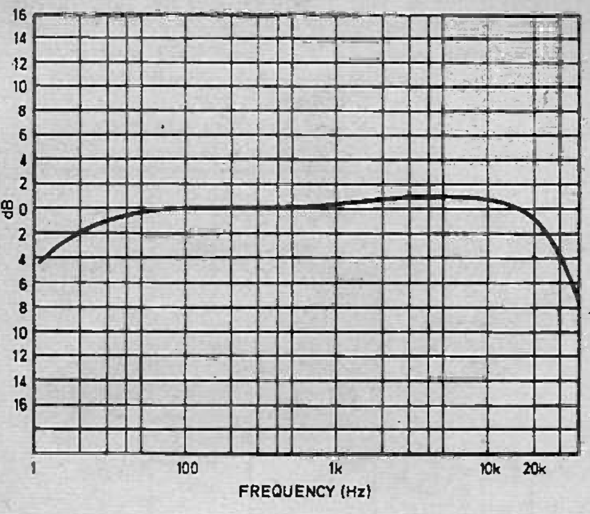


Fig. 1. Graph showing frequency response of complete amplifier.

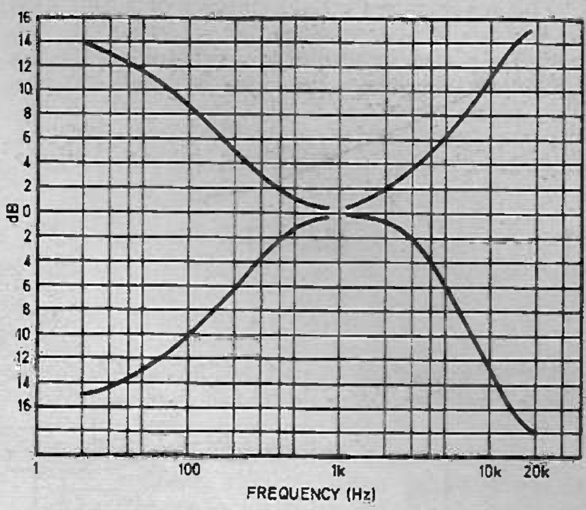


Fig. 2. Graph showing frequency response with the controls in their maximum positions.

The frequency response curve shown in Fig. 1 shows that the output of the amplifier is almost flat from 30Hz to 20kHz. This covers the whole of the audible range and shows that any audio signal fed to the input will be reproduced at the correct level compared to any other signals.

Action of the tone controls is shown in Fig. 2 the alteration of the frequency response with treble and bass cut and lift is clearly indicated. The square wave output at 1kHz is shown in Fig. 3 this shows a good overall frequency response since a square wave is made up of a number of sine waves at the harmonics of the square wave. The slight roll-off at the leading edge of the square wave shows that the response falls at high frequency and this is confirmed by Fig. 1. However, it does not start to fall within the audible range.

The signal to noise ratio indicated in Table 1 shows that the difference between the signal output and the noise generated in the amplifier is reasonably large. The figure compares with that quoted for many medium price range commercial audio amplifiers.

The Sanyo power modules are protected by fuses in the output from short circuit damage. The output stage of those modules is class AB, d.c. coupled, and no damage will result from an open circuit output.

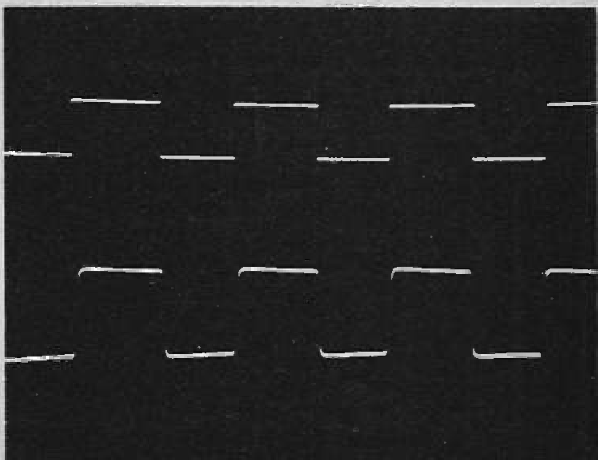
PREAMPLIFIER

The preamplifier module is a Mullard type LP1184/2 which has only recently been produced by Mullard and was not available to the home constructor before the publication of this design. The circuit of the complete preamplifier with its power supply components is shown in Fig. 4. Only the right hand channel is shown, component numbers in the other channel are the corresponding numbers plus 100. The tinted areas are the module and the untinted areas show the external components and wiring that the constructor must complete.

Inputs have been provided for magnetic cartridge, radio and guitar, an additional auxilary input can be provided if required—sensitivity 80mV. Input and equalisation switching is accomplished by S1a and S1b respectively. For guitar input the switch must be in the radio, position, and a stereo jack socket inserted in SK3 then disconnects the radio socket SK2.

The amplifier can be used on both channels with a guitar simply by shorting the two "tips" on the stereo jack plug together, this provides a 40 watt output. To simplify switching some of the input connections on the module have not been used and the associated resistors are replaced by R1, R2 and R3.

Fig. 3. The square wave input and output (below) at 1kHz into 8 ohms.



The preamplifier circuit consists of a high gain amplifier with equalisation provided by TR_1, TR_2 and their associated components (to obtain the specified frequency response C_4 and C_{104} are removed from the module—details are given later). This is followed by the external balance and volume controls VR1 and VR2 and a standard Baxandall tone control circuit formed by

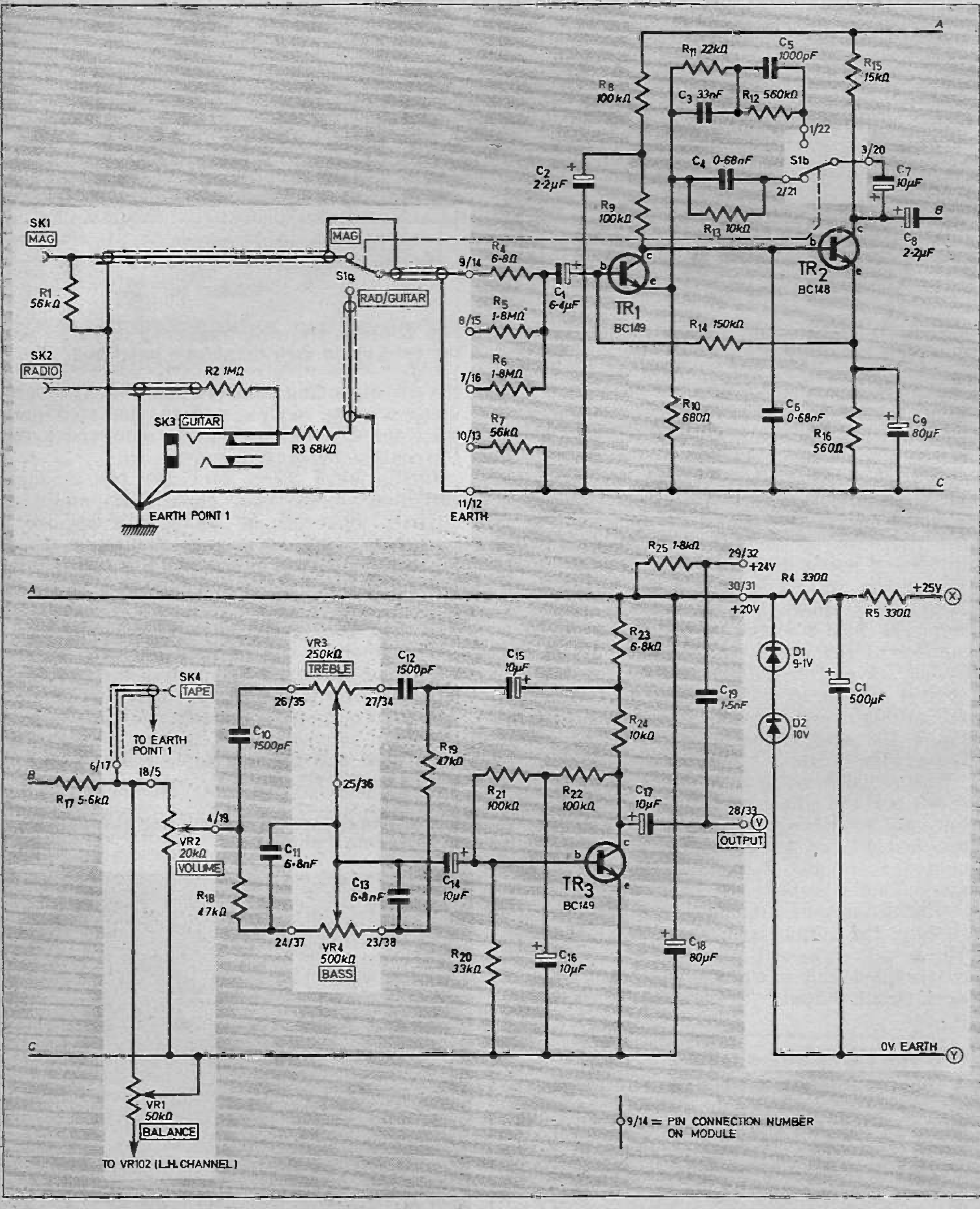


Fig. 4. Preamplifier circuit diagram, the tinted areas represent components mounted on the module.

VR3, VR4 and the associated components on the module. This control stage forms the feedback of a second amplifier (TR_3).

An output for a tape recorder is provided at SK4. This output comes before the volume and tone controls and is thus unaffected by them. It is, however, affected by the balance control.

The preamplifier supply is initially taken from the smoothed d.c. provided for the main amplifiers. This voltage is dropped by R5 and additionally smoothed by C1 and then dropped further to 20V and stabilised with Zener diodes at this voltage. Further smoothing capacitors C18 and C118 are provided on the module.

The supply components in the lower right hand untinted area and the balance control are not repeated for the second channel. A 9V and a 10V Zener diode are used, wired in series, to provide the 20V supply. This arrangement is used in preference to a single 20V Zener due to the oscillation problems that have arisen with some 20V types.

EARTHING

The earthing of the amplifier in general is important and only two earthing points must be used, one for the preamplifier and one for the main amplifiers. **It is important to follow carefully the details to be given later in the text for connecting earthing lines.**

The correct earthing is shown on the preamp circuit with the module being earthed to the chassis at the input sockets via the magnetic input screened lead. A second earth is provided for the screened leads to the tone controls (screens not shown on circuit) but these are not connected to the module in any way, they are simply taken to earth point 2 (see later) because it is physically most convienient.

It is worth mentioning at this stage that the push button switch originally used for S1/S101 (shown on the cover photograph) has been replaced by a rotary switch due to the difficulty in obtaining a suitable make-before-break push button. This alteration actually enhances the appearance of the finished unit—compare the heading and cover photographs.

POWER AMPLIFIER

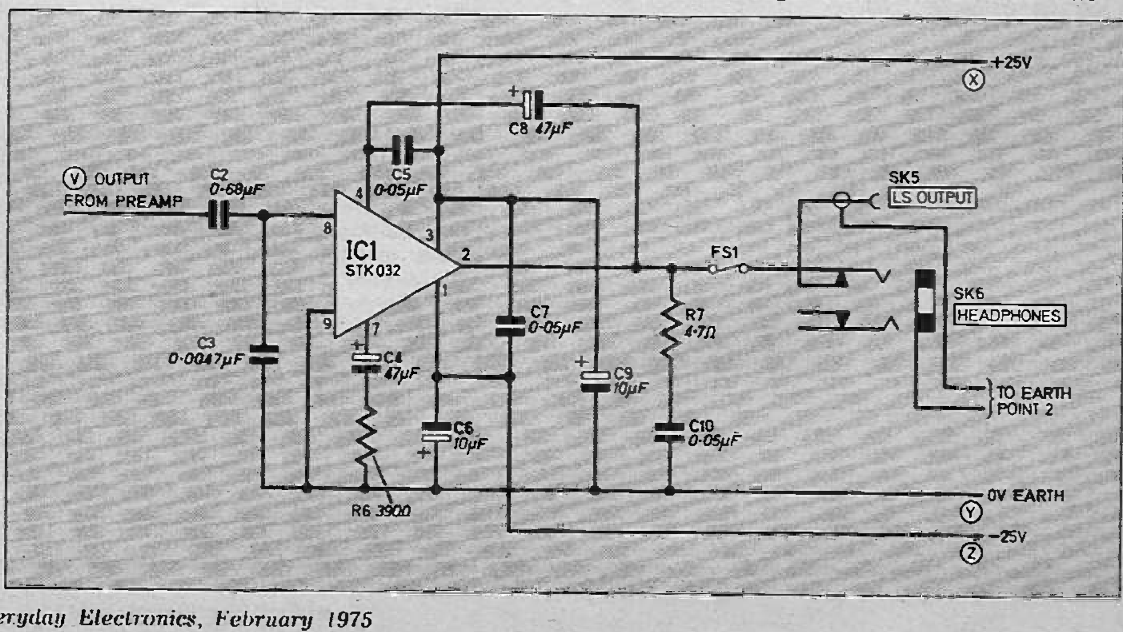
A circuit diagram of the power amplifier modules has not been provided simply because the circuit available gives very little information about the operation of this device and no component values. The circuit is available from the suppliers of the modules and should be included with the general information on the modules at the time of purchase.

The modules require some equalisation and decoupling components in addition to the ±25V supply and input and load (loudspeaker), these components are shown as C3 to C10, R6 and R7 in Fig. 5. Capacitor C3 is provided to prevent any tendancy to high frequency oscillation. Resistor R6 has been reduced in value from that quoted in the Sanyo literature to increase the gain of the amplifier since the output available from the preamplifier is only 150mV. This resistor should be a close tolerance type to ensure equal gain from both channels.

The output from pin 2 of the module is fed via a short circuit protection fuse (FSI) to the headphone output socket and to the loudspeaker socket (SK5). As shown the headphone output is suitable for low impedance type headphones or phones with built-in attenuators. On insertion of the headphone jack plug the speakers are automatically disconnected.

Attenuator details will be provided later.

Fig. 5. The circuit diagram of the power amplifier, refer to Figs. 4 and 6 for connections.



POWER SUPPLY

The supply required by the output modules is ±25V at a maximum current of 1·8 amps (28 watts per channel), this is provided by the circuit shown in Fig. 6. This circuit provides power for both channels.

Transformer T1 provides 18·0·18V r.m.s. from the mains and this is rectified by the bridge rectifier D3-D6 to provide 25-0-25V d.c. Capacitors C11 and C12 provide smoothing to remove most of the ripple voltage. The value of these capacitors could be reduced slightly but only at the expense of increased hum.

Switch S2 is the mains on/off switch and neon LP1 provides visual indication that the amplifier is switched on. Capacitor C13 prevents switch on and switch off noise spikes which would otherwise cause noise at the amplifier output. The amplifier is protected by a 1 amp slow-blow fuse FS2. A slow-blow fuse is required because of the large initial current taken by C11 and C12.

In the prototype amplifier C11 and C12 were each made up from two 2,500µF, 50V capacitors wired in parallel—see photographs. There is however, room for single 5,000µF capacitors and since these are cheaper to buy they have been specified.

CHASSIS CONSTRUCTION

The chassis for the prototype unit was made from one piece of 12 s.w.g. aluminium; however, this material is difficult to bend without a proper bending machine. If readers are unable to get the metal bent by a local workshop it is

Components....

SEE SHOP TALK

Resistors

R1, 101 56kΩ
R2, 102 1MΩ
R3, 103 68kΩ
R4, 330Ω
R5, 330Ω
R6, 106 390Ω ±2%
R7, 107 4·7Ω 1W wirewound
2 off each except R4 and R5, all ¼W ± 10% carbon except where stated

Capacitors

C1 500µF elect. 30V
C2, 102 0·68µF
C3, 103 0·0047µF
C4, 104 47µF elect. 16V
C5, 105 0·05µF
C6, 106 10µF elect. 35V
C7, 107 0·05µF
C8, 108 47µF elect. 25V
C9, 109 10µF elect. 35V
C10, 110 0·05µF
C11 5,000µF elect. 35V
C12 5,000µF elect. 35V
C13 0·1µF, 400V
2 off each except C1 and C11 to C13.
Values marked 0·05 µF can be 0·047µF

Semiconductors

D1, D2 10V and 9·1V 400mW Zener diodes (1 off each)
D3-D6 2A, 100V bridge rectifier

Modules

IC1, 101 STK032 Sanyo amplifier (2 off)
Preamplifier LP1184/2 Mullard stereo preamplifier module

Potentiometers

VR1 50kΩ lin. carbon
VR2, 102 20kΩ log. carbon dual gang (25kΩ or 22kΩ may be used)
VR3, 103 250kΩ lin. carbon dual gang
VR4, 104 500kΩ lin. carbon dual gang

Switches

S1, 101 4pole 3-way make before break rotary switch (two poles for each channel—only 2 ways used—see text)
S2 d.p.d.t. rotary mains switch

Sockets

SK1, 101 stereo phono
SK2, 102 stereo phono
SK3 stereo switched jack
SK4, 104 stereo phono
SK5, 105 stereo phono
SK6 stereo switched jack

Miscellaneous

FS1, 101 skeleton fuse holders and 2 amp fuses (2 off)
FS2 panel mounting fuse holder and 1 amp slow blow fuse
T1 mains, 18-0-18V, 2 amp secondary transformer not higher than 65mm (Type 1024 Zeta Windings)
LP1 panel mounting mains neon indicator with built-in resistor. Two-way chassis mounting tag strip, 4BA earth tags (2 off), 6BA earth tag, 4BA and 6BA fixings, 4BA and 6BA spacers (10mm), 16 s.w.g. tinned copper wire approx. 350mm, stereo screened lead (miniature) approx. 2·5m. 7-strand connecting wire—various colours, 14-strand connecting wire, fixing or clips for C11 and C12, mains cable 3 core length as required with 3-pin plug, cable clip for mains lead, Letraset or similar material, paint. Knobs type R62 black with chrome top cap and skirt with indicator 6 off (Re-An products). Veroboard 0·15inch matrix 14 strips by 18 holes (2 off), grommet for mains cable.

Aluminium for chassis 1 piece, 12 s.w.g. approx. 400mm by 344mm. Alternatively 1 piece, 12 s.w.g. 344mm by 250mm, 2 pieces 344mm x 70mm, angle aluminium—3mm material thickness, 10mm x 10mm cross section, 688mm length. 1 piece 200 x 200mm x 20 s.w.g. for preamplifier screen.

Materials for case—see text.

