elektor 35 decoder

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What is a TUN?
What is 10 n?
What is the EPS service?
What is the TQ service?
What is a missing link?

Semiconductor types
Very often, a large number of equivalent semiconductors exist with different type numbers. For this reason, 'abbreviated' type numbers are used in Elektor wherever possible:
- '741' stand for µA741, LM741, MC641, MIC741, RM741, SN72741, etc.
- 'TUP' or 'TUN' (Transistor, Universal, PNP or NPN respectively) stand for any low frequency silicon transistor that meets the following specifications:

UCEO, max	20V
IC, max	100 mA
hfe, min	100
Ptot, max	100 mW
fT, min	100 MHz

Some 'TUN's are: BC107, BC108 and BC109 families; 2N3856A, 2N3859, 2N3860, 2N3904, 2N3947, 2N4124. Some 'TUP's are: 8C177 and BC178 families; BC179 family with the possible exeption of BC159 and BC179; 2N2412, 2N3251, 2N3906, 2N4126, 2N4291.

- 'DUS' or 'DUG' (Diode Universal, Silicon or Germanium respectively) stands for any diode that meets the following specifications:

	DUS	DUG
UR, max	25V	20V
IF, max	100mA	35mA
IR, max	1µA	100 µA
Ptot, max	250mW	250mW
CD, max	5pF	10pF

Some 'DUS's are: BA127, BA217, 8A218, BA221, BA222, BA317, BA318, BAX13, BAY61, 1N914, 1N4148.
Some 'DUG's are: OAB5, OA91, OA95, AA116.

- 'BC107B', 'BC237B', '8C547B' all refer to the same 'family' of almost identical better-quality silicon transistors. In generel, any other member of the same family can be used instead.

BC107 (-8, -9) families:
BC107 (-8, -9), BC147 (-8, -9),
BC207 (-8, -9), BC237 (-8, -9),
BC317 (-8, -9), BC347 (-8, -9),
8C547 (-8, -9), 8C171 (-2, -3),
BC182 (-3, -4), BC382 (-3, -4),
BC437 (-8, -9), BC414

BC177 (-B, -9) families:
BC177 (-8, -9), BC157 (-8, -9),
BC204 (-5, -6), BC307 (-8, -9),
8C320 (-1, -2), BC350 (-1, -2),
BC557 (-8, -9), BC251 (-2, -3),
BC212 (-3, -4), BC512 (-3, -4),
BC261 (-2, -3), BC416.

Resistor and capacitor values
When giving component values, decimal points and large numbers of zeros are avoided wherever possible. The decimal point is usually replaced by one of the following abbreviations.

p (pico-) = 10^{-12}
n (nano-) = 10^{-9}
µ (micro-) = 10^{-6}
m (milli-) = 10^{-3}
k (kilo-) = 10^{3}
M (mega-) = 10^{6}
G (giga-) = 10^{9}

A few examples:
Resistance value 2k7: 2700 Ω.
Resistance value 470: 470 Ω.
Capacitance value 4p7: 4.7 pF, or 0.000 000 000 004 7 F . . .
Capacitance value 10n: this is the international way of writing 10,000 pF or .01 µF, since 1 n is 10^{-9} farads or 1000 pF.
Resistors are ¼ Watt 5% carbon types, unless otherwise specified. The DC working voltage of capacitors (other than electrolytics) is normally assumed to be at least 60 V. As a rule of thumb, a safe value is usually approximately twice the DC supply voltage.

Test voltages
The DC test voltages shown are measured with a 20 kΩ/V instrument, unless otherwise specified.

U, not V
The international letter symbol 'U' for voltage is often used instead of the ambiguous 'V'. 'V' is normally reserved for 'volts' For instance: U_b = 10 V, not V_b = 10 V.

Mains voltages
No mains (power line) voltages are listed in Elektor circuits. It is assumed that our readers know what voltage is standard in their part of the world! Readers in countries that use 60 Hz should note that Elektor circuits are designed for 50 Hz operation. This will not normally be a problem; however, in cases where the mains frequency is used for synchronisation some modification may be required.