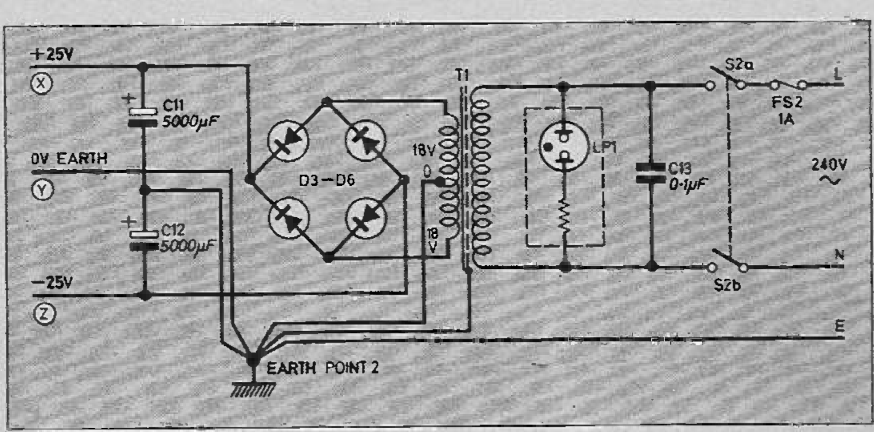
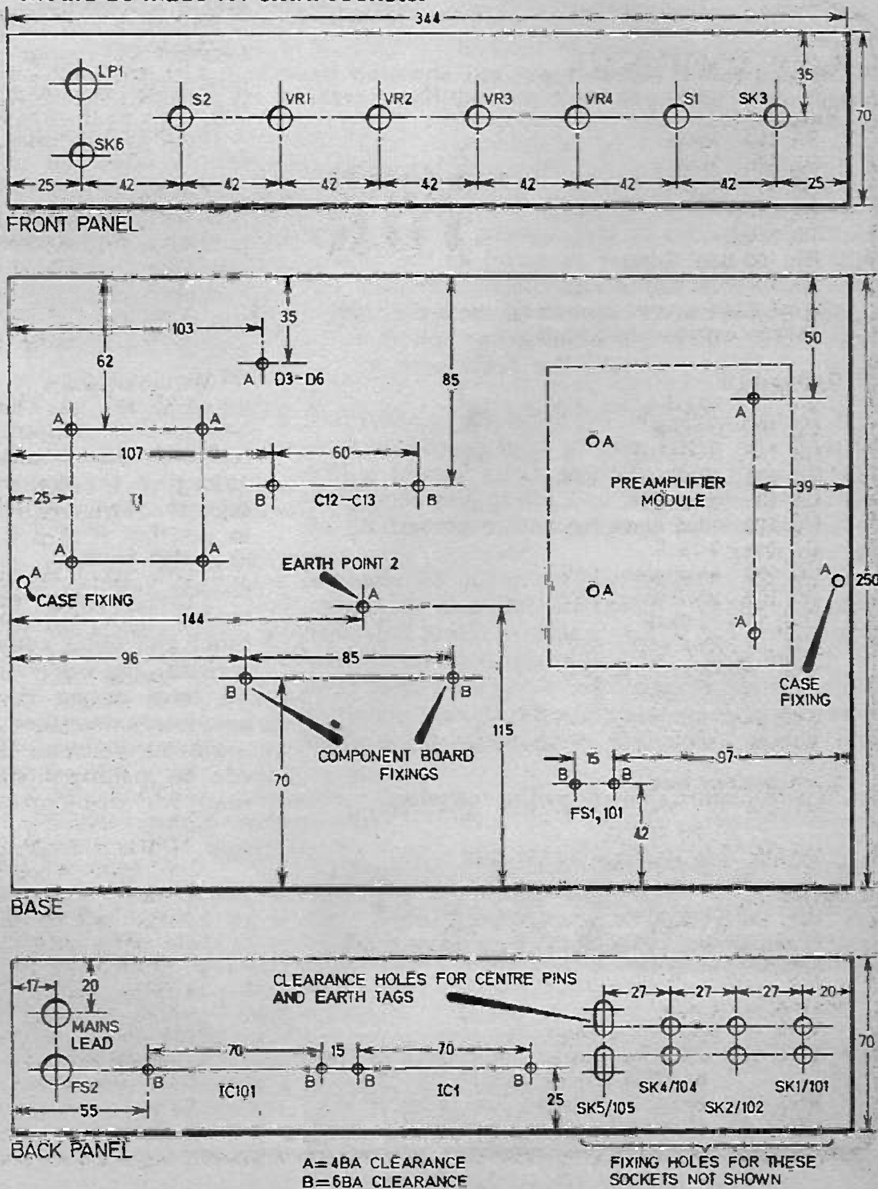
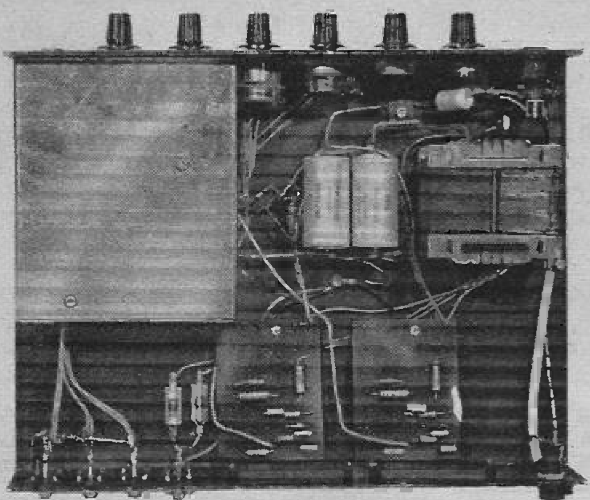


Fig. 6. The power supply circuit — see text concerning earthing.

Fig. 7. Chassis drilling details, some measurements may vary slightly depending on individual components. Viewed looking from the underside with panels "bent down". If an extra auxiliary input is required provision should be made for extra sockets.





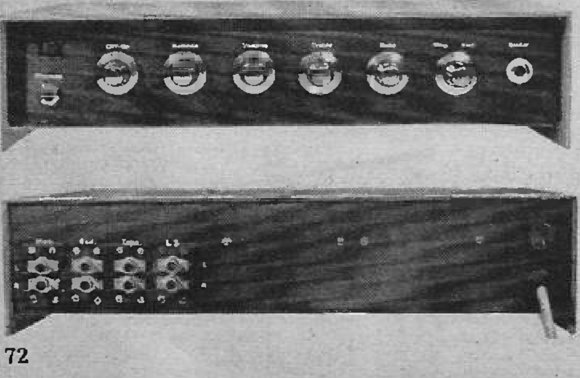
Photograph of the prototype unit showing the component positions, the preamplifier screen is shown fitted.

suggested that the chassis be made from three separate pieces of aluminium joined by angle aluminium bolted at the corners. It is not permissible to use thinner material as the chassis provides a heat sink for the power modules. For this reason it is also essential to use a reasonably heavy piece of angle aluminium, bolted at, at least six points, to join the rear panel to the chassis floor.

If three panels are used the neat appearance of the front panel may be kept by countersinking the bolt heads (three bolts should suffice here) into the metal and filling the remaining indentation with Araldite before smoothing off and painting.

Once the chassis has been cut to size and bolted together or bent as shown in the photographs and Fig. 7, the necessary fixing holes can be drilled using the actual components as templates wherever possible, since individual components vary in some respects. Having done this and checked that all components fit in their

Front and back panels showing lettering.



positions the chassis can be rubbed down inside and out with fine wet and dry paper—used wet—before painting.

It is recommended that the inside and outside of the amplifier excepting the front panel, be painted matt black using a car type aerosol paint. This will help the heat dissipation. The front panel may be painted any required colour —matt black was used on the prototype and this, together with the specified knobs, gives a good finished appearance.

When painting the inside of the chassis it is necessary to draw around the power modules whilst they are mounted and then mask the area under each one with masking tape. The lack of paint between the modules and chassis helps thermal conduction.

It was found that one can of spray paint was just enough to complete the whole chassis, giving a reasonable coating. Once the painting is complete the lettering can be applied, using Letraset or similar materials, as shown in the photographs of the unit. Use the knobs to decide the position of the lettering on the front panel.

Having completed the chassis the components can be mounted in position as shown in the photographs and indicated in Fig. 7. Do not at this stage mount the two power amplifier modules or the earth tags for the two earthing points.

When mounting the input and tape sockets the earthing tags for these parts can be flattened against the body of the socket and paint scraped off the chassis in the relevent positions to ensure an earth contact. **This must not be done with the loudspeaker output sockets which must be isolated with Paxolin under the socket or by enlarging the holes to accomodate the earth tags as shown.** With all the components mounted in position it is a good idea to check with an ohmeter for any shorts between sockets and chassis and the tags of other components and chassis. This is particularly important with **the inner and outer connections of the loudspeaker sockets.** The other "back panel" sockets should all have outers connected to the chassis as previously described.

Having done all this the preamplifier screen can be made up (Fig. 8) and then the unit is ready for wiring up. *Continued next month.*

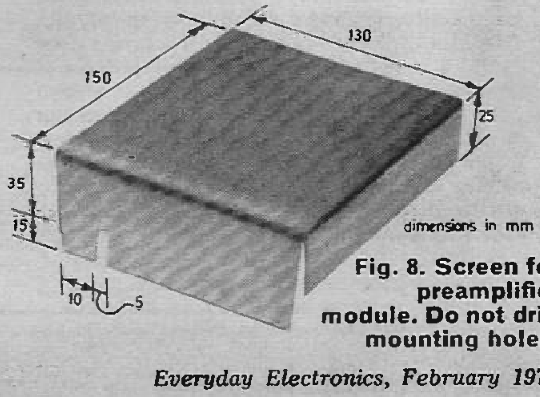


Fig. 8. Screen for preamplifier module. Do not drill mounting holes.

Physics is FUN!

By Derrick DAINES

MAKING SMALL MAGNETS

Take a discarded razor blade and stroke it many times with one pole of a permanent magnet (see also August issue), thereby magnetising it. If you remember that like poles repel and opposite poles attract, you will be able to determine which end of the razor-blade is North seeking; mark it with a scratch, or dab of paint.

Now break the blade lengthwise into two halves and test each half—each is equally magetised and as might be expected, the North-seeking poles are at the same end. What might happen if we break one of the halves across into quarters? The same rule applies—we create two smaller magnets, see Fig. 1.

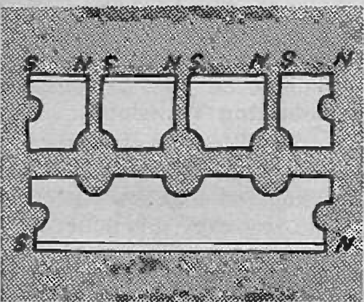


Fig. 1. Breaking a magnet creates more magnets.

With a little thought, we could see that the process could be continued indefinitely, creating smaller and smaller magnets, until—in imagination, at least—we reached individual molecules.

Every molecule of iron has its own magnetic field.

We can now see why the centre of a magnet does not attract iron filings; a North- and South-seeking pole cancel each other out.

One of my readers queried the process of magnetisation and others have put the query another way—what happens when we de-magnetise a metal, such as a screwdriver? How is it done? Well here is a method in which you can actually *see* it.

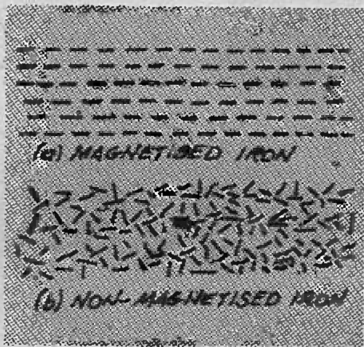


Fig. 2. The effect of a strong magnet on iron filings in a phial.

Fill a small glass phial with iron filings and hold it near a strong magnet. Now repeated tapping will slowly turn the phial into a magnet. If you examine the filings through a strong magnifying glass, you will observe that the majority of the filings have aligned themselves along the length of the phial. Now shake the phial and re-examine. The filings are now randomly-aligned and the total magnetism has disappeared.

As you know, the smallest piece of iron-filing is as big as many thousands of molecules, so we are not actually seeing the realignment of molecules, but the method is a very good analogy of what really happens, Fig. 2.

As a boy, I remember there was an iron fence near my home which was appreciably magnetic. Since it lay in a North-South direction, it was aligned with the earth's magnetic field. Repeated vibration and taps from a multitude of sources had gradually aligned the molecules and it had become magnetic.

The same thing frequently happens to tools. By their nature they are frequently banged and tapped and if they happen to be in a magnetic field they become magnetised. A magnetic screwdriver can be very useful for inserting tiny screws into inaccessible crevices, but often we do not want the magnetism—what then?

Shaking a spanner is not going to realign the molecules as it did the iron-filings in the phial. One way to demagnetise is by heating, which makes the molecules vibrate more vigorously. Another is to utilise a strong magnetic field to align the molecules *across* the tool so that the end of the tool is effectively the *side* of the magnet as in Fig. 3. This is the principle adopted in bulk tape erasers.

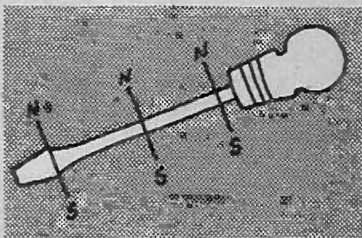
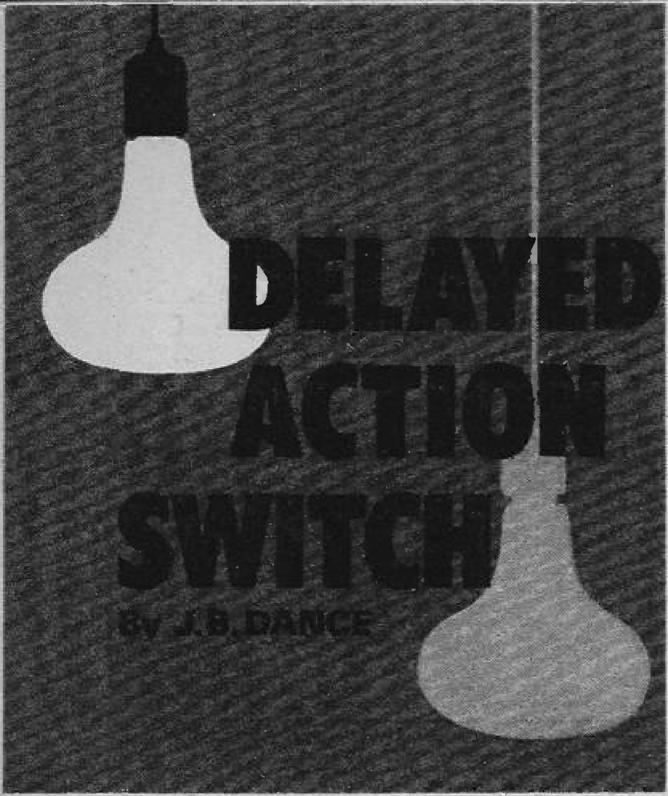


Fig. 3. Laterally magnetised tool will not pick up objects.

Steel is more difficult to magnetise than iron, but it will also hold its magnetism longer. This is because steel contains molecules of carbon that act rather like a film of glue, holding the iron molecules firmly in whatever position they are placed.

Permanent magnets are therefore made of steel, but transformer cores, which are required to accept and lose magnetism quickly, are made of soft iron.



The very simple circuit to be described automatically switches off the controlled light(s) and isolates itself from the power supply. It can be employed for controlling lamps supplied from a battery or from the mains; if a small power supply is constructed the whole unit may be operated from the mains.

The basic circuit itself can be used in many other applications for which a short delay is required. Although the delay period is not intended to be highly accurate and cannot be very long, the circuit is much simpler than those normally used in timing circuits.

Enables a lamp or other device to be switched off after a predetermined delay

It is often convenient to have a facility which enables a lamp to be extinguished after a certain delay. For example, a light outside a garden shed which will switch itself off after about a minute, may be used to enable one to return to the house whilst the path is illuminated.

Another use occurs when one has a light which enables visitors to leave a house with the path outside illuminated. A circuit which automatically switches the lamp off after a preset time will avoid the necessity of anyone having to remember to switch off the light when the visitors have left the path.

The circuit to be described may also be fitted in a car so that when one arrives home one can leave the headlamps operating with the car in one's drive. One can then find the key-holes to lock the car and to unlock the house door with ease; this is especially convenient if one is carrying large articles from the car to the house. **It is illegal to leave a car stationary in a street with the headlamps switched on and therefore this device should only be used when the car is off the road.**

The unit is also suitable for switching off the interior light in a car a certain time after the car door is closed. This helps people who have just entered the car. It is also an aid to anyone who has just locked the car before leaving his garage.

DARLINGTON CIRCUIT

A Darlington amplifier consists of two transistors connected as shown in Fig. 1(a). The input to the base of the first transistor is amplified and the resulting current is fed to the base of the second transistor where it is amplified again.

This results in the Darlington pair behaving like a single transistor of extremely high current gain. The base, emitter and collector electrodes of the equivalent transistor are marked in Fig. 1(a).

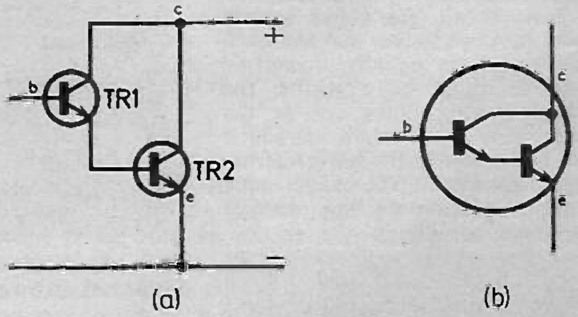


Fig. 1. Details of a Darlington Transistor.

A Darlington circuit can be made from two seperate transistors connected together externally as shown in Fig. 1(a). However, it is generally more convenient to employ a device containing both transistors in a single encapsulation. The equivalent circuit is shown in Fig. 1(b).

One such family of Darlington amplifiers is the silicon D40C group of devices manufactured by the International General Electric Company. The various devices in this range have a further

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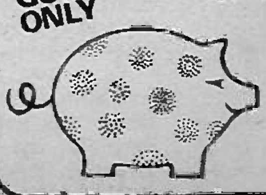
ESTIMATED COST* OF COMPONENTS including V.A.T.



£1.90

*Based on prices prevailing at time of going to press

digit added at the end of the device coding to specify the different voltage ratings and current amplification factors. The cheapest device in the range, the D40C1, is quite suitable for use in the circuit to be described, since it has a 30V collector rating and a d.c. current gain of between 10,000 and 60,000.

THE DEVICE

The D40C1 has the type of construction shown in Fig. 2. It is not necessary to connect the tab of the device to a heat sink in this application, since the power dissipation of the device itself is 1·25W at an ambient temperature of 25 degrees C. (The use of a heat sink can raise the maximum permissible dissipation to 6W if the metal tab of the device is kept at 25 degrees C or less.)

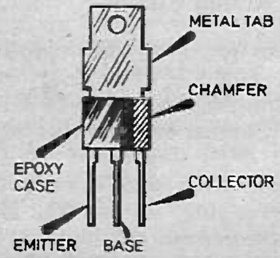


Fig. 2. Physical details of the transistor used in the prototype.

The circuit used is shown in Fig. 3. It has been designed to operate from a 12V supply, but the supply voltage is not at all critical provided that it is suitable for the operation of the relay.

When S1 is pressed, C1 charges to the full power supply voltage. The current flowing through R1 can be estimated in the following way.

The base to emitter voltage of each of the silicon transistors in the D40C1 is about 0·5V when forward biased. Thus there is about 1V between the base and emitter of the whole device. As there is about 12V across C1, approximately 11V will appear across R1. The current through this resistor is therefore about 11/180,000=0·061mA.

If the gain of the Darlington device is the minimum of the tolerance range, namely 10,000, one might expect its collector current to be 10,000×0·061mA=0·61A. However, the resistance of the relay will limit the current to less than this figure. The D40C1 therefore operates in the "saturated" condition; in other words, most of the 12V supply appears across the relay coil and only a very small voltage between the collector and the emitter of the D40C1.

OPERATION

A push-to-make switch is used for S1, this automatically opens when released. When this switch opens, the capacitor C1 slowly discharges into the base-emitter junction of TR1. Thus this capacitor provides a base current to the device and the relay remains closed.

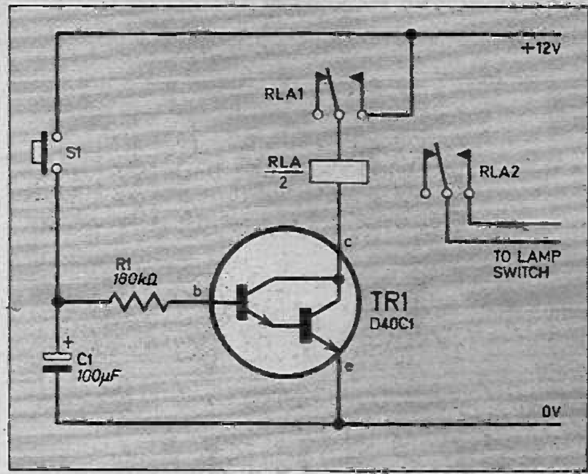


Fig. 3. The circuit diagram of the Delayed Action Switch.

As C1 discharges, the potential across it falls and this results in the base current being reduced. However, the device remains in the saturated condition for about a minute, since enough current is still flowing into the base to ensure that the collector current is limited only by the relay resistance. After about a minute, however, the base current becomes so small that the collector current commences to fall. Shortly afterwards the relay opens.

The opening of the relay causes the contacts RLA1 to open and this isolates the circuit from the supply. This isolation should not really be necessary, since the circuit should not pass any appreciable current in its quiescent state. However, a spare set of contacts are available on the relay and constructors are advised to use them in this way to avoid the possibility of the battery being discharged if a fault should occur in the device.

LAMP CONTROL

The other pair of relay contacts, marked RLA2 in Fig. 3, are used to switch the controlled lamps off at the instant the relay opens. These contacts are merely connected to the existing switch contacts for the lamp concerned and do not interfere with the normal operation of the lamp in any way.

One might expect that a transient voltage would be generated across the relay coil as the current through the latter is switched off. However, in this circuit the current falls fairly slowly in the relay coil and no appreciable transient is generated. This avoids the need for a transient suppressing diode across the relay to prevent damage to TR1.