Technical services to reeders
- EPS service. Meny Elektor articles include a lay-out for a printed circuit board. Some — but not all — of these boards are available ready-etched and predrilled. The 'EPS print service list' in the current issue always gives a complete list of available boards.
- Technical queries. Members of the technical staff are available to answer technical queries (relating to articles published in Elektor) by telephone on Mondays from 14.00 to 16.30. Letters with technical queries should be addressed to: Dept. TQ. Please enclose a stamped, self addressed envelope; readers outside U.K. please enclose an IRC instead of stamps.
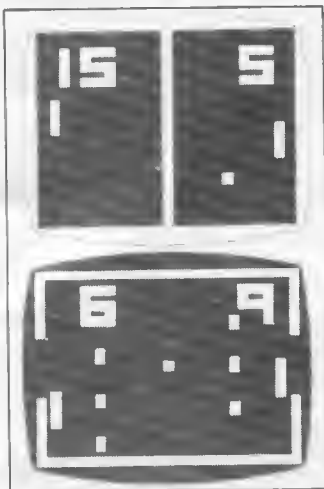- Missing link. Any important modifications to, additions to, improvements on or corrections in Elektor circuits are generally listed under the heading 'Missing Link' at the earliest opportunity.

Playing games on a TV screen has become quite popular. The colour TV games circuit described this month offers on-screen scoring, sound and colour (either NTSC or PAL), and some interesting handicap features. The same circuit and printed circuit board can be used with more versatile chips when they become available.

In order to expand the memory capacity of microcomputers use is often made of plug-in memory cards. The 4 k RAM card described this month is primarily intended as an extension of the SC/MP system, however it can also be used with any other 8-bit microprocessor.

Formant, the Elektor music synthesiser, is now beginning to take shape. This month, the low frequency oscillators and noise generator are described.
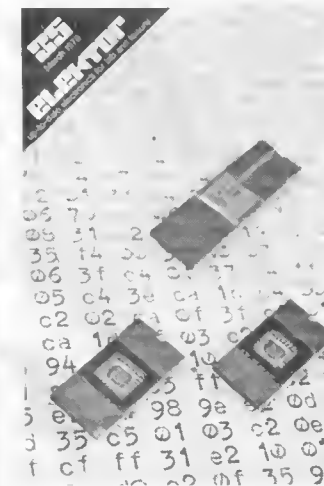
Without software, any computer is little more than an expensive heap of worthless electronics . . . This month, 'experimenting with the SC/MP' takes on a new meaning with the publication of the 'Elbug' monitor software.

contents

selektor

Laser glass

Special laser glasses that could be used to develop the concept of laser fusion will be melted and tested by Corning. Corning scientists are to investigate techniques of melting and forming beryllium-fluoride glasses and other fluoride-containing glasses for use in extremely high-power lasers.

Laser fusion is a potential process for harnessing the heat and power of thermonuclear microexplosions to generate electricity in fusion reactors. Beryllium-fluoride glass has the lowest non-linear index of refraction of any known glass. Because non-linear index relates to the ability to propagate the passage of light energy through the glass, it is a significant power-limiting characteristic of high-power laser glass. Extremely intense light energies can cause changes in the refractive index of laser glass. The extent depends upon the glass' non-linear index. In turn, changes in the refractive index alter the uniform-

ity of energy flow through the glass, causing breakup of the beam as a result of a phenomenon called self-focusing. Thus, the lower the non-linear index of a glass, the more it is possible to increase the deliverable power of laser systems developed for fusion.

The laser for powering an economically practical fusion reactor has not yet been invented. Scientists developing laser systems to demonstrate the feasibility of laser fusion are now using lasers that employ neodymium-doped glass components. These glasses fill the need of experimental systems that produce as much as 20 to 40 trillion kilowatts of power. However, new glasses with a lower non-linear index will be required in the decade ahead for proposed laser systems with about 200-trillion-kilowatt power output.

The laser fusion concept is based on the use of high-energy, short-pulse laser beams focused on suitable fuel pellets. The fuel targets are made of a gaseous mixture of deuterium and tritium,

isotopes of hydrogen frozen into a hollow glass sphere less than one millimeter in diameter.

The pulses of light generated by the laser last less than one-billionth of a second, but they have such power that they heat and compress the fuel target to the point where a thermonuclear microexplosion occurs. The nuclei of the deuterium and tritium combine, releasing energy in the form of neutrons and alpha particles. In the process, a fuel pellet density of up to 10,000 times normal solid density is achieved, and temperatures up to 100 million degrees Kelvin are reached.