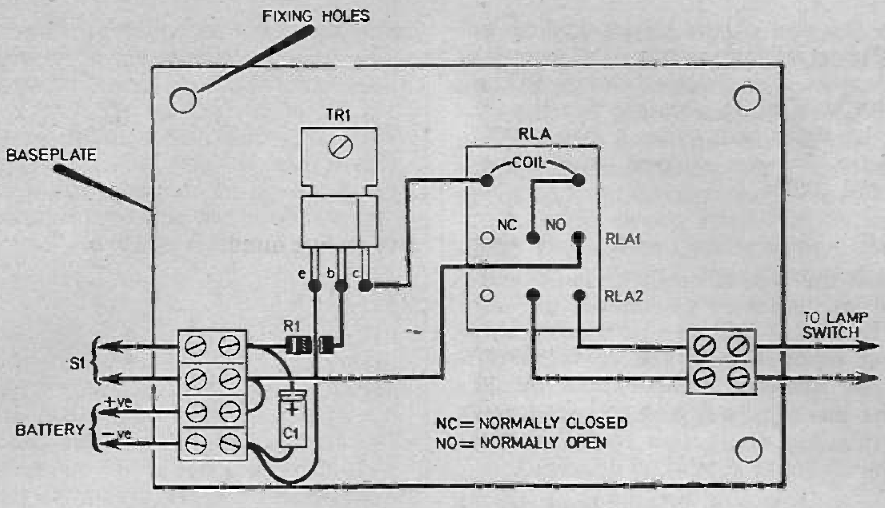


Fig. 4. Construction and wiring of the Delayed Action Switch.

Components.... SEE SHOP TALK

R1	180kΩ ¼W carbon ± 10%
C1	100μF 20V elect.
TR1	D40C1 Darlington transistor silicon *npn*
RLA	Any 12V relay with coil resistance greater than about 100 ohms and two pairs of normally open contacts (see text)
S1	Push-to-make release-to-break s.p.s.t. switch

Paxolin size 150 x 100mm; terminal block 6-way; battery connectors; 6BA fixings.

CONSTRUCTION

In the prototype, a piece of Paxolin was used as the baseplate although any other insulator material such as Perspex, plain matrix board, Formica etc. will do just as well, see Fig. 4.

Begin construction by making a suitable bracket to hold the relay securely to the baseplate. The four fixing holes, one near each corner should now be made, and holes drilled to accommodate TR1, relay bracket and terminal blocks. When the components have been secured they should be wired up as detailed in Fig. 4, and mounted in a case most suitable to the application of the device.

OTHER DELAY VALUES

It has been found that the circuit shown provides a delay of rather over one minute before the lights are switched off. This time is approximately proportional to the product of the values of R1 and C1. If a delay of about 30 seconds is required, the value of R1 may be reduced to 100 kilohms or the value of C1 reduced to 50μF.

Times longer than one minute may be obtained by increasing R1 or C1. However, R1 should not be increased much above 500 kilohms or the relay may not close if TR1 has a gain near to the minimum tolerance value for this type of device. No damage can be done by trying a higher value of R1, however.

THE RELAY

The relay used in the prototype was the microswitch relay type MS2B which is available (through retailers) from Keyswitch Relays Ltd. This will operate with supplies in the recommended range 9·6 to 14·4V if the coil has a nominal operating voltage of 12V (although it was found that one of these relays would operate with less than 7V across the coil). The coil resistance is about 465 ohm in the case of the 12V relay, so the operating current is about 26mA.

The MS2B is designed to switch up to 2A at each set of contacts at voltages up to 250V in a.c. circuits, but the maximum recommended contact current is smaller in d.c. circuits. (In a.c. circuits the voltage across the contacts falls to zero between alternate half cycles and this helps to break any arc.) The maximum recommended contact currents are 2A in a 24V d.c. circuit, 0·25A in a 100V d.c. circuit and 0·2A in a 250V d.c. circuit.

The MS2B should not be employed to switch car headlamps; a relay which can switch larger currents should be used for this application. For example, the Keyswitch Relays type KMK2P or the R. S. type 1A can switch up to 10A and are suitable for this application. They have 12V coils and an operating coil current of about 100mA. ▣

NEW DIMENSIONS IN SOUND QUAD AND OTHER MULTICHANNEL SYSTEMS

PART 1 **By ADRIAN HOPE**

IF THEY gave away prizes for confusion, the last few years of surround-sound, quadraphonics and four-channel reproduction would win hands down. I do not think that any other topic in the history of the world can have been so widely discussed and so little understood.

Over the past few years I have been lucky (or perhaps unlucky) enough to attend demonstrations of different surround-sound systems and have heard all manner of experts pontificate on how wonderful one system is in comparison with all the others. I have also read the technical literature put out by those with a commercial axe to grind and have understood very little of it.

Where so-called "easy to understand" literature has been given to me, it has been so over-simplified as to convey no real meaning.

Reluctantly, I have come to the conclusion that most of the wizards involved in the research and development of surround-sound systems are incapable of describing them intelligibly to anyone other than another wizard, and that the more down to earth people involved in selling the hardware (such as amplifiers and equipment) and the software (such as records) have not the faintest idea how what they are selling actually works.

In between these two schools falls a large number of interested enthusiasts who would dearly like to get to grips with the basic essentials of the various surround-sound systems.

Certainly I have felt frustration in this respect and have tried hard to get something clear in my mind. Being no mathematician I don't feel I have yet achieved an all round understanding, but I have (I hope) started in the right direction. The knowledge I have gained is imparted in this series of articles.

MULTI-CHANNEL SYSTEMS

All surround-sound or multi-channel systems have one thing in common. They seek to cram more than two channels of information into a two-channel (stereo) recording medium. Usually an attempt is made to cram four channels into two and for this reason the term "quadraphonic" is often used to describe a multi-channel system. But there is no reason why a multi-channel system should not reproduce three channels or five or five hundred and five.

TWO WAYS

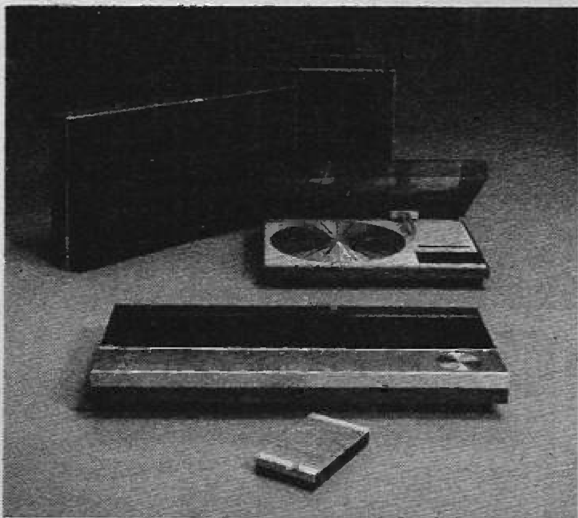
There are two basic ways of tackling the problem. On the one hand there is the matrix approach, and on the other there is the multiplex approach. The latter technique is used in many fields of electronics, including radio transmission, where the two stereo channels are multiplexed for transmission as a single channel and separated on reception to produce the two channels of stereo radio.

The JVC-Nivico CD4 discrete four-channel disc system involves a process akin to radio multiplexing and is out of place in the context of the present articles which concentrate on the matrixing approach as being that most immediately relevant to the audio man in the street who wants to know about four channel for entertainment *now*.

Although the discrete approach has much to offer from a technological point of view (incidentally discrete recording by multiplex techniques dates back to at least 1954) there is still very little discrete software (records) available.

MATRIX SYSTEM

"Matrixing" is really nothing more than a fancy term for mixing. In a four-channel matrix system the four original channels are mixed



The Beosystem 6000 (4 x 40 watts) with f.m. receiver. Plays mono, stereo, amblo, quad SQ matrix, quad CD4. Shown in foreground is remote control box. *(Bang & Olufsen)* together into two for recording or transmission in stereo fashion, and then unmixed again on playback or reception.

In practice the unmixing is only partial, which means that although four channels are retrieved, they are not as independent of each other as the original four channels were before mixing. In other words the separation between the unmixed (decoded) channels is not as clean as the separation between the original channels before they were mixed (encoded).

In even simpler terms this means that four totally separate sounds which existed, one in each of the original four channels, will spread over between channels after encoding and decoding.

Most of the technical literature which purports to describe matrixing techniques is replete with phase diagrams, circles and heart-shaped polar diagrams. But in many respects these technical excesses are totally unnecessary. There is only one basic electronic concept that must be grasped to understand matrixing, and that is the manner in which in-phase and out-of-phase signals behave when combined.

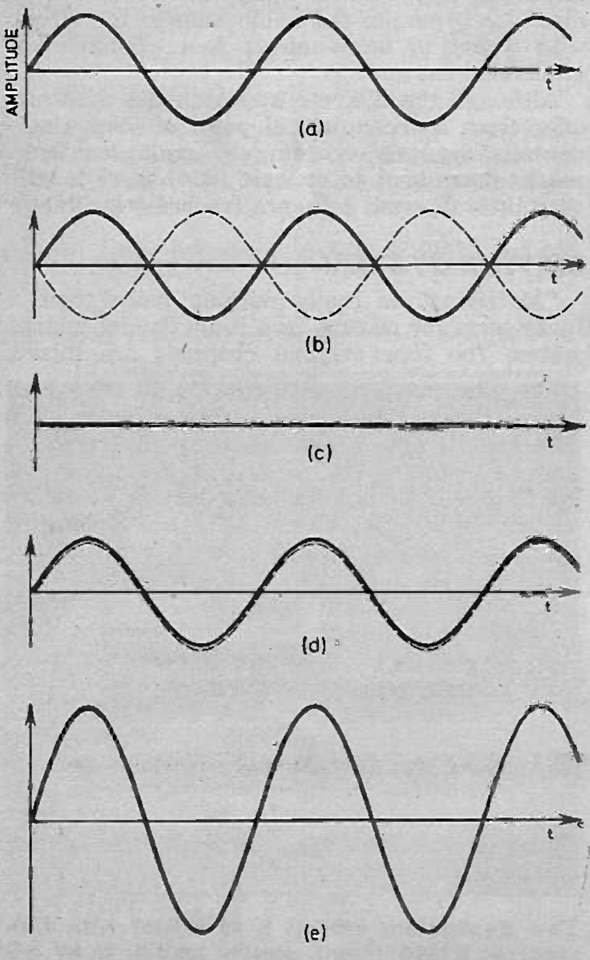


Fig. 1. The results of mixing in and out of phase identical signals.

The JVC Nivico 4VR-5456 f.m./a.m. CD4 discrete four channel stereo receiver. Also handles all other matrix systems. *JVC (U.K.) Ltd.*

SIGNAL MIXING

In Fig. 1(a) a simple audio signal is shown. It does not matter what frequency (pitch) or what amplitude (volume) it is. What does matter is that if a second identical signal is added to it, the result will depend on whether the two signals are in or out of phase with each other.

In Fig. 1(b) two exactly similar signals are shown, one in full lines and one in broken lines, and one signal is exactly 180 degrees out of phase with the other. In other words, when one signal is peaking, the other is dipping, or when one is pushing the other is pulling. The result, as shown in Fig. 1(c) is absolutely nothing. The one signal has completely cancelled out the other to leave no signal.

If on the other hand, as shown in Fig. 1(d), the two signals are exactly in phase with each other, so that the peaks and the dips correspond, then the result as shown in Fig. 1(e) will be a greatly increased final signal, with the energy of the two signals added together.

Thus just as the two signals of Fig. 1(b) were pushing and pulling against each other, so the two signals of Fig. 1(d) were pushing and pulling together. And whereas the competing signals of Fig. 1(b) cancelled out, the co-operating signals of Fig. 1(d) boosted each other to produce a final signal which is larger than either one alone. In-between circumstances produce in-between results.

All the matrixing systems for surround-sound rely on this fact by using one signal to boost or reduce another during encoding and decoding. Of course the actual signals involved are infinitely complex, being usually music or speech, but the same basic principle applies however complicated the signals involved.

PATENTS

With this effect (hopefully) clear in our minds, we can look at how matrixing systems apply the principle in practice. Often the clearest descriptions are obtainable from patent specifications and as all patent specifications are open to the public for inspection free of charge at various libraries (such as that attached to the British Patent Office in Southampton Buildings, Chancery Lane, London WC2), relevant patent numbers will be given where applicable for reference.

Matrixing history started in 1931 when Alan Dower Blumlein of EMI filed a patent application (BP 394 325) which laid down the principles not only for most modern stereo recording and microphone techniques but also for matrixing.

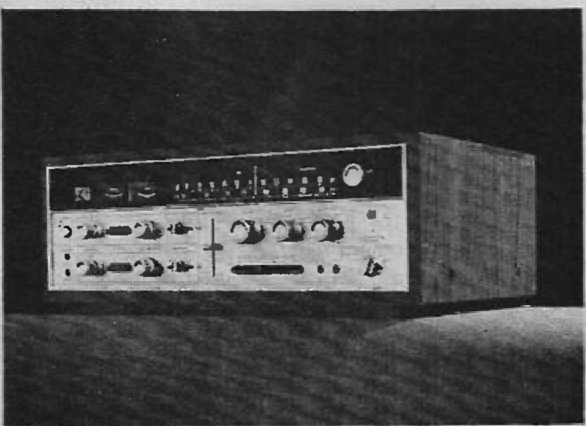
Blumlein explained how the relative loudness of sounds emitted from loudspeakers could be made dependent upon the relative phasing of the original signals. He also explained techniques for converting phase differences into amplitude or volume differences.

There is no need in the present context to look closely at what Blumlein wrote, but it would be unfair not to at least acknowledge the existence of this pioneer work.

Further work in this area was carried out around twenty years ago (e.g. Telefunken, German patent No. 1077710) but it was not until the sixties that interest in matrixing as a means for cramming more than two channels into a stereo recording gained momentum.

It is easy to forget how long it took for stereo to take over from mono and there was little or no incentive to devise extra channel systems until stereo had become a domestic way of life.

Some of the earliest discussions of simple matrixing came from Ben Bauer, of CBS, and David Hafler, of Dynaco, in the first half of the sixties. We shall meet both these names again as the plot thickens, but for the moment Bauer and Hafler enter the picture as men who both suggested simple techniques for encoding an extra centre front channel and an extra rear channel into stereo recordings. But even before looking at what Bauer and Hafler were proposing a decade ago, it is best to digress for a while and consider how the so-called "ordinary" stereo record is made.



The Sansui QRX 6500 four channel receiver.
(Venitron Ltd.)

RECORDING

Recording began in 1877 when Thomas Edison suggested (USA Patent No. 200521) that sound waves could be captured in grooves cut in wax by a vibrating needle. The grooves could then be made to release their captured sound by tracking them with a needle attached to a diaphragm which then vibrated in a manner which corresponded to the original vibrations which had cut the groove.

The grooves were cut in either up and down (hill and dale) or sideways (lateral cut) manner. As most people realise, hill and dale recording eventually fell by the wayside and mono records as we played them on our old 78 gramophones, and for that matter on our old mono 33⅓ players, were lateral cut.

Stereo recording became a reality when the technique was evolved of cutting the two sides of the groove differently.

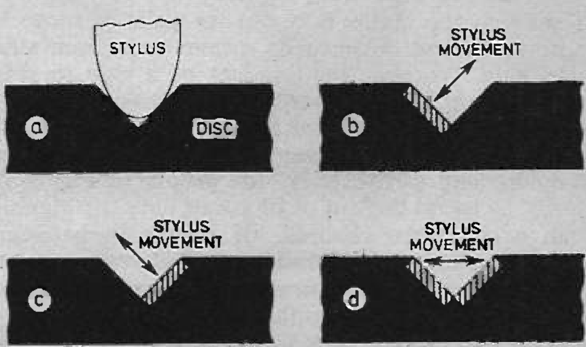


Fig. 2. Details of stylus movement in the groove of a disc.

In Fig. 2(a) the record groove has two walls which are at right angles to each other and at 45 degrees to the record surface. The playback stylus runs in the groove and touches both of its sides. If one side is cut away (as shown by the hatching in Fig. 2(b) then the stylus will move to that side. If the other side of the groove is cut away, as shown by the hatching in Fig. 2(c), then the stylus will move to that side.

Thus in Fig. 2(b) the left hand wall of the groove only is cut with a simple sound and the stylus will move up and down, towards and away from that groove wall, as indicated by the arrow. The pick-up is so constructed that this movement will produce sound in one channel only.

If on the other hand only the other wall of the groove is cut, as shown in Fig. 2(c), then the stylus will move up and down, towards and away from the cut wall, as again shown by the arrow. The pick-up will in this case produce sound only in the other loudspeaker.

If the walls of the grooves are both cut, Fig. 2(d) in matching snake-like fashion the stylus will move only from side to side (not up and down) and will produce the same sound in both

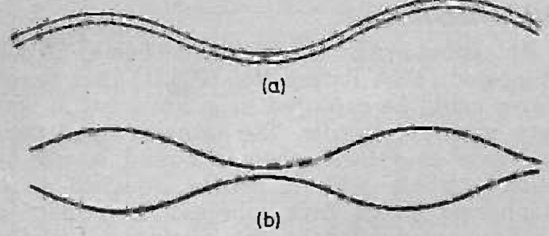


Fig. 3. A plan view of a disc groove for (a) in phase (b) out of phase signals.

loudspeakers; Fig. 3(a) shows the walls of the groove moving ganged together in snake-like fashion or "in phase" with each other.

Once in a while, however, either intentionally or otherwise, the groove will be cut so that the wall movements are opposed to each other or "out of phase". Thus the result then will be a bulbous shaped groove, as shown in Fig. 3(b).

This bulbous shaped groove will tend to squeeze the stylus between its walls to move it upwards and downwards rather than from side to side. Whereas the product of a side to side movement, as produced by the groove of Fig. 3(a), will be equal and in phase signals in each stereo channel, the result of an up and down movement, as caused by the groove of Fig. 3(b), will be equal but out of phase or opposite signals in each stereo channel. Of course in between circumstances will produce in between results.

On an ordinary stereo (two speaker) record playing set-up, the in-phase signals produced by the groove of Fig. 3(a) will produce equal sounds from both loudspeakers which will seem to come from a point in space half way between the loudspeakers (this is a psycho-acoustic effect which is best taken for granted in the present context or we shall be off on another digression).

The equal but out-of-phase or opposite signals produced by the groove of Fig. 3(b) will also be reproduced by both loudspeakers but (because of another of those psycho-acoustic effects) will tend to be lost to the ear or confuse it. This is one reason why most recording and cutting engineers try and keep their records as relatively free of out-of-phase sounds as possible.

But there are occasions when out of phase sounds are deliberately or accidentally present and we shall see later how this can be of interest and importance.

THIRD SPEAKER

But to return now to those simple methods of matrixing proposed by Bauer and Hafler. We have already seen how an illusion of a centre channel is created between left and right speakers if the same signal is present on both left and right channels.

This can be achieved either by recording with two microphones spaced equally apart from the instrument or voice that is to be in the centre, or it can be achieved artificially by taking a sound intended for the centre and applying that sound to each of the left and right channels as a simple addition.

In 1965 David Hafler patented (USA patent 3417203) a system of going one better than having the centre channel appear in space between the left and right loudspeakers. What he suggested was a method of deriving power for a third loudspeaker which would be physically located between the left and right loudspeakers in an ordinary stereo set up.

There was nothing new in suggesting the use of a third speaker to fill the "hole in the middle" between the left and right loudspeakers, but previous proposals had tended to be rather complicated and require an extra amplifier.

The Hafler circuit, as shown in Fig. 4(a), is simple and requires no extra amplification. Similar and in-phase signals feeding the left and right channel speakers will tend to cancel each other out and so produce reduced signal levels in the left and right speakers, while the centre, extra speaker will be driven by the sum of such signals. Thus a centre sound will tend to appear from the centre loudspeaker rather than from the left and right loudspeakers.

In practice there will be some loss of the left-right separation and in the patent Hafler explains various ways of overcoming this problem. For instance a simple blend resistor across the amplifier inputs may suffice.

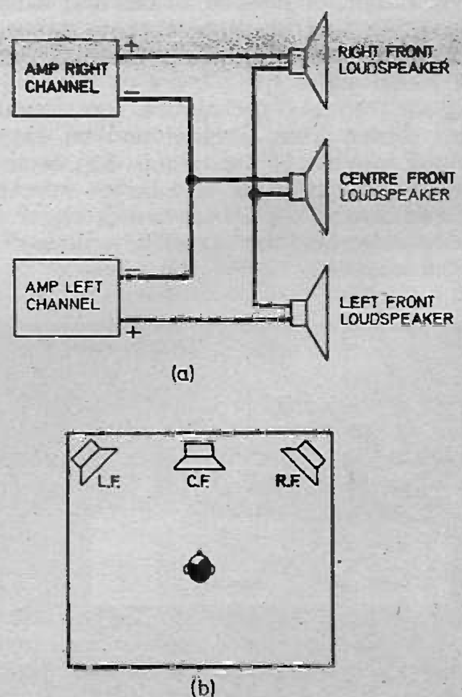


Fig. 4(a). The Hafler circuit for producing a signal, from in-phase signals, in a front central speaker; (b) shows domestic arrangement of speakers and listener.

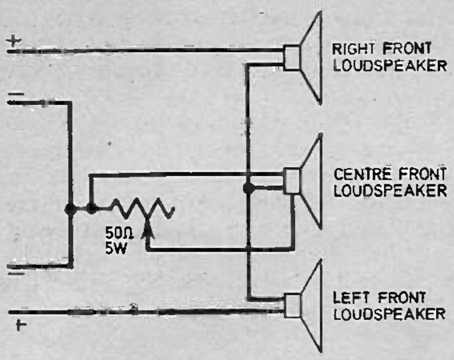


Fig. 5. Circuit to give a degree of volume control for the centre speaker.

For a degree of volume control for the centre speaker, all that is necessary, as shown in Fig. 5, is a 50 ohm, 5 watt potentiometer as a variable shunt across the centre loudspeaker, to by-pass it to a controllable degree.

So here we have a simple way of imposing an extra (third) channel on an ordinary stereo recording and recovering it on playback.

REAR SPEAKER

It is also relatively simple to impose a fourth channel and this is achieved by deliberately putting out of phase signals onto the left and right channels so that the stylus will be confronted with a groove like that of Fig. 3(b), and will move in an up and down fashion to produce out of phase signals on the left and right loudspeaker channels.

Just as the in phase centre signals can be extracted by the simple summing technique just described, so the out of phase signals can be likewise extracted by a simple subtraction technique.

Much of the inspiration in this direction also comes from David Hafler and it was in fact his suggestions for deriving a rear channel in simple manner (in an article in August 1970) that has made his name something of a household word. We shall come back to Hafler's suggestions for deriving a rear channel when we have finished looking at the whole question of matrixing.

In the meantime, suffice it to say that there are simple techniques for imposing a fourth channel on to a recording in out of phase fashion.

Most straightforward, the fourth channel signal is divided into two equal parts and these applied in phase opposition to the left and right channels. This produces similar but opposite components in the two stereo channels (left and right) and these can be most simply extracted by the simple subtraction circuit shown in Fig. 6(a).

The right and left channels feed the left and right speakers in conventional fashion, but the positive output terminals of each channel are connected together via the extra loudspeaker, which is thus fed by whatever currents flow from the positive terminal of one amplifier to the positive terminal of the other. Such currents will flow when there is any difference between the output of the two amplifiers; maximum current will flow when the signals of each channel are similar and out of phase with the other; minimum current will flow when the two channels are in phase. In simple terms, a peak in one channel and a dip in the other channel will cause a current flow between channels through the extra loudspeaker.

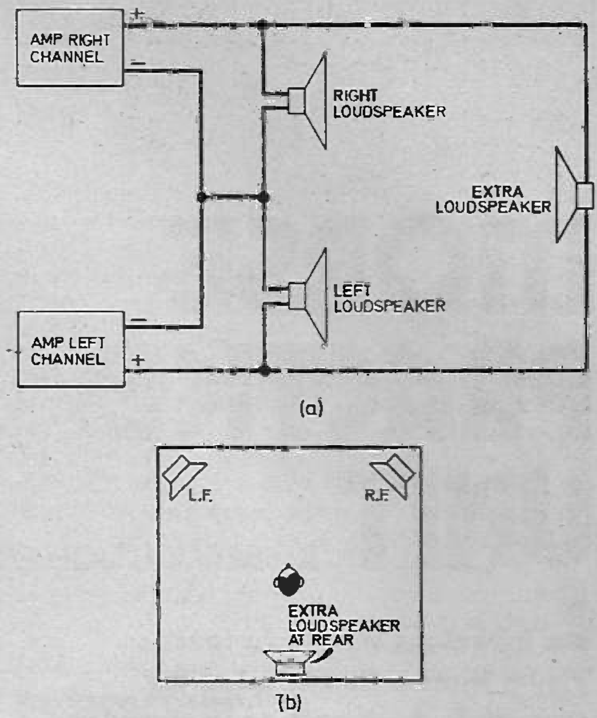


Fig. 6 (a) The Hafler circuit for producing signals in a rear speaker from out of phase signals in left and right channels; (b) shows the domestic arrangement.

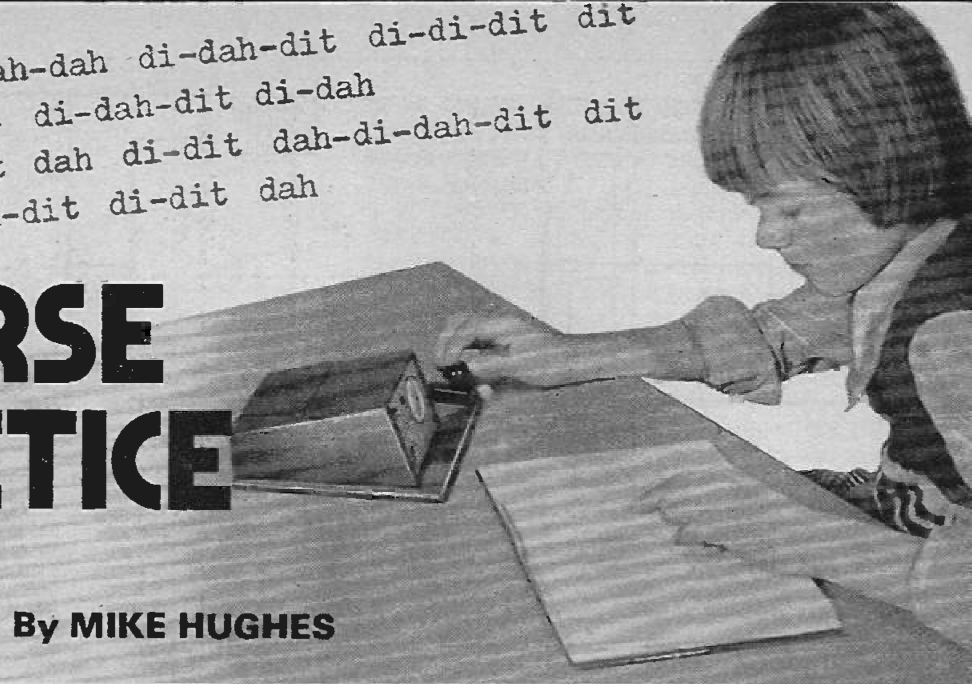
ANOMALOUS RESULTS

It would seem that by now we have enough to provide four channels. This is true, but the problem is that the separation between those channels is not particularly good and all manner of anomalous results will occur in practice, with some wanted signals being lost and other signals appearing from the wrong loudspeaker or from too many loudspeakers at the same time.

All in all the techniques described so far cannot achieve the ultimate aim of recorded sounds cleanly separated into their four original channels on playback. In other words, these matrixing techniques provide only partial decoding.

To be continued

dah-dah dah-dah-dah di-dah-dit di-di-dit dit
di-dah-dah-dit di-dah-dit di-dah
dah-di-dah-dit dah di-dit dah-di-dah-dit dit
di-di-dah dah-dit di-dit dah



MORSE PRACTICE UNIT

By MIKE HUGHES

An ingenious devise to teach visual Morse. Can be used for record/playback with tape recorder

This design arose from the request of a friend who was attempting to obtain his maritime "Master's" certificate. He had to learn to send and read visual Morse code, and as he wanted to learn quickly, was hoping it might be possible to use ready made Morse gramophone records to operate a flashing light. This gadget was quickly hooked up and it worked very successfully.

Thinking more about this simple project the author felt that there might be a more general application for an instrument that will enable one to record morse and play it back either aurally or visually; potential users range from sailors to boy scouts and radio amateur clubs to sailing clubs.

The design requirements were that it should be very simple to operate, not require a lot of power, be simple to construct and plug directly into a cassette recorder.

CIRCUIT DESCRIPTION

The complete circuit is shown in Fig. 1; TR1 is a transistor operating as a class C amplifier and is the first stage of the playback circuitry. Any signals greater than a certain value (about 50 millivolts) that are fed to its base through C1 will produce negative going signals (heavily distorted as far as conventional audio is concerned) at the collector. If S1 is in the "play" position these signals are fed through C2 to the base of TR3.

In the absence of a signal, the base of TR3 is returned to ground through R3 and the transistor is cut off. However, when the large amplitude signals from TR1 collector are present (these exceed a volt—provided the tape has been correctly recorded) TR3 is driven into conduction as they rise in a positive direction. When this happens the light emitting diode, D1, glows brightly.

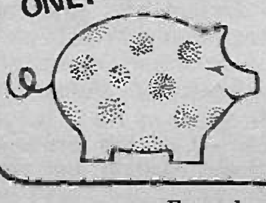
In practice the signal will be pulses of a high frequency tone and the effect is that D1 glows for the duration of the pulse. It is essential to use an l.e.d. because an ordinary tungsten filament bulb has too great a thermal inertia and the filament does not respond to high speed Morse.

The large amplitude signals at the collector of TR3 are fed, via C4, to TR2 which is normally biased heavily into conduction by R4 (thus keeping its collector at near zero volts), however, when a signal is present it is forced out of conduction during the negative excursions and this resulting signal is fed via an emitter follower (TR4) to loudspeaker LS1.

PLAYBACK

When a pre-recorded morse tape is played back, the light emitting diode flashes in the same rhythm as the dots and dashes giving visual stimulus and at the same time the tone is heard in the loudspeaker. If desired the loud-

FOR GUIDANCE ONLY



ESTIMATED COST* OF COMPONENTS
including V.A.T.

£5.00

excluding case

*Based on prices prevailing at time of going to press

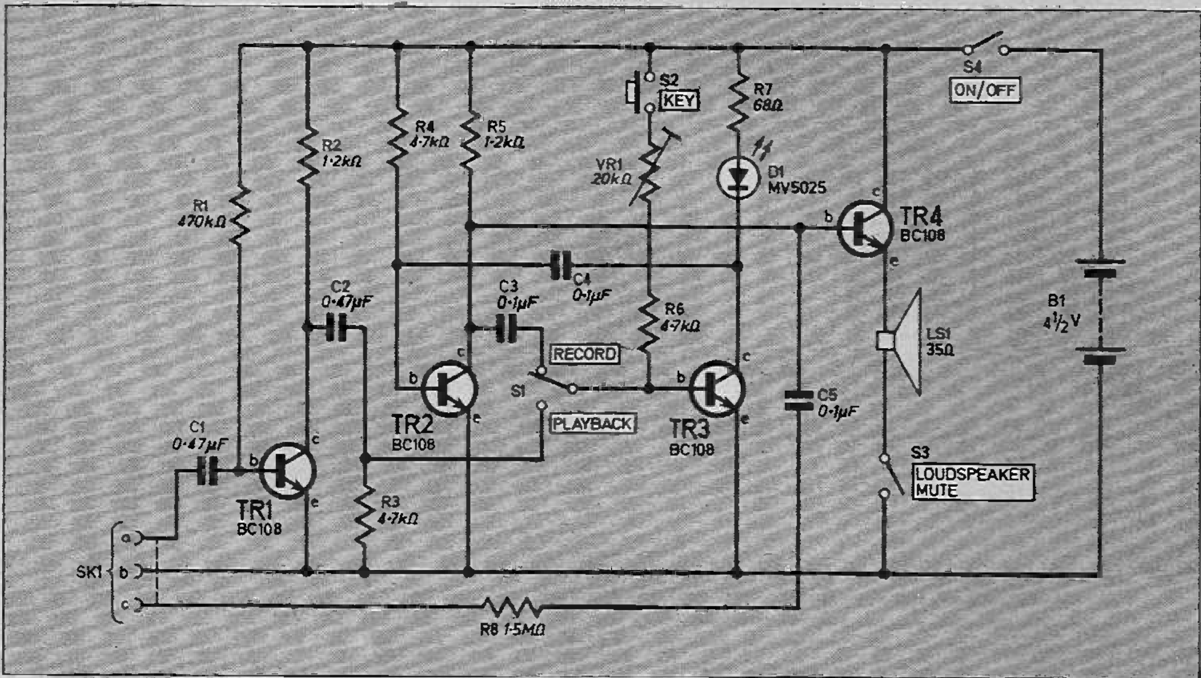


Fig. 1. The circuit diagram of the Morse Practice Unit.

speaker can be muted by means of S3 but the light will continue to follow the input signals.

Notice that we assumed—during the playback operation—that the Morse key (S2) played no role; it should be open circuit i.e. not depressed, during the playback cycle. No harm will come if it is pressed but it might produce a slight parasitic glow in the l.e.d. which would be distracting.

MULTIVIBRATOR

For normal practice, use of the key, and for recording a signal onto tape, S1 should be put in the "record" position. This removes C2 from the base of TR3 and instead switches to C3. This action turns TR2 and TR3 into a simple cross coupled astable multivibrator whose time constants are set by C4 with R4, and C3 with R6 and VR1.

The astable will only work when the Morse key is depressed. Its pitch is controllable by VR1 and the l.e.d. glows each time the key is pressed; likewise the loudspeaker will continue to give an audible tone (provided it is switched in with S3).

The signal at the collector of TR2 is taken via C5 and R8 to the recording input lead of the cassette tape recorder. When recording a signal it is important that the level be set correctly to ensure that there is sufficient signal level on playback.

RECORDER CONNECTION

An advantage with using the Philips recorder is that the input and output terminate at the

Components....

Resistors

R1 470kΩ
R2 1·2kΩ
R3 4·7kΩ
R4 4·7kΩ
R5 1·2kΩ
R6 4·7kΩ
R7 68Ω
R8 1·5MΩ
All ¼ watt carbon ±10%

Capacitors

C1 0·47μF
C2 0·47μF
C3 0·1μF
C4 0·1μF
C5 0·1μF

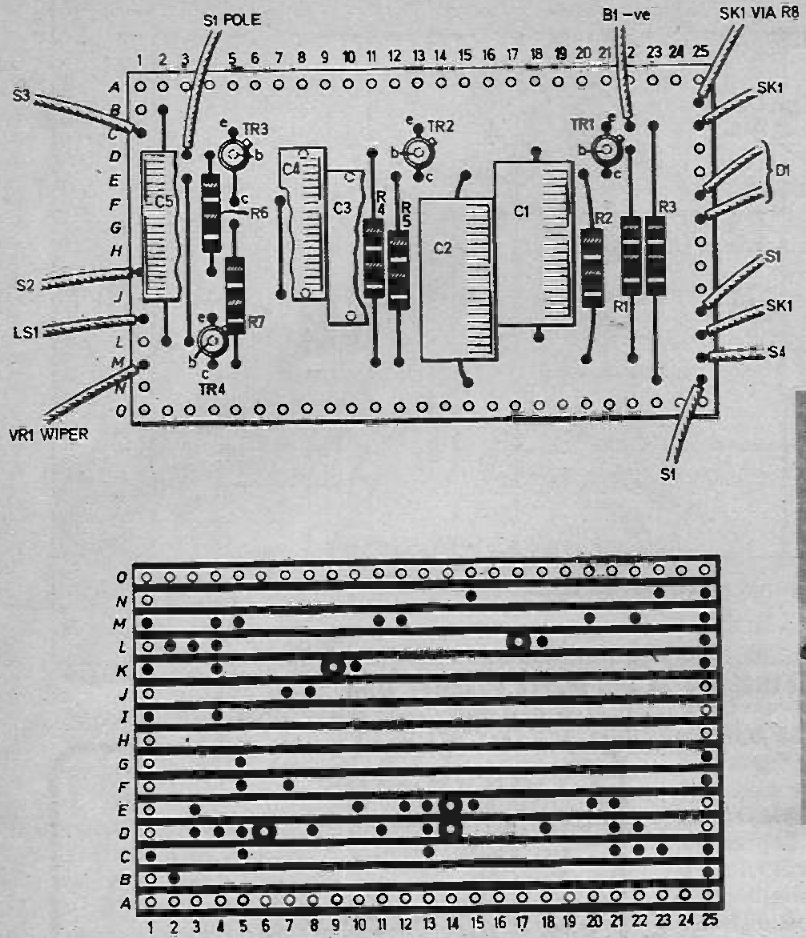
SEE
SHOP TALK

Semiconductors

TR1 BC108 silicon *npn*
TR2 BC108 silicon *npn*
TR3 BC108 silicon *npn*
TR4 BC108 silicon *npn*
D1 MV5025 (or similar) light emitting diode

Miscellaneous

S1 miniature single pole two-way toggle
S2 Morse key
S3 miniature on/off toggle
S4 miniature on/off toggle
VR1 20kΩ linear carbon (22kΩ or 25kΩ are suitable
LS1 35o hm 50mm dia. loudspeaker
SK1 5-pin 180 degree DIN socket
PL1, PL2 5 pin 180 degree DIN plug (2 off)
B1 4½ volt bell battery with screw terminals
Veroboard: 0·1in. matrix size 15 strips x 25 holes; aluminium for front panel; expanded aluminum (loudspeaker grille); twin-screened cable (connection to recorder); plywood for case and base.



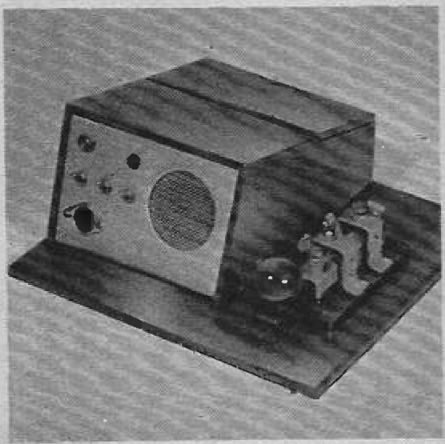


Fig. 2. The layout of the components on the topside of the Veroboard and the region of copper strip to be removed.

same DIN plug, hence interconnection is simplicity itself with a single piece of twin screened lead. The fact that the playback signal is taken from this connection instead of, as was first considered, the loudspeaker means that the volume control of the recorder can be set to zero without interfering with playback.

We recommend you make up your own lead for coupling to the recorder because some standard leads have resistors within the DIN plugs and these can cause the equipment to malfunction.

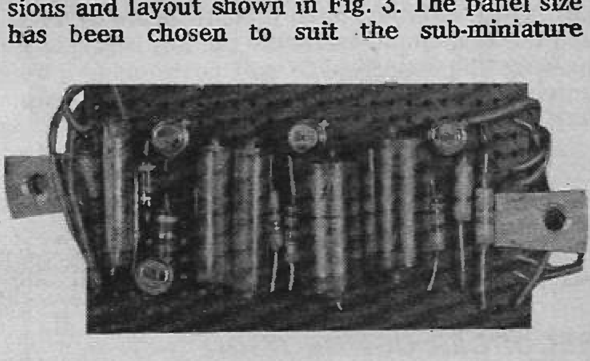
CONSTRUCTION

The circuitry for the prototype was made up on a piece of 0·1in matrix Veroboard size 40 x 65mm approximately. The layout of the components on the topside of the board and the areas of copper strip to be removed on the underside are shown in Fig. 2. The components are rather closely grouped so be careful about solder blobs bridging conductors.

Begin assembly by soldering in the two link wires followed by the resistors and capacitors. The transistors should be soldered in last of all and a heat shunt used to prevent thermal damage from the soldering iron. Finally solder suitable lengths of lead to the board as indicated in Fig. 2.

In the prototype, two small aluminium lugs, with mounting holes, were next Araldited to either end of the board (on the unclad side), see photograph.

The remainder of the components are to be mounted on the aluminium front panel, dimensions and layout shown in Fig. 3. The panel size has been chosen to suit the sub-miniature



Photograph of the prototype component board showing boxing lugs glued in place.

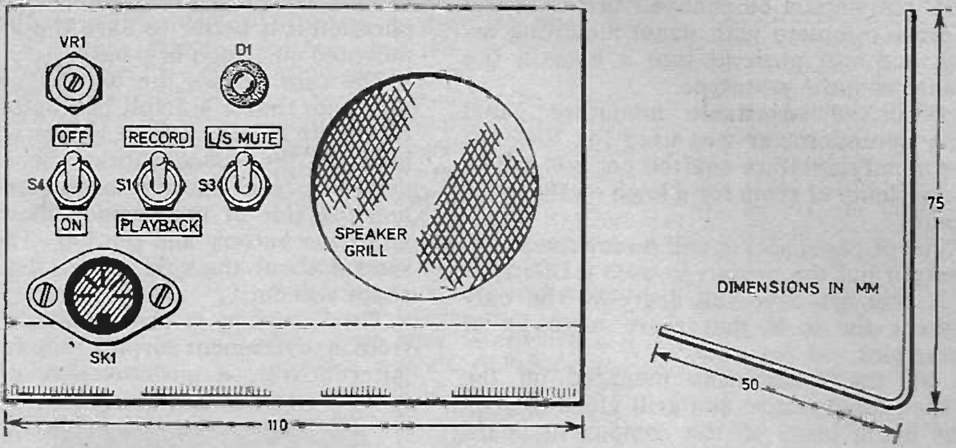
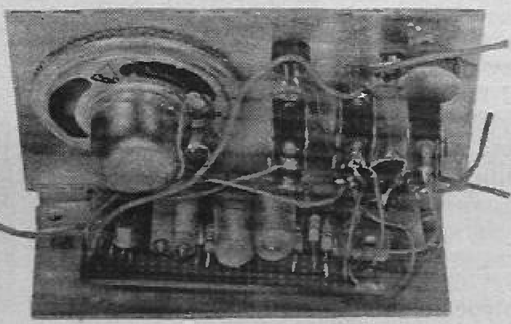


Fig. 3 (above and top left). Details of the front panel layout and construction.



Left. Photograph of the prototype wiring.

MORSE PRACTICE UNIT

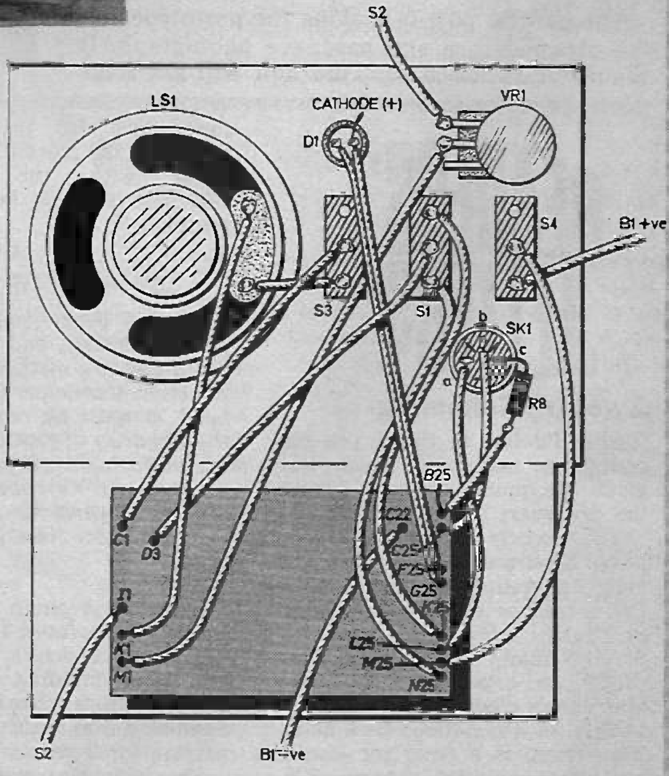


Fig. 4. Complete wiring up details of the front panel components to the component board.

switches used. If the larger switches are used, the panel size should be changed to suit. Some l.e.d.'s come complete with panel mounting accessories and will push fit into a hole in the front panel as in the prototype.

A screwdriver adjustable miniature panel mounting potentiometer was used for VR1 but a conventional miniature shafted pot will suffice as there is plenty of room for a knob on the front of the unit.

Any type of panel socket will do for the signal input/output but the prototype used a DIN type having 5 pins set over 180 degrees. The only requirement for it is that there must be at least three pins.

With all the components mounted on the front panel, loudspeaker and grill glued in position, the flying leads on the component board should be wired up to the panel mounted components as shown in Fig. 4.

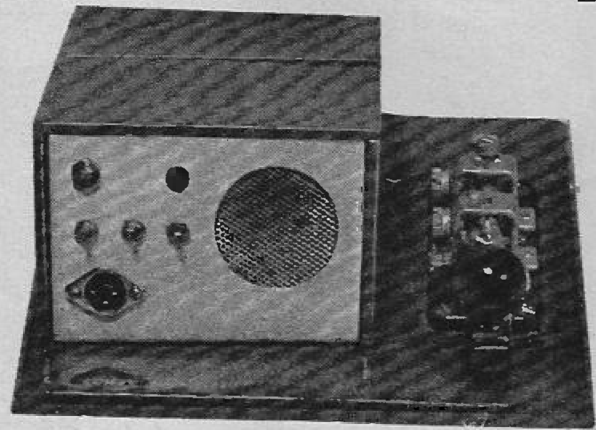
The component board should now be secured to the angled base of the front panel by means of two small nuts, bolts, washers and spacers through the aluminium lugs. The two wires to switch S2 should be wrapped together and taken to the morse key S2. Similarly, the other two leads to B1.

CASE

The hardest part in making the prototype was the plywood case and base, see photograph. It should be foreseen that the unit will get some pretty heavy treatment so it should be made from fairly substantial material and for the application it is better to have the Morse key (S2) mounted on a good firm base.

The case houses the battery under a hinged top. Note that a 4·5 volt bell battery with screw terminals is used and it is this which takes up most of the space within the cabinet. Holes drilled in the internal compartment separator and the side of the cabinet allow the wires to go to the battery and the key. There is nothing special about the case shape, and any size and shape will do.

The key used in the prototype was obtained from a government surplus shop for a few pence. Alternatively, a push-to-make, release-to-break switch can be used. ▣



READERS' LETTERS

Swedish Schooling

First I'd like to thank you for your nice magazine, which has given me much pleasure during the few years I've known it.

Your article in the November issue *Electronics At School* was very interesting to me, because I'm a teacher at a Swedish comprehensive school. My school, as well as many others, give their pupils an opportunity to learn elementary electronics as a hobby, mainly on a non-theoretical basis. Thus there is a need for simple building projects, where E.E. comes in very handy. Many pupils, however, need much help, and plenty of prepared material.

Therefore, if E.E. had full-size suggestions for printed-circuits, e.g. like the recent mini-organ, along with the Veroboard sketches, it would be even more useful.

Hans Nyström,
Sandviken,
Sweden.

We note your point regarding printed circuits, and we do sometimes use this method in our constructional articles. On the other hand, it must be recognised that the majority of readers appear to prefer to build on such standard products as Veroboard. We will of course continue to use both methods from time to time.

Delta

I enclose a photo of my *Delta Guitar*, as featured in your October issue, which I have had a lot of fun building and playing. It is quite a change from my Spanish guitar which I have been playing for 2 years!

The body was made from plywood and chipboard joined with Resin W. The neck was beech stained "mahogany", the fretboard. $\frac{3}{8}$ inch plywood. I got the pickups for my 13th birthday and they give a high output. I found that the pickups were about the same price as the transformer and the magnets. I tried making the tailplate out of aluminium but I found it was too weak so I made a steel one.

All I have to do now is make an amplifier so dad can have his hifi back!

Arthur Lowery,
Yorkshire.

New products and component buying for constructional projects

SHOP TALK

By Mike Kenward

THIS month we start publication of the largest and most expensive project we have ever tackled, the *Modula 3 Stereo Amplifier*. Readers should take note of the advice given at the start of the article before attempting construction. Although some warnings are needed, the amplifier should work properly if the construction is carefully followed.

Being a large, specialised project, there are a few buying problems that need some comment. First of all, the two Sanyo power amplifier modules are available from Guest International Ltd, who are offering the modules, when purchased together for this project, at a specially reduced price of £8·86, inclusive of V.A.T. and postage—this is a saving of a few pounds on previously advertised prices. To get the modules, write to Guest Distribution Division, Redlands, Couldon, Surrey, CR3 2HT quoting reference EE1 on the envelope and order, enclosing a cheque or P.O. for the above amount and an order for two STK 032 Sanyo power amplifier modules.

The transformer for this project has been specially designed for a low external field, good regulation and to be the correct physical size and electrical specification. It is therefore recommended that this transformer be used. It is available from Zeta Windings, who are advertising in this issue, the cost being £4·75 including postage, packing and V.A.T. The transformer is adequately rated for the amplifier and incorporates a screen to help prevent hum pickup by the sensitive preamplifier circuitry.

The third module, the Mullard LP 1184/2 preamplifier, is available from Home Radio Components who are regular advertisers in our pages or Electrospares, 288 Ecclesall Road, Sheffield S11 8PE (D). Prices had not been finalised at the time of going to press. One point concerning all the parts mentioned above—they may all take some time to reach you if demand is high. Obviously suppliers cannot afford to stock large quantities of expensive single items until they have some gauge of the demand—if it is high they will have to re-stock and that will take a few weeks, however, there is plenty of metalwork to be getting on with!

All other parts for this project should be readily available and in fact we bought them all from various suppliers in the London area with no trouble. The knobs used on the prototype give it an excellent finished appearance and are available from Re-An Products Ltd., Burnham Road, Dartford, Kent. The total cost including V.A.T., post and packing for the 6 knobs is £1·84.

When ordering please ask for "6 knobs for the EE *Modula 3 Stereo Amplifier*" and enclose a cheque or P.O. for the above amount.

Lighting-up Warning

No doubt most drivers have at some time or other been "flashed" for not having lights on after dark, and many of us have been stopped by the police for a "friendly" warning. The *Lighting-up Warning* should prevent this ever happening again.

There should be no problems in buying for this project, the only point that may need clarification is that we have not provided a type number for the miniature transistor output transformer. This can be any small type—if the retailer has a number, buy the cheapest. It does not need to be a push-pull type or anything sophisticated, simply a cheap miniature one.

Make sure you order the correct transistors for the polarity you require; check if your car is negative or positive earth before buying for this project.

Morse Practice Oscillator

Just a couple of parts need special mention for the *Morse Practice Oscillator*, they are the morse key and the l.e.d.—the old and the new? The Morse key is available from various suppliers new, however they are not cheap and many army surplus stores will be able to provide a good secondhand one for much less, so have a look around.

The l.e.d. used can be almost any small type but make sure you know which lead is which—ask when you buy it if you are not sure. The case used for the prototype unit was made from three-ply and painted to provide a neat appearance.

Delayed Action Switch

The active device used in the *Delayed Action Switch* is rather special and is not generally available. However, Jermyn are able to supply for a total cost of 58p including postage and V.A.T. Send your cheque or P.O. to Jermyn, Cash Sales Dept, Vestry Trading Estate, Sevenoaks, Kent.

Most 12V relays with the required contacts will operate in this device, the minimum coil resistance is given. The main point is to make sure the contacts are capable of switching the required current, e.g. for a 200W 240V bulb use 1 amp contacts, for car headlights use 10 amp d.c. rated contacts.

The case for this device can be any small plastic box that will hold the relay, and a power supply if mains operation is required.

"Your self-controlled electronic lawn mower has just been spotted on the M1 heading for Birmingham at 70 m.p.h."

BEGIN HERE

PART THREE INTEGRATED CIRCUITS

By DONALD MAYNARD

EVERY week, it seems, designers find more and more uses and applications for integrated circuits. As their name implies, integrated circuits (i.c.s) are devices that contain within one package, a large number of active and passive components. In fact, with the latest large scale integration, many thousands of components can be accommodated on one chip a few millimetres square. The problem then becomes, not "how much can you cram into such a small space?", but rather "how do you obtain access to all the points in the circuit that you require?". There are three main divisions of i.c.s that we will look at—digital, linear and hybrid types.

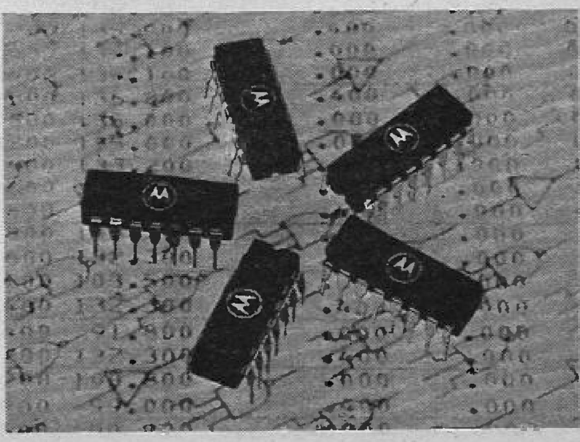
DIGITAL I.C.s

Digital i.c.s operate on the presence or absence of certain voltages, usually in the form of pulses. While many different conventions are possible when considering the states of conduction and non-conduction of the circuits, the following (positive logic) is the arrangement that a lot of i.c.s use. All positive voltages above about 2 volts are called logic "1", and voltages below about 0·8 volt, including all negative voltages, are logic "0". The operation of the circuits is then described in terms 1s and 0s. When interfacing with other circuits, care should be taken that the voltages present are suitable for the i.c.s used. In some cases, for example, a "1" may be a negative voltage while a "0" is around zero volts and any positive voltage (negative logic).

The circuit within the integrated package can take many forms. The early digital integrated circuits used direct coupled transistor logic (DCTL) which had the disadvantage that, within the package, one of the transistors could tend to "hog" most of the current. Later, integrated circuits were produced that were based on discrete component arrangements in early computers. They used diode-transistor logic (DTL). Its immunity to faulty operation due to noise was good although they were rather slow in operation.

Today, by far the most common type of i.c. in the digital field is the family of transistor-transistor logic (TTL). This is the best compromise for high noise immunity, large feeding capability (fan out), small propagation delay (time taken to transfer information from input to output), and cost. This last, the cost, makes the TTL family of i.c.s ideal for the home

Some Motorola 14-pin dual in line i.c.s.



constructor. In addition, for the low outlay, you get a circuit that is small, reliable and capable of high circuit complexity with high performance to go with it. Often these i.c.s are called the 7400 series because this series of numbers is common to many manufacturers' designations.

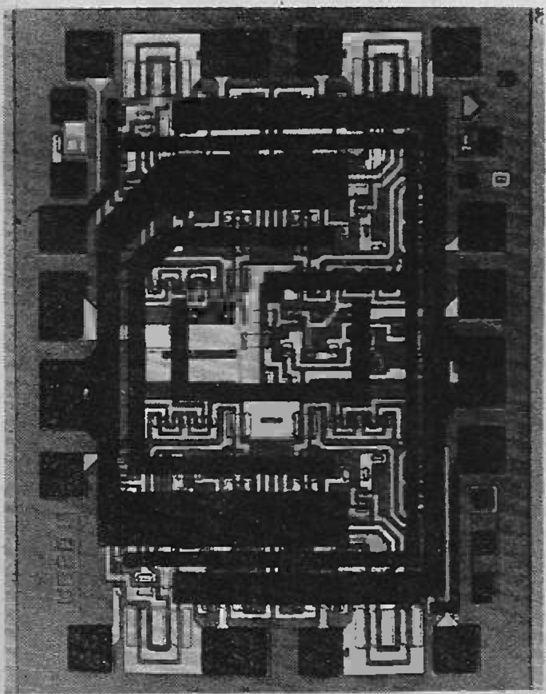
When very fast operation is required a different sort of circuit is used, called either emitter coupled logic (ECL) or current mode logic (CML). In this arrangement the transistors do not saturate (i.e. they do not switch hard on). The time taken to go from the "on" state to the "off" state is therefore much less. Propagation delays down to 1nS (one nanosecond) are possible.

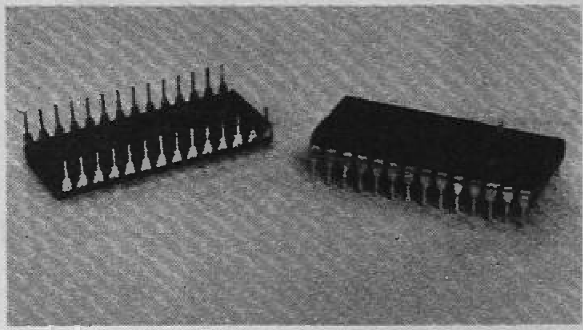
In recent years devices employing large scale integration (LSI) have come onto the market. They use metal oxide semiconductor (MOS) material as their basis. Typically this enables 5,000 component devices to be accommodated on one chip 4mm square. The LSI of these i.c.s makes them ideal for data handling, computer memories, delay lines, calculators and display system applications.

LINEAR I.C.s

Linear i.c.s are available for carrying out a number of different functions. Let us first look at the operational amplifier. This is a circuit having very high gain, high input impedance, low output impedance and wide bandwidth. It usually has two inputs, one the non-inverting

A much enlarged photograph of an i.c., the Signetics 10125 which employs ECL.





Examples of LSI. The Texas TMS0017 "number cruncher"—a sort of mini computer.

input, the other the inverting input, designated "+" and "−" respectively. The device amplifies the voltage between these two inputs. While the open circuit gain of the op. amp. may be as high as 200,000 operation in this mode would be highly unstable. The gain and frequency response of the final circuit is determined by external components. Operational amplifiers can be used for straightforward amplification or they may be used to carry out mathematical functions including differentiation and integration.

COMPARATORS

Comparators are also circuits which have two inputs. The output switches to one of two states depending on the relationship between the two input voltages. It is similar to the operational amplifier in that it has gain. Differences of less than a millivolt at the inputs are translated into a change of volts at the output.

Then we have the many integrated circuits that are made for specific applications. There are audio amplifiers, intermediate frequency and radio frequency (i.f. and r.f.) amplifiers, video circuits and many others. It is not possible in this article to include details of i.c.s, but information is available in many magazines, books and manufacturers' data sheets.

HYBRID I.C.s

Hybrid microcircuits use a combination of conventional i.c. manufacturing techniques together with thin-film and thick-film deposition. Deposition allows passive components with relatively high values of resistance, inductance and capacitance to be incorporated in the package. With conventional manufacture, only semiconductors and resistors are easy to produce. The Japanese seem to be well to the fore in offering hybrid circuits for audio applications. The *Modula 3* audio amplifier featured in this issue uses two Japanese hybrid amplifiers for its main amplifiers.

Some manufacturers will even undertake to produce a custom design for a particular requirement. The packaging of hybrids takes many different forms and it is best to consult manufacturers' data sheets for pin allocations and heat sink requirements etc.

I.C. PACKAGING

There are three main types of integrated circuit packaging. Fig. 3.1b shows a 14-pin dual-in-line package but this is also available in 8, 16 and 24 pin configurations. Pin numbering is always anticlockwise when looking down on top of the i.c. The first pin, anticlockwise from the inlet semicircle is number 1. The flat-pack numbering (Fig. 3.1c) is also anticlockwise from on top, starting from the T-shaped pin or the spot.

Finally there is the TO-5 type of encapsulation shown in Fig. 3.1a. This looks like a transistor except that it has 8 or 10 leadouts coming from it. Pin numbering is clockwise looking at the bottom with pin number 8 or 10 nearest the pip on the can, depending on whether it is an eight or ten-lead package.

Sometimes i.c.s, especially the linear ones, are manufactured in both 8 pin and 14 pin dual-in-line packages. The 8 pin version can then be put physically onto a printed circuit board designed for the 14 pin type. Pin holes 3 to 6 and 9 to 12 (of the 14 pin design) will be the only ones occupied by the 8 pin package.

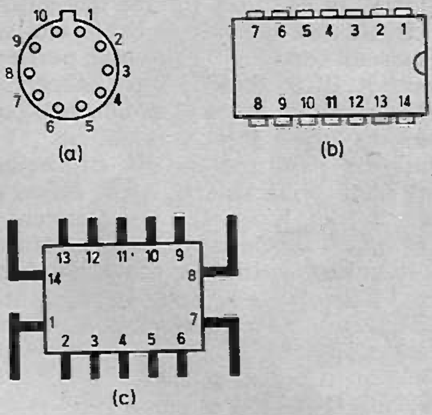


Fig. 3.1. The three most common types of i.c. packages.

Next month: circuit construction.

...Counter Intelligence

BY PAUL YOUNG

A retailer discusses component supply matters.

The other day a customer came into our shop, clutching a small pocket portable. He wanted a small earphone to plug into his radio. As he had no idea what impedance was required, I tried my entire stock from 10 ohms to one kilohm. The difference between them was negligible.

What goes for earphones would also apply to speakers excluding perhaps hi fi and those handling large wattages. If speaker and earphone impedances are not critical, when it comes to potentiometer, resistors and capacitors the tolerances can be even greater.

MESSAGE

This is the message I have been hammering home ever since the inception of this column in the hope that the designers of the articles would give wider parameters, and you, the constructor would make substitutions if necessary.

Sometimes I think the designers are responding; I did the other day, when I saw among the list of components "Speaker 30 to 100 ohms", but alas it was just a flash in the pan! In the end I think it will be you the experimenter who will solve the problem, and by way of a start let me suggest you try the following.

OLD PROJECT

Take one of your finished projects, preferably one that you have no further use for and do not mind spoiling, and change the value of the components and observe the effect. Something in the nature of a radio circuit would offer the best scope. Concentrate on the resistors first. Using the well known Ohm's law formula, work out the wattage dissipated by each one. In most cases it will be negligible.

If you have in your junk box a few spare potentiometers, select one of a slightly higher resistance than a particular resistor in the unit, and provided the wattage dissipated across it is less than $\frac{1}{2}$ watt, replace it with the pot and you will be able to judge how far the results are affected by changing the value.

If you have no potentiometers, use a few fixed resistors, first increasing the value by 25 per cent, 50 per cent, 75 per cent and then decreasing it by the same amounts.

The same treatment can be applied to the capacitors as long as you make sure that the ones you are using are of sufficient voltage.

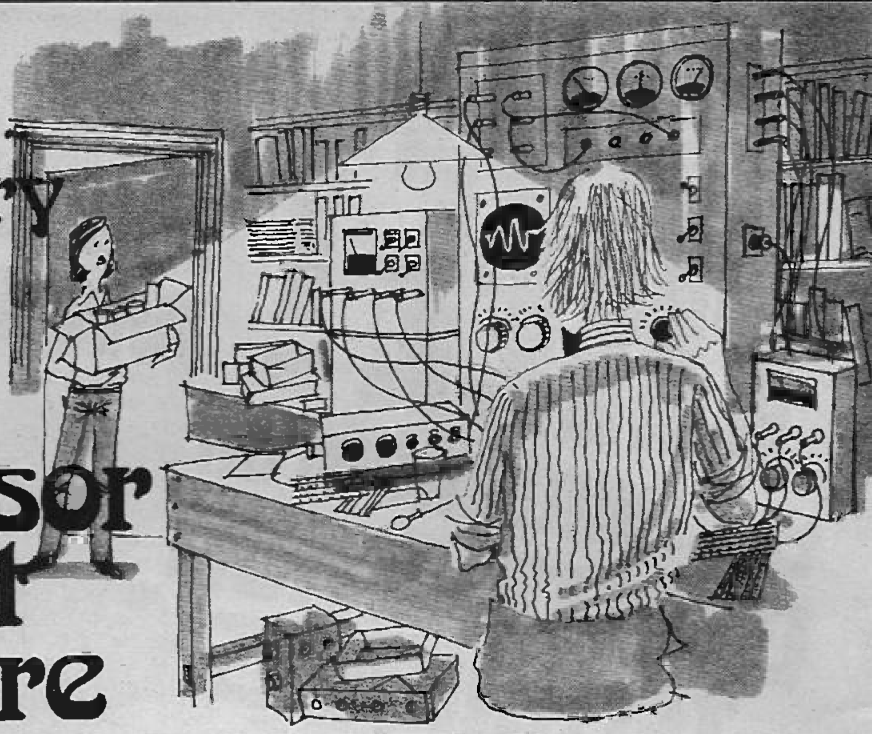
Next try different value potentiometers in place of the existing ones, but do not substitute log. for lin. types or vice versa or you will get some odd results.

Finally if you have a few speakers of different impedances, try them to see what difference they make. I think having carried this out you may be astonished at how little the results are changed by these alterations.

VALUE

The value of this experiment, is, that it will give you far greater confidence and next time you need a 100 kilohm resistor and have run out, instead of tearing down to the shops you will simply select an 82 kilohms or a 120 kilohms knowing that nineteen times out of twenty it will work just as well. Just think of the possible frustration you will avoid in the future.

The Extraordinary Experiments of Professor Ernest Eversure



by Anthony John Bassett

Professor Ernest Eversure, or the Prof. as his friends call him, has been experimenting in electronics for more years than anyone can remember and we thought that you might like to hear of, and perhaps repeat, some of his extraordinary experiments. Anthony J. Bassett will be recounting some of the experiments every month so why not follow the Prof's work and learn along with young Bob, his friend.

THE Prof. was seated before a huge panel covered in meters, oscilloscope displays, controls and coloured flashing lights. On each side of him were more panels covered with an amazing variety of gadgets. The robot fussed around in the background, making alterations and connections to some of the equipment, and occasionally communicating with the Prof. in a code of clicks and whistles as results and measurements were obtained.

This fantastic scene was the setting for one of the Prof's remarkably complex, and fascinating experiments, but when one particular lamp began to flash, the Prof. left his robot assistant to continue the preparations. The Prof. knew that he had a visitor, and he could see on his monitor screen that it was his young friend Bob, just arriving to do some experiments in the laboratory. He and the Prof. were hoping to make some experimental microphones, a gramophone pickup, and maybe some other types of vibration pickups.

"Hi, Prof." Bob greeted the Prof. as he entered, and proceeded to deposit a strange collection of oddments on the nearest available workbench.

"Hallo there, Bob," replied the Prof., "I'm glad to see that you were able to bring all the parts we'll need."

He examined the things which Bob had brought. Most of them did not look like electronic components at all, but a strange collection of bottles, plastic jars and beakers, and a variety of thin sheets of paper and plastic wrapping-foil. With these were a few resistors and capacitors, and a 9 volt battery.

"How on earth do we make microphones from these things, Prof.?" asked young Bob in puzzlement.

"The microphones which we will attempt to make," explained the Prof., "consist basically of thin, lightweight sheets of paper or plastic foil, which vibrate whenever sound waves strike them. Each thin sheet is stretched across the mouth of a container. A line is drawn across the sheet using either a soft graphite pencil, or a fluid graphite composition, and this makes it sensitive to sound waves. Each graphite line is attached at both ends to wires, and sounds can be picked up, amplified and either recorded on a tape-recorder or heard directly from a loudspeaker."

The Prof. drew a sketch showing how a simple microphone can be constructed, his drawing is shown in Fig. 1. A thin piece of paper is pasted carefully across the mouth of a plastic container. A graphite line drawn across the paper acts as a conductor of electric current, as described by the Prof. in earlier experiments, and it is this line which is sensitive to vibrations. The resistance of the graphite line varies as the paper is vibrated by sound waves.

A SIMPLE EXPERIMENTAL MICROPHONE

Young Bob decided to start right away and make his first trial model. He selected a plastic beaker, placed it open end down on a piece of thin paper, and marked the circular outline of the beaker on the paper. Then he drew a slightly larger circle to give a border of about 8mm round the first. With a sharp pair of scissors, he cut out the larger circle, and cut out a number of

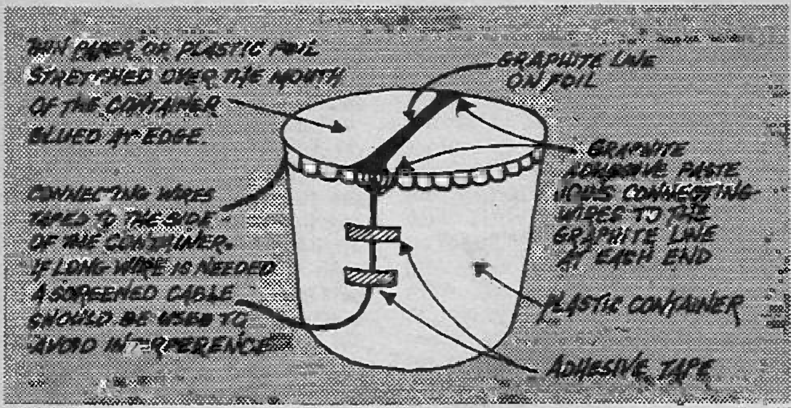


Fig. 1. The basic microphone arrangement

V-shaped notches from the larger to the smaller circle at intervals of about 8 mm to give a piece of paper shaped like Fig. 2.

"What resistance should this microphone have, Prof.?" he asked.

"Almost any value could be used," replied the Prof., "But very high or low values could be troublesome. To start with, I suggest you try about 10 kilohms."

Using a soft graphite pencil (about 5B), Bob carefully rubbed graphite onto the paper to produce a wide, dense line right across the paper disc. He used a multi-meter to measure the resistance of the pencil line by laying the probes of the multi-meter onto the ends of the pencil line.

The resistance was higher than 10 kilohms, so Bob rubbed some more graphite onto the paper until the resistance was about right.

Turning the paper disc over, so that the graphite was on the underside, Bob placed a small smear of contact adhesive on each of the tabs round the edge of the disc, and also round the outer edge of the beaker. He also glued a ball of cotton wool to the inside of the beaker (Fig. 3).

When the adhesive became tacky, Bob carefully glued the paper disc to the top of the beaker, folding down the tabs at the edge of the disc so that the disc was slightly taut, and firmly fastened to the beaker. Then he taped two flexible insulated wires a few inches long to the sides of the beaker. The wires were bared near the ends, and he glued the bared ends to the ends of the graphite line on the paper, using a thick paste of glue and graphite.

This paste can be made by mixing powdered graphite with adhesive gum or thin varnish, and serves both to attach the wire to the graphite line, and to form an electrical connection.

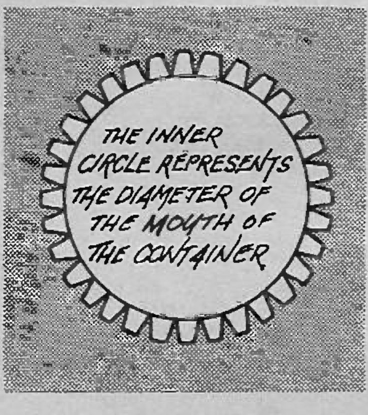
Whilst waiting for the paste to dry on the first microphone, Bob cut out a further quantity of discs to suit some of the other containers which he had brought. Some of the discs were made from thin paper, and for others he tried using thin plastic wrapping-foil, see-through cooking foil, and similar sheet materials such as polythene, and thin rubber cut from a balloon.

He attached these discs to the various containers, and soon had a row of experimental microphones of many shapes and sizes waiting to be tested. Some of these used straight graphite lines, and others were zig-zag (Fig. 4). For some, the lines were made with a soft graphite pencil or a lump of pure Artist's graphite, and for others, the graphite lines were painted on using a composition of graphite and varnish.

Bob then consulted the Prof. about the connection between the microphone and the amplifier.

"This type of microphone can easily be connected to most types of audio amplifier, and either valve or transistor amplifiers can be used. With some amplifiers a pre-amplifier might be needed," said the Prof., "However, a carbon microphone like this needs to be activated in use by means of a small electric current, and for this purpose it is convenient to use a simple energiser circuit."

Fig. 2. Disc shape used for Fig. 1



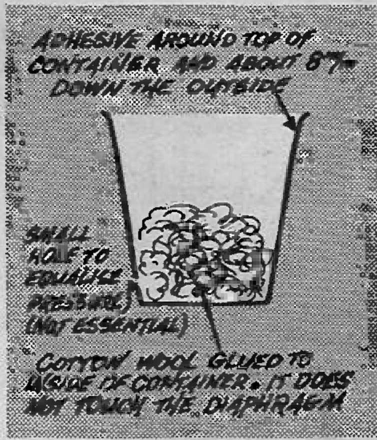
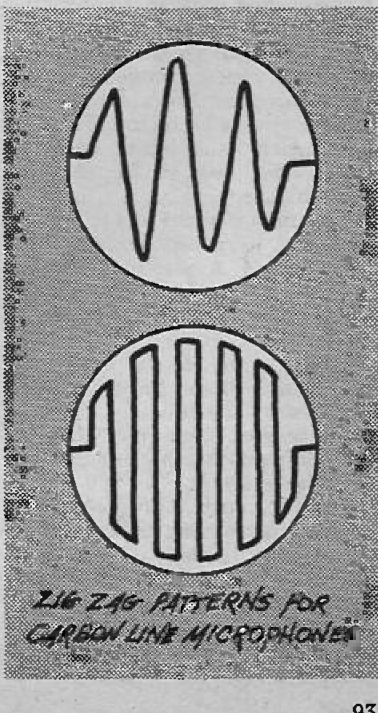


Fig. 3. Container arrangement

ENERGISER CIRCUIT

The Prof. drew the circuit diagram (Fig. 5) for a simple energiser consisting of a battery, two resistors, and one capacitor together with an on/off switch.

Fig. 4. Zig-zag graphite lines



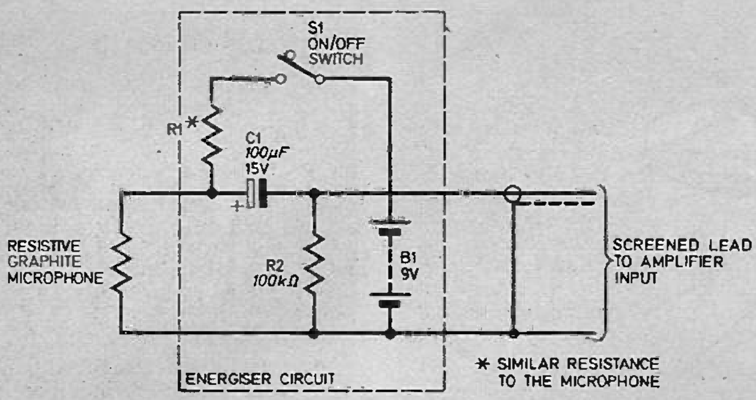


Fig. 5. The circuit diagram of the energiser used for the experimental microphones.

Using a piece of miniature tagboard, Bob soon built the energiser circuit and connected the microphone. Then by way of a length of screened audio cable, he prepared to connect the output of the microphone to the high gain input of an audio amplifier.

"Before you switch the microphone on," said the Prof., "Turn down the volume control on the amplifier, so that the switch-on does not produce a loud noise from the loudspeaker."

Bob connected the screened cable from the output of the energiser to the amplifier, switched on, then gradually turned up the volume.

Meanwhile the Prof. had also been busily making experimental microphones similar to, but not identical with those made by Bob. The microphones which the Prof. produced were somewhat more elaborate than Bob's simple prototype, and some of the materials used, such as graphite emulsion type 568C, had to be specially ordered.

The microphones made by the Prof. are, like those made by Bob, based upon a plastic container such as a tumbler or small jar. The container should not be of plastic which is very soft or thin, as this might easily bend and cause the diaphragm to wrinkle and distort. Fortunately, suitable containers of more rigid material are readily obtainable from household goods stores.

The Prof. used a fine saw to cut out and remove the middle section of a plastic tumbler, as shown in Fig. 6, so that the bottom section could slip through the top section. He smoothed the cut edges using and file and some sandpaper, and glued a strip of tissue paper about 25 x 12 mm over the edge of the bottom section. Then he used electrically-conducting graphite emulsion paint type 568C to paint inside both top, and bottom sections of the tumbler to provide an electrically-conducting screen over the inside of each. He also painted over the tissue-paper strip to form a connecting tab on the outside. (With some types of plastic it may be necessary to sandpaper the surface or to apply a primer paint before using type 568C conducting paint).

The conducting paint dried very rapidly, and the Prof. then glued a layer of sound-absorbing material (thick felt or BAF wadding is suitable) to the bottom of the tumbler. He cut out, very carefully, so as not to damage or wrinkle the delicate material, a disc of thin plastic film (100-gauge polythene, thin see-through cooking-foil or wrapping foil are suitable), and cut a series of V-slots in the edge as shown in Fig. 2. After making a small hole in the side of the container, the Prof. glued the disc over the mouth of the lower section in just the same way Bob had glued his paper version earlier.

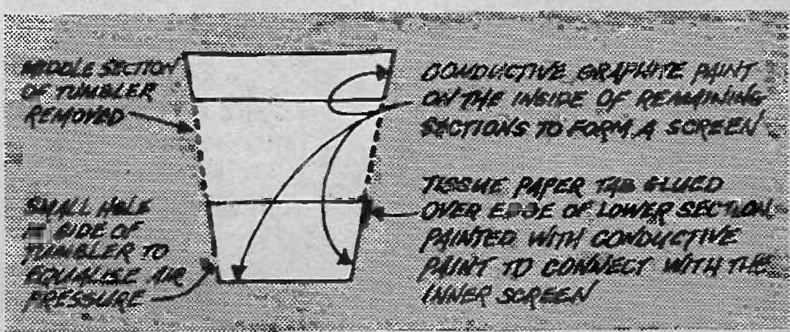
The Prof. glued two further pieces of tissue paper, each about 10 x 20mm to opposite sides of the tumbler, so that one of them overlapped the larger strip he had applied earlier, and one end of each strip projected over the top surface of the plastic disc for a distance of about 3mm (see Fig. 7). He used a small paintbrush to cover these strips with 568C graphite paint to form conducting tabs, so that one of these contacted the tab of tissue which connected to the inside screen. He then painted a line of graphite from one tab, across the diaphragm, to the opposite tab. This line forms the sensitive graphite pickup.

If the 568C paint does not adhere to the plastic film directly, it may in some cases be necessary to key it on. This may be done by rubbing the surface very gently with a grease-removing solvent or some acetone, or by roughening it slightly with fine scouring powder or other very fine abrasive. Then apply a very thin smear of gum adhesive before using the 568C paint.

Now it only remained to attach the connecting wires to the microphone before fitting the top grille and surround. The Prof. bared the end of a length of single-screened miniature audio cable for a distance of about 10 mm, and soldered a length of stranded flexible wire to the outer braid, sufficient to run a half way around the outer edge of the container.

He attached the screened cable to the side of the container, near to one of the tissue-paper tabs (not the one which connects

Fig. 6. The Prof's more complex microphone. The top section of the beaker is cut to fit over the lower section.



directly to the inner screen) using quick-set epoxy or contact-adhesive, and further securing it with P.V.C. plastic adhesive tape. Next he ran the length of stranded wire round to the screen tab to connect both the inner screen, and one end of the graphite line, to the outer braid of the audio cable. The stranded wire was held in position around the edge of the container using contact adhesive, and connected to the tab by a dab of 568C paint. The inner wire of the audio cable was similarly connected to the other end of the graphite line by a dab of 568C paint.

GRILLE AND SURROUND

The grille consists of a disc of wire mesh (obtainable from engineers suppliers for use as oil filters and similar purposes) cut to size which will just fit inside the mouth of the top section of the tumbler. The edge may be bent under, with care, to give a good appearance and freedom from sharp projections. A piece of dark-coloured cloth or thin felt is glued to the underside of the mesh, using only a small amount of adhesive around the edge and a few small dabs elsewhere to prevent sagging.

In order to fit the grille and surround, the surround (which consists of the top half of the tumbler) is first passed over the screened lead, then over the lower section and into position as shown in Fig. 7. It is wedged into place by means of a number of small pieces of Balsa wood or similar material. These are painted with 568C paint to connect the screen on the surround to the outer braid of the screened lead, and to the stranded flexible wire around the edge of the inner section.

Before applying the 568C paint, the Prof. carefully adjusted the wedges so that the surround was concentric with the remainder of the microphone. He popped the wire grille into the top of the surround and sealed it carefully into place with a neat bead of white flexible sealing compound or silicone rubber sealant (this can be obtained from d.i.y. shops for sealing around baths, etc.).

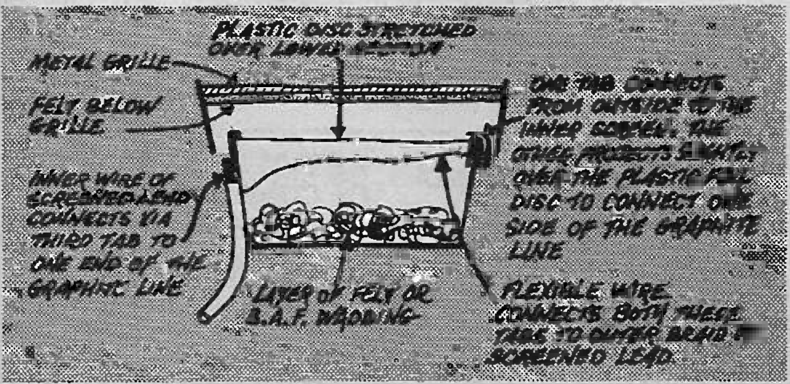
Then to put the finishing touch, he applied a further quantity of white sealant to fill in beneath the lower edge of the surround.

While the Prof. had been constructing his microphone Bob was getting ready to test some of his. He placed one of the microphones he had made a near to a ticking clock, and the sound of the clock could be heard quietly through the loudspeaker. As Bob altered the volume control, the ticking became louder, and it was obvious that the microphone was picking up the sound of the clock very effectively.

Turning down the volume-control on the amplifier, he then disconnected the energiser from the amplifier, and substituted another of the microphones. As Bob tried a few of the microphones, in some cases changing R1 to match the resistance of the microphone, he noticed that the tone quality of each microphone was different. Some made the ticking of the clock sound deep and boomy, others made it sound light and sharp. Even though the same amplifier and clock were being used, the tone was different.

Bob looked around for the Prof., but could not see where he was.

Fig. 7. The complete microphone as constructed by the Prof.



He picked up the microphone and shouted: "Prof., where are you?"

"Over here came the Prof's reply in a loud, rather strange-sounding voice. Unknown to Bob, the Prof. had taken his microphone and rigged it up with another energiser circuit, amplifier and loudspeaker at the other end of the laboratory. Now they communicated with each other from one end of the lab. to the other, by way of the microphones!

"Why is it," asked Bob, "that each of these microphones has a different tonal sound?"

"This is because of the differences between the sizes of the cavities associated with the microphones due to the different containers you have used," the Prof. replied, "and also there are differences in the diaphragms. I notice that you have "damped" some of the the microphones by the use of sound-absorbing materials such as cotton-wool or felt, and these tend to sound more natural."

While the Prof. was speaking, the Robot came into view, and began to communicate with him in its strange code of clicks and whistles. Bob began to experiment with the controls of the amplifier and a moment later the peaceful atmosphere of the laboratory was shattered by a series of loud crackling noises and ear-splitting shrieks of acoustic feedback!

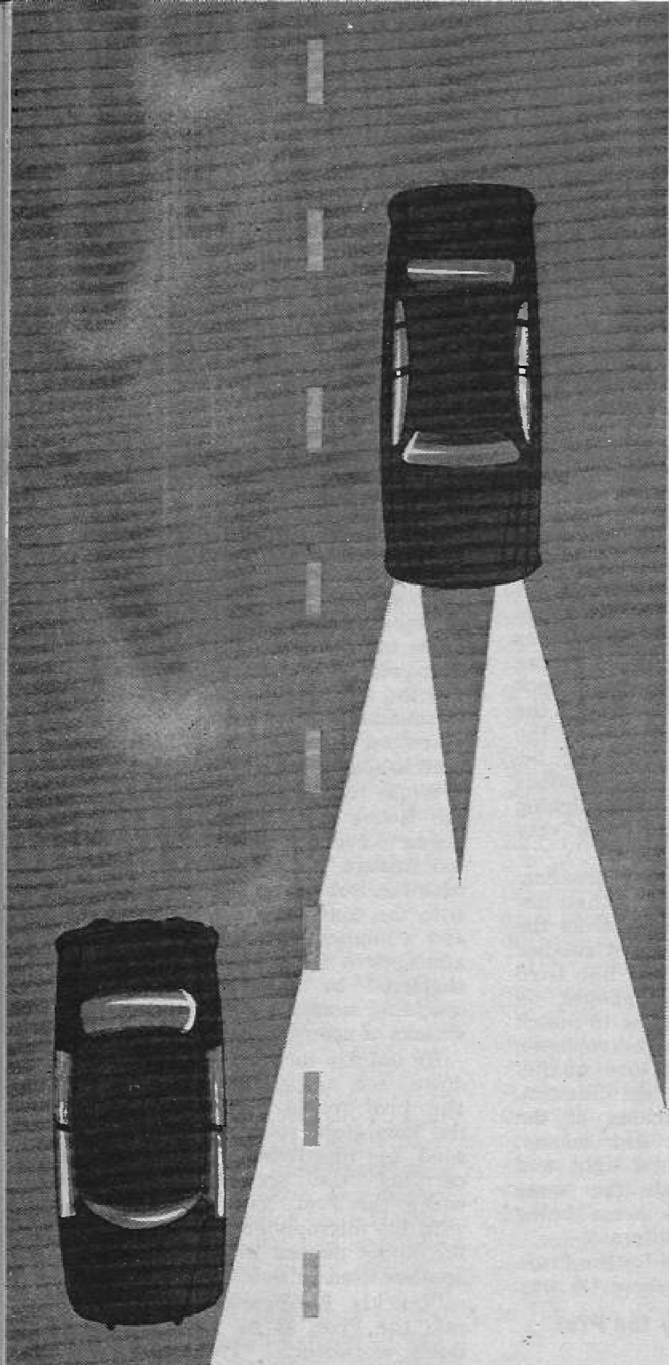
He quickly turned the amplifier down, and as he did so, he saw the Prof. come running across the laboratory towards him, pursued by the Robot, which was carrying the speaker cabinet which the Prof. had been using with his microphone. On its way, the Robot paused to pick up the speaker used by Bob.

"Quickly, Bob, come with me," said the Prof. as he sped up to Bob's workbench, "Those noises you just made overloaded the Robot's communicator circuits, and I cannot communicate with him! He thinks that those speaker cabinets are our voice-boxes, and is coming to put them in their 'proper' places!"

"What!" exclaimed Bob in horror, "Does the Robot intend to cram those speaker cabinets down our throats?"

He put on an extra spurt of speed as he and the Prof. passed rapidly through the laboratory exit, followed closely by the Robot carrying two wooden cabinets!

Continued next month.



Lighting-up Warning

FOR THE MOTORIST

By DAVID SMITH

Audible warning is sounded as lighting-up time approaches.

Every year, motorists find themselves in court being charged with the offence of driving without lights. Even so, such a simple, absentminded mistake can confront the motorist with a heavy fine, even an endorsement. What is required is somebody to keep an eye open for signs of dusk and then to warn the driver to switch on his lights.

This is done for you electronically with the device described here. It's a simple device which produces an audible warning as dusk approaches; this alerts the driver that it's lighting up time and when he switches on his lights he automatically switches off the audible warning.

A built-in refinement stops the device operating under dark bridges etc. The driver may if he wishes delay the device from operating for up to 10 seconds, which would get him well past an average bridge.

CIRCUIT DIAGRAM

The circuit diagram for the Lighting Up Warning is shown in Fig. 1. The heart of the unit is composed of TR1, PCC1, VR1 and R1. For the moment ignore the presence of PCC1, whose ohmic value varies from about 100 ohms to about one megohm in bright and dark conditions respectively.

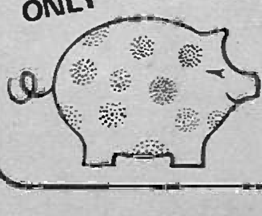
As the ignition is switched on, with S1 on, current flows through R1 and VR1 charging up capacitor C1. The time taken to charge up C1 is controlled by the setting of VR1. It is seen from Fig. 1 that PCC1 is in parallel with C1 and under "light" conditions the capacitor discharges through this parallel low resistance and TR1 does not turn on. As darkness approaches, the ohmic value of PCC1 rises until ambient conditions (lighting-up time) allow the capacitor to charge up sufficiently to turn on TR1.

Transistors TR2 and TR3 and associated components form a simple astable multivibrator producing an audible frequency that is coupled via transformer T1 to the loudspeaker LS1.

When TR1 is switched on, its collector, and hence the emitters of TR2 and TR3 are at approximately 12 volts.

FOR GUIDANCE ONLY

ESTIMATED COST* OF COMPONENTS including V.A.T.



£2.70

excluding case

*Based on prices prevailing at time of going to press

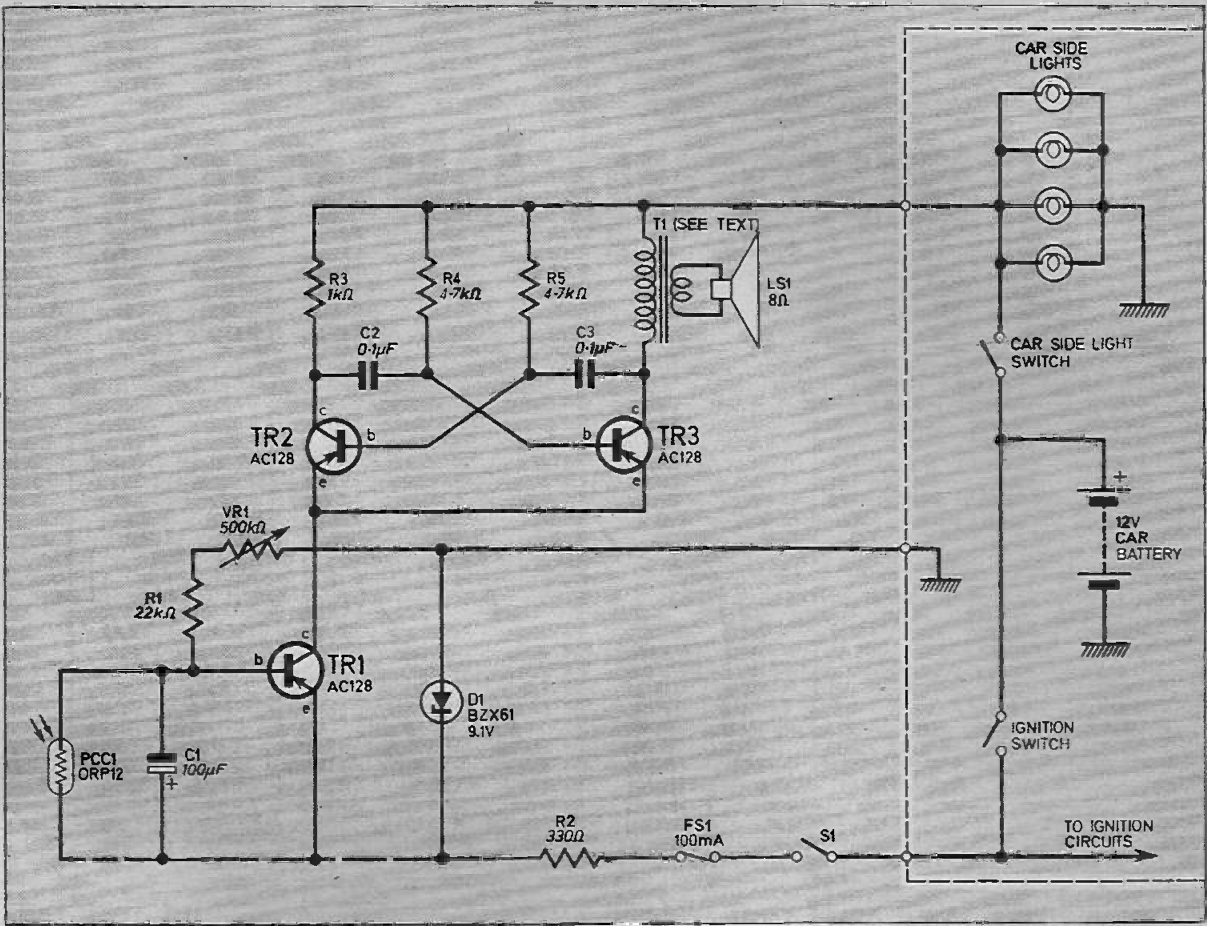


Fig. 1. The circuit diagram of the Lighting-up Warning device showing wiring to car electrical system.

The negative supply rail is derived through the car side lights to chassis while the lights are switched off; when the latter are switched on, a positive voltage is applied to the negative supply rail to the multivibrator of the same magnitude as that on the emitters of TR2 and TR3. Consequently the oscillations cease.

Potentiometer VR1 controls the charging up time of capacitor C1 so that bridges and other obstacles can be negotiated without the audible alarm being triggered.

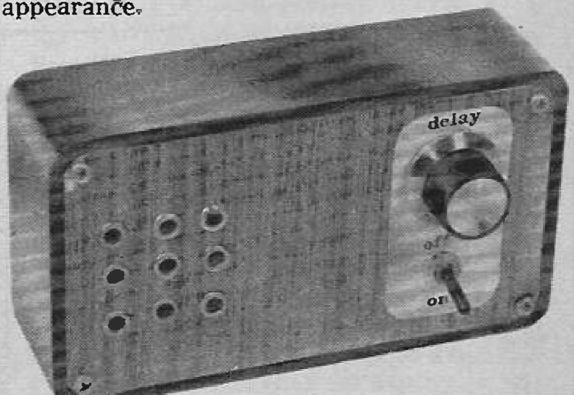
Resistor R2 and Zener diode D1 provide voltage stabilisation to the circuit. The unit may be switched off at S1 if required; a fuse has been added for safety.

The circuit components shown in Fig. 1. are for negative earth systems only. For positive earth systems, change all the transistors to type AC127 and reverse the polarity of C1 and D1.

CONSTRUCTION

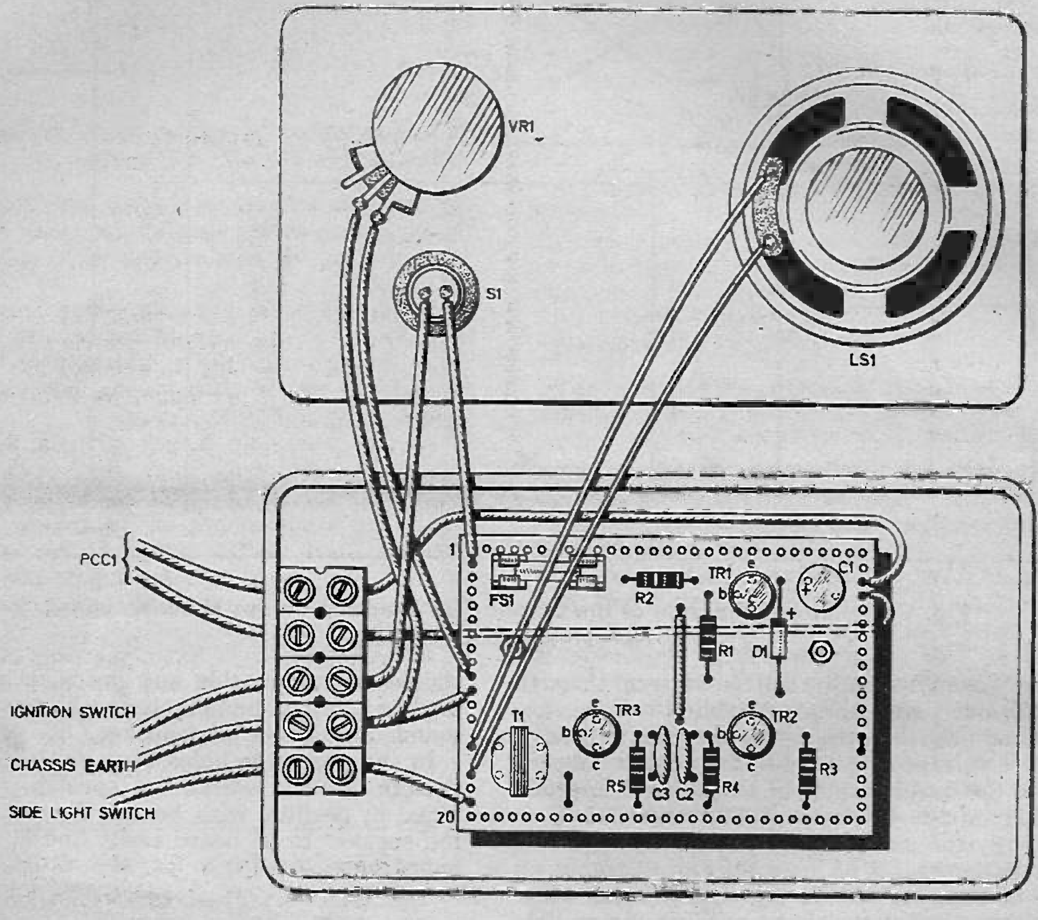
The prototype unit was housed in a commercially available fibreglass case approximate dimensions 130×70×40mm. The front panel should be removeable and prepared to accommodate the potentiometer VR1, the on/off switch, S1, and the loudspeaker LS1.

In the prototype holes were drilled and brass eyelets inserted where the speaker was to be glued in position with Bostik. This is to enable the speaker to be heard easily and gives a neat appearance.



The completed prototype showing details of front panel.

Lighting-up Warning



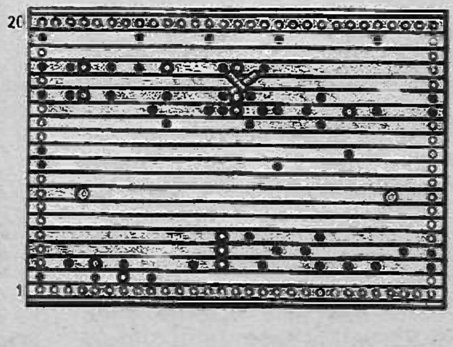


Fig. 2. The layout of the components within the case and full wiring up details. Also shown is layout of components on topside of Veroboard and breaks in copper strips on the underside.

Components....

SEE SHOP TALK

Resistors
- R1 22kΩ
- R2 330Ω
- R3 1kΩ
- R4 4·7kΩ
- R5 4·7kΩ

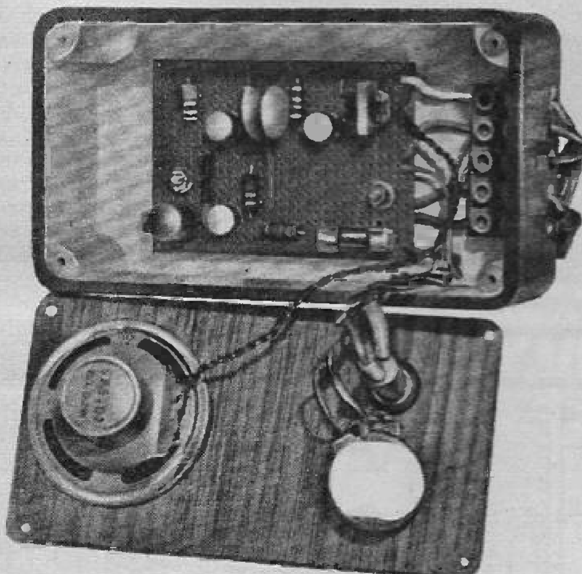
All ½ watt carbon ± 10%

Capacitors
- C1 100μF 12V elect.
- C2 0·1μF
- C3 0·1μF

Semiconductors
- TR1 AC128 germanium *pnp* } see text
- TR2 AC128 germanium *pnp* } see text
- TR3 AC128 germanium *pnp* } see text
- D1 BZX61 9·1 volt 400mW Zener diode
- PCC1 ORP12 light dependent resistor

Miscellaneous
- VR1 500kΩ lin. carbon
- S1 on/off toggle switch
- FS1 100mA fuse with p.c. type holder
- T1 miniature transistor radio output transformer

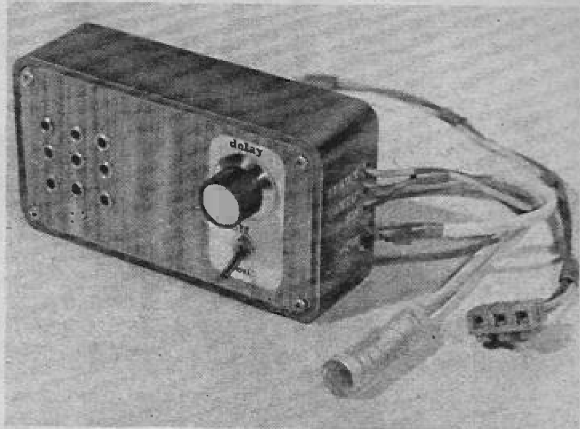
Veroboard: 0·1in. matrix, size 30 holes by 20 strips; 5-way terminal block; knob; case; brass eyelets; twin flex and wire.



A view of the prototype unit with lid removed.

The remainder of the components are mounted on a piece of 0·1in. matrix Veroboard, the layout and cut-outs to be made are shown in Fig. 2. Make the cut-outs and assemble and solder the components as indicated.

Five holes should now be drilled in the end



The completed prototype ready for installation showing sensor and connector.

of the case so that they align with the terminal block glued to the base of the case. Wiring up should now be carried out with reference to Fig. 2.

When complete, the component board should be secured to the base of the case by means of some small nuts, bolts and shakeproof washers; next label the front panel as indicated in the photograph and fit the knob.

Solder a suitable length of twin flex to the l.d.r. and wrap the joints and device with a couple of layers of insulating tape. Do not obscure the front window of the device. The l.d.r. can be glued in the corner of the windscreen using a thin smear of clear Bostix over its front face . This was found not to impede the passage of light.

All that remains is to connect the l.d.r. flex to the terminal block in the unit and wire in to the car ignition and side light switch and a good earth point on the chassis. Secure the lid and place the unit in a convenient position within the car. ▣

Harmonics

I am told that square waves are made up of several sinewaves.

If one makes a multivibrator one generates square waves but where do the sinewaves come from?

This is a terribly difficult question to answer in a short space and in simple terms, however we appreciate your problem and will try to give a simple explanation. We have to refer back to a man named Fourier who proved that any repeating waveform of a cyclic nature could be synthesised by adding together the voltages of individual sinewaves at identical points of time. The stipulation of his theory was that the individual sinewaves had to have a precise harmonic relationship and be of known phase.

Provided the waveform that needed to be synthesised was perfectly cyclic (i.e. after a certain period of time it repeated itself in an *identical* fashion) then it did not matter what the shape of the wave was within one basic cycle—it could still be generated from a set of sinewaves. By looking at a complex cyclic wave on an oscilloscope one can usually see the period of the basic repeating cycle; this is called the *fundamental* frequency. To generate the complex signal synthetically we would have to start with a sinewave having this fundamental frequency and then it is only necessary to add to it carefully calculated levels of sinewaves that are twice, three times, four times etc., etc., the frequency of the fundamental. These latter signals are all harmonics of the fundamental.

We have mentioned three orders of harmonics in the above list (which is called a *series*) but in actual fact there is no upper limit; however, in practice if one was to try and carry out a genuine synthesis of, say, a musical instrument one only has to consider the first 8 harmonics. The higher order harmonics tend to define the very small detail of the waveform. The magnitude of each harmonic that is added depends on the shape of the final waveform and relative to the fundamental these can range from zero to many times the amplitude of the fundamental. The factor that gives the relative amplitude of each harmonic is called the *coefficient*.

The major problem in synthesising a waveform is knowing what these coefficients, or harmonic relationships, are. It requires considerably complex mathematics to do what is called Fourier analysis of a wave to work out its components but nevertheless this can be done. For example we now know that a square, or rectangular wave is made up of a fundamental sinewave having identical frequency to the square wave and to this has to be added proportions of the third (times three), fifth (times five), seventh and all further odd harmonics. Even harmonics have zero coefficient and so play no part in a square wave. On the other hand a sawtooth wave contains all the odd and all the even harmonics in controlled proportions.

If one looks at a square wave on an oscilloscope one can cast a critical eye at what we call its rise time (this is the time taken for the leading edge of the wave to get from zero volts to its maximum excursion). The sharpness, or speed, of this risetime is controlled by the higher order harmonic content; if the higher orders are missing the square wave has a curving or slow rise time.

The harmonic content of a square wave is exploited in simple test oscillators in which a multivibrator is made to oscillate at an audio frequency—thus giving out an audio tone for testing amplifiers but the same oscillator can also be used for injecting signals into the radio frequency stages of a radio. In the latter case the radio's tuned circuits are responding to the harmonics of the fundamental audio tone and these must be odd order harmonics.

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By Adrian Hope

THE machine that takes over is by now a science fiction cliché; Stanley Kubrick's film "2001" said it all with HAL, the soft spoken computer that developed a mind of its (his) own. Unfortunately, science fiction clichés have a nasty habit of becoming science fact.

Some electronic intrusions into human life are of course very welcome. Self-seeking car radios (which automatically scan the wave bands and tune in only to good strong signals) leave the driver's hands where they should be—on the steering wheel. And it was the much maligned computer that made possible the design of zoom lenses for cameras and projectors which are so cheap that almost every photographer can now afford them.

Likewise computer techniques made the production of cheap plastic Fresnel lenses a possibility. These flat sheets have a myriad of concentric prism rings cut in their surface, the computer-calculated angling of the rings making the disc either a magnifying (positive) lens or a reducing (negative) lens for wide angle viewing.

COMPUTER WRITES OWN PROGRAMME!

But some recent developments are rather disturbing. A few months ago IBM patented a computer which effectively writes its own programme! The dividing line between computers and humans has so far been fairly clear. Whereas we can programme computers to perform tedious tasks which are so time-consuming that they would be impossible or take a lifetime for us to perform, some tasks are so complicated that we cannot programme a computer to do the job as well as we can.

For instance, computers usually lose at chess because of the programming problems involved. What IBM said in their patent was that although a human can learn to make machine-like decisions, it is difficult to build a machine to make a human-like decision. So the IBM line of approach is now to build a machine which imitates a person who is imitating a machine.

NUMBER PLEASE

If you feel confident that this is all still only theory or science fiction, let me tell you what happened when I tried to phone Washington DC in the USA recently. I was calling a private number in the Georgetown area which for present purposes we will call 338 1234.

Each time I dialled the number I was answered by a female voice which asked "What number are you calling". After putting the question the voice remained silent until I had recited the number. The voice then answered "the number you have called, 338 1234, is a working number. Will you dial 338 1234 again please. This is a recording".

I recorded the voice and a colleague and I are satisfied that although the first query "what number are you calling" may be a human voice, the remaining words are definitely uttered by a machine.

I checked with the London International Exchange and they are only familiar with operator intercepts where the local operator abroad buts in live to say that a number is no longer in service. But "working number" is telephone jargon for a number that is in service so there seems no point in butting in. And sure enough later that night I did get through to the Georgetown number, thereby proving that it was indeed working.

Anyone with an electronically inquiring mind is likely to get shivers down their spine if they think this one through. The only reasonable conclusion is that the Washington exchange now has equipment which can listen to the voice of a caller and then accurately repeat to him the number that he has asked for (probably by reconstituting the number from a bank of pre-recorded digits). The questions to be answered are not only how, but why, this is being done.

COMPUTER TERMINAL

By coincidence at around the same time, I visited an exhibition where the National Development Programme in Computer Assisted Learning was showing how computers could be used to help teachers in schools. The idea is to use a terminal in the classroom linked by telephone lines to a central computer, perhaps miles away.

The exhibition was just drawing to a close and although the computer was due to close down the terminal was still switched through. Sympathetically the exhibitors allowed a passing child to try his wits against the computer.

"Who are you?" typed the child. "Syntax error in command", flashed up the automatic computer response on the TV display above the keyboard. "Are you Santa Claus?" asked the child. "Syntax error in command" flashed the reply. "And the same to you", typed the child angrily. But of course up came "Syntax error in command" again. "It is my birthday today" typed the child in a last desperate attempt at getting through to the machine.

At this moment an odd thing happened. Presumably the computer operator all those miles down the wire was just about to close the machine down and saw what was coming up on the monitor screen at his end. One can only assume that he quickly sat down at his keyboard and switched the computer off automatic response, for up on the screen to the child's delight came back the message "Happy Birthday to you".

DOWN TO EARTH

By GEORGE HYLTON

"My amplifier is designed for a 5 ohm speaker but I have only speakers of 3 ohms and 8 ohms impedance. Can I use one of these?"

You can almost certainly use the 8 ohm loudspeaker, but the amplifier will not deliver full power. Using the 3 ohm speaker might be dangerous.

First, what is it about an amplifier that determines what is the correct load impedance (the speaker is the load in the present instance)? Not the gain, or the supply voltage, or whether it's valve or transistor, but the design of the output stage in the amplifier and the ratings of the valves or transistors in it—that is, how much power and current they can deliver safely, without overheating, or breaking down, or causing severe distortion.

AUDIO GENERATOR

As far as the load is concerned, the amplifier is just a generator of audio power. It might just as well be some other kind of generator, such as an alternator, if all we want to do is explore the effects of different loads. The entire circuit might then, for this restricted purpose, be simplified to Fig. 1.

Here the amplifier is shown as a voltage generator V_s whose internal resistance is R_s. The load (speaker) is R_L. This circuit is a reasonable equivalent, for our purposes, of a class B amplifier.

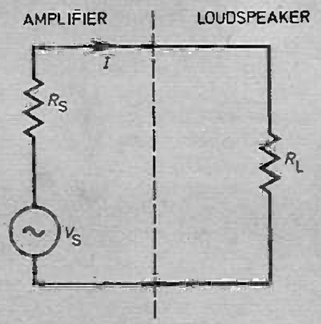

Fig. 1. Equivalent circuit of a class B amplifier.

This crude, oversimplified circuit, plus Ohm's law, tells you that the output current depends on both R_s and R_L.

In practice, of course, you can't reduce R_s because it's inside the amplifier. You can only alter R_L, the external load—the speaker impedance.

It's possible to argue, wrongly, that R_L should be the same as R_s. A well-known theorem of electrical engineering says that if R_L equals R_s you get maximum power. There's nothing wrong with the theorem, but when I tell you that in practical transistor power amplifiers R_s is in the region of one ohm I hope you'll smell a rat. Nobody makes one ohm speakers!

PRACTICAL CASE

What's wrong, then? Simply this: in practical amplifiers, reducing R_L to the same size as R_s causes the output current I to rise far too high for the output transistors. They may be destroyed in the process. So in practice R_L has to be a lot more than R_s. This is no bad thing. It increases the electrical "damping" of the speaker, making it perform better on transients. Less obviously, it increases the efficiency of the circuit.

Look at it this way. If R_L equals R_s, half the power is developed in each resistance. In other words, only half the power reaches the load. The rest is wasted in warming up the output transistors. On the other hand, if R_L is bigger than R_s, a greater proportion of the power is spent in R_L. If R_L equals $9R_s$, only one-tenth of the power is lost in R_s.

It sounds from this as if the original notion that you get maximum output power when R_L equals R_s must be wrong, but it isn't. You see, when R_L is bigger than R_s the total amount of power is reduced. The increasing proportion which gets to R_L isn't enough to compensate for the fall in total power.

SPEAKERS

Anyway, you can now see why it's usually safe to use a speaker of higher impedance than specified. The power output is reduced, which is safe from the amplifier's point of view. However the volume may go down.

If both speakers were equally efficient, the one with the correct impedance would produce more volume than the one whose impedance is too high. But in practice speaker efficiencies vary enormously so the reverse of this may be what actually happens.

In any case, so long as the too-high impedance isn't enormously too high, the audible effect shouldn't be all that great. Doubling the impedance reduces the power by less than 3dB, which is a just easily noticeable drop in volume.

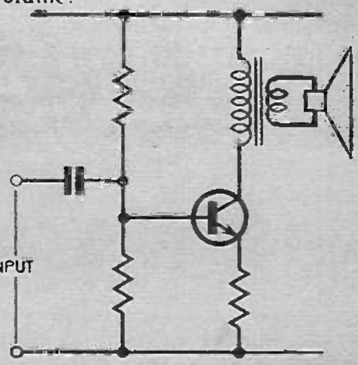

Fig. 2. A transformer driven output stage.

I should now point out that there is one type of amplifier to which the above reasoning does not apply. This is the kind with a very high internal resistance R_s, and is chiefly encountered, these days, as the single-transistor class A output stage of the older types of car radio.

The essential circuit (Fig. 2) shows that the load is driven (via a transformer) by the collector current of the output transistor. Transistor data shows that the impedance, looking back into the collector, is high. The transistor, in effect, pushes a *current* through the load. This would seem to favour a high load impedance, but a limit is soon reached where the current cannot develop enough *voltage* across the load. The voltage is limited by the supply.

look ! electronics really mastered

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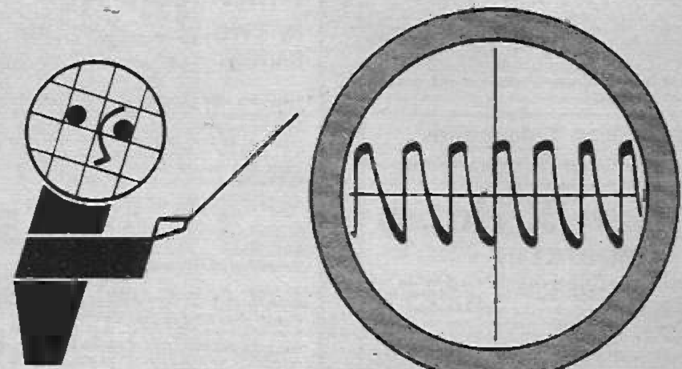

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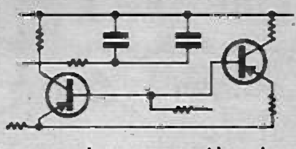

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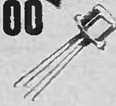

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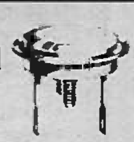

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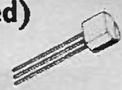

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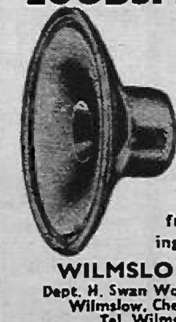

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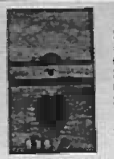

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2N1671A 1·54	2N3702 0·11	40395 0·65	BC107 0·16	BC303 0·54	BF184 0·30	CD4028 2·34	SC45D 1·89
2N1671B 1·72	2N3703 0·12	40406 0·44	BC108 0·15	BC307 0·11	BF185 0·30	CD4029 3·79	SC46D 1·96
2N1671C 4·32	2N3704 0·14	40407 0·33	BC109 0·19	BC307A 0·10	BF194 0·12	CD4041 2·11	SC50D 2·60
2N1711 0·45	2N3705 0·12	40408 0·50	BC113 0·15	BC308 0·12	BF195 0·12	CD4044 2·11	SC51D 2·39
2N1907 5·50	2N3706 0·09	40409 0·52	BC115 0·17	BC308A 0·12	BF196 0·13	CD4047 1·65	SL414A 1·80
2N2102 0·50	2N3707 0·13	40410 0·52	BC116 0·17	BC308B 0·09	BF197 0·15	CD4049 0·90	SL623 4·59
2N2147 0·78	2N3708 0·70	40411 2·25	BC116A 0·18	BC309 0·10	BF198 0·18	CD4050 0·90	TAA263 1·00
2N2148 0·94	2N3709 0·11	40414 3·55	BC117 0·21	BC309A 0·10	BF199 0·18	LM301A 0·48	TAA350 2·10
2N2160 0·60	2N3710 0·12	40430 0·85	BC118 0·11	BC309B 0·10	BF200 0·40	LM304A 2·03	TAA621 2·03
2N2192 0·40	2N3711 0·11	40583 0·23	BC119 0·29	BC237 0·21	BF225J 0·19	LM309K 1·88	TAA661B 1·32
2N2192A 0·40	2N3712 0·96	40601 0·67	BC121 0·23	BC238 0·19	BF237 0·22	LM702C 0·75	TAD100 1·50
2N2913 0·40	2N3713 1·20	40602 0·46	BC125 0·16	BC337 0·19	BF238 0·22	LM709T099 0·48	Filter 0·70
2N2193A 0·61	2N3714 1·33	40603 0·53	BC126 0·23	BC338 0·19	BF244 0·21	8DIL 0·38	TBA271 0·64
2N2194 0·73	2N3715 1·50	40604 0·56	BC132 0·30	BCY30 0·64	BF245 0·33	14DIL 0·40	TBA641B 1·25
2N2194A 0·30	2N3716 1·80	40636 1·10	BC134 0·13	BCY31 0·64	BF246 0·58	LM723C 0·90	TBA800 1·50
2N2218A 0·22	2N3771 2·20	40669 1·00	BC135 0·13	BCY32 1·15	BF247 0·23	LM741T099 0·40	TBA810 1·50
2N2219 0·24	2N3772 1·80	40673 0·70	BC136 0·17	BCY33 0·45	BF254 0·16	8DIL 0·40	TIL209 0·30
2N2219A 0·26	2N3773 2·65	AC107 0·51	BC137 0·17	BCY34 0·49	BF255 0·17	14DIL 0·38	TIP29A 0·49
2N2220 0·25	2N3779 3·15	AC113 0·16	BC138 0·24	BCY38 0·55	BF257 0·46	LM747 1·00	TIP30A 0·58
2N2221 0·18	2N3790 2·40	AC117 0·20	BC140 0·34	BCY39 1·50	BF258 0·59	LM7488DIL 0·60	TIP31A 0·62
2N2221A 0·21	2N3791 2·35	AC126 0·20	BC141 0·29	BCY40 0·87	BF259 0·55	LM7805 2·00	TIP32A 0·74
2N2222 0·20	2N3792 2·69	AC127 0·20	BC142 0·23	BCY42 0·28	BFS21A 2·30	14DIL 0·73	TIP33A 1·01
2N2222A 0·25	2N3794 0·10	AC128 0·20	BC143 0·25	BCY58 0·21	BFS28 0·92	LM7805 2·50	TIP34A 1·51
2N2368 0·25	2N3819 0·37	AC151V 0·25	BC145 0·21	BCY59 0·22	BFS61 0·27	MC1303p 1·26	TIP35A 2·90
2N2369 0·37	2N3820 0·38	AC152V 0·17	BC147 0·12	BCY70 0·17	BFS98 0·25	MC1310 2·92	TIP36A 3·70
2N2369 0·41	2N3823 1·42	AC153 0·25	BC148 0·13	BCY71 0·22	BFX29 0·30	MC1458CP1 0·70	TIP41A 0·79
2N2646 0·55	2N3900 0·21	AC153K 0·25	BC149 0·12	BCY72 0·13	BFX30 0·27	MJ480 0·90	TIP42A 0·90
	2N3901 0·32	AC154 0·20	BC153 0·18	BCY87 3·54	BFX44 0·33	MJ481 1·14	TIP2955 0·93
	2N3903 0·24	AC176 0·18	BC154 0·18	BCY88 2·42	BFX63 2·48		TIP3055 0·60
	2N3904 0·27	AC176K 0·25	BC157 0·14	BCY89 0·97	BFX68 0·30		ZTX300 0·13
		AC187K 0·23	BC158 0·13	BD115 0·75	BFX84 0·24		ZTX302 0·20
		AC188K 0·34	BC159 0·14	BD116 1·00	BFX85 0·30		ZTX500 0·15
		ACY18 0·24	BC160 0·37	BD121 0·75	BFX87 0·28		ZTX502 0·18
		ACY19 0·27	BC167B 0·13	BD123 0·32	BFX88 0·25		ZTX530 0·21
		ACY20 0·22	BC168B 0·13	BD124 0·67	BFX89 0·45		
		ACY21 0·26	BC168C 0·11	BD131 0·40	BFY18 0·52		

Integrated Circuits TTL (SN 7400 Series)

SN7400	16p	SN7410	16p	SN7437	35p	SN7454	16p	SN7484	95p	SN74107	43p	SN74154	1·66	SN74176	1·74
SN7401	16p	SN7411	25p	SN7438	35p	SN7460	16p	SN7485	1·58	SN74118	1·00	SN74155	1·55	SN74180	1·44
SN7401AN	38p	SN7412	28p	SN7440	16p	SN7470	30p	SN7486	45p	SN74119	1·92	SN74157	1·00	SN74181	5·18
SN7402	16p	SN7413	50p	SN7441	85p	SN7472	38p	SN7490	65p	SN74121	57p	SN74160	1·58	SN74190	1·95
SN7403	16p	SN7416	45p	SN7442	85p	SN7473	44p	SN7491	1·10	SN74122	80p	SN74161	1·58	SN74191	1·95
SN7404	24p	SN7417	30p	SN7445	1·59	SN7474	48p	SN7492	75p	SN74123	72p	SN74162	1·58	SN74192	2·05
SN7405	24p	SN7420	16p	SN7446	2·00	SN7475	50p	SN7493	65p	SN74141	1·00	SN74164	2·01	SN74193	2·30
SN7406	45p	SN7423	37p	SN7447	1·30	SN7476	45p	SN7494	85p	SN74145	1·44	SN74165	2·01	SN74196	1·58
SN7407	45p	SN7425	37p	SN7448	1·50	SN7480	75p	SN7495	80p	SN74150	1·44	SN74167	4·10	SN74197	1·58
SN7408	25p	SN7427	45p	SN7450	16p	SN7481	1·25	SN7496	1·00	SN74151	1·10	SN74174	1·00	SN74198	3·16
SN7409	33p	SN7430	16p	SN7451	16p	SN7482	87p	SN74100	2·16	SN74153	1·00	SN74175	1·29	SN74199	2·88
		SN7452	45p	SN7453	16p	SN7483	1·20								

Diodes & Rectifiers

PIV	50	100	200	400	600	800	1000
1·5	0·15	0·17	0·20	0·22	0·25	0·27	0·30
3	0·15	0·17	0·20	0·22	0·25	0·27	0·30
10	—	0·35	0·40	0·47	0·56	—	—
35	0·84	0·92	1·18	2·15	2·52	3·05	4·20

Cathode Stud only IN3766 (35 A 800pv) £3·65. IN3768 (35 A 1000pv) £4·20

IN34A	0·10	BA110	0·25	BY100	0·15	BYZ12	0·30	OA81	0·08
IN914	0·07	BA115	0·07	BY126	0·15	OA9	0·10	OA85	0·10
IN916	0·07	BA141	0·17	BY127	0·17½	OA10	0·20	OA90	0·07
AA119	0·07	BA142	0·17	BY140	1·00	OA47	0·07½	OA91	0·07
AA129	0·15	BA144	0·12	BY237	0·12½	OA70	0·07½	OA95	0·07
BA100	0·15	BA145	0·17	BYZ10	0·35	OA73	0·10	OA200	0·07
BA102	0·25	BA154	0·12	BYZ11	0·32	OA79	0·07	OA202	0·10

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0·20 diameter 33p
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100	0·36	0·37	0·70	0·75
200	0·30	0·41	0·75	0·80
400	0·36	0·45	0·85	1·10
600	0·40	0·52	0·95	1·25

SCR's	100V	200V	400V	600V
½A	0·43	0·44	—	—
1A	0·45	0·50	0·60	—
1·2A	0·38	0·42	0·53	0·75
3A	0·47	0·53	0·60	0·90
4A	0·50	0·55	0·65	—

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BSTB0246 £1·05 Transformer £2·75
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DL 707 £2·35 or 4 for £8·00

Resistors W	Tol	Price	Tant Beads Value	
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¼	5%	1·5p	·22/35	14p
½	5%	2p	·47/35	14p
1	10%	2·5p	2·2/35	14p
2	10%	6p	4·7/35	18p
2½	5%	7p	10/16V	18p
5	5%	9p	47/6·3V	10p
10	5%	10p	100/3V	20p

Veroboard	Copper ·1	Copper ·15	Plain ·1	Plain ·15
2½x3¾	36p	26p	—	17p
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