In addition to generating large amounts of electrical power, laser fusion has other advantages. For one, the fuel supply is virtually unlimited. Deuterium abounds in sea water, and the supply is estimated to be sufficient to provide for the world's energy needs for 350 million years.

Beryllium-fluoride glasses were discovered a half-century ago, but they have not been commercially exploited because of the toxicity of batch materials.

Corning has developed and built a specially designed beryllium-handling laboratory to allow safe handling of raw materials. Glass melting and grinding and polishing of finished pieces will be done in a controlled environment. Characterization of properties of various glass samples developed during the study will be carried out by Corning in conjunction with other major laser fusion laboratories.

Corning Glass Works,
Corning, NY 14830, USA

(281 S)

Toxic batch materials for the beryllium-fluoride glasses being melted by Corning are mixed in sealed units by employees wearing rubber gloves.
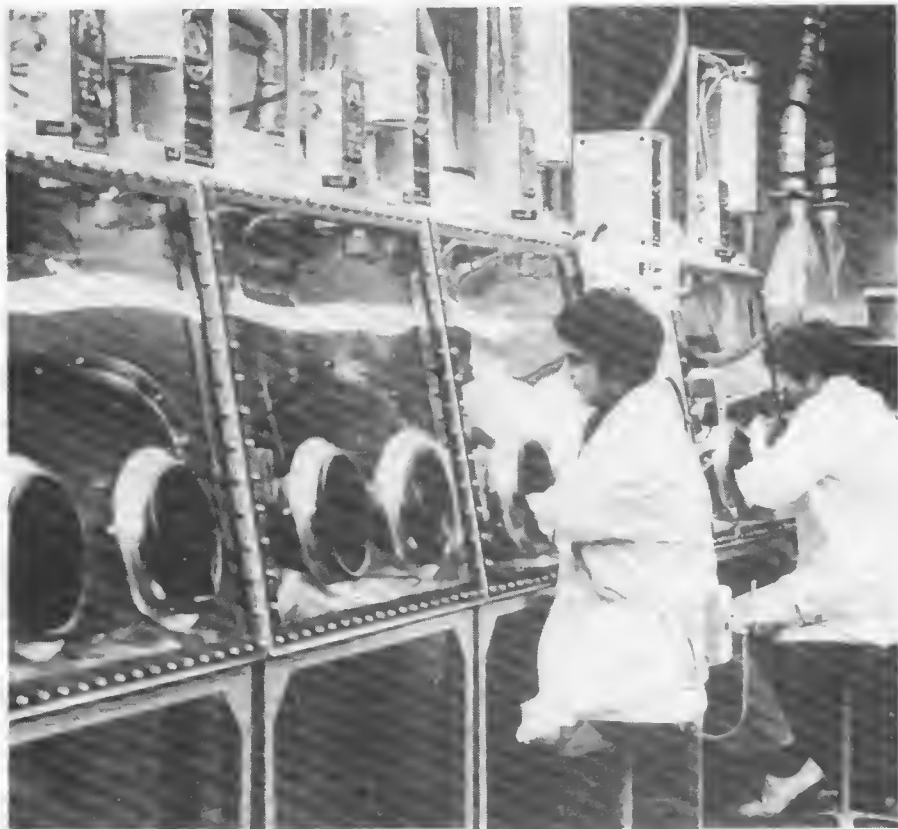
µP for traffic signals

Now even the traffic signals at road junctions can be controlled by microcomputers.

At the heart of Siemens new Series M signal control equipment is a fast microprogrammable control unit and extensive software, making the equipment extremely flexible. Its applications range from fixed-time or traffic-dependent control at individual crossings to complex control systems governed by a traffic computer. In addition to the electronic signal safeguarding feature designed to detect signaling conditions which might endanger the traffic, the series M equipment is also able to make sure that the length of green phases and intermediate phases does not drop below the permissible minimum.

The control equipment can be programmed on the spot. Large data blocks are entered by means of paper tapes or magnetic tape cassettes. Smaller program modifications are performed with the 'terminal M', a device rather like a pocket calculator. The work of

selektor

maintenance personnel is greatly simplified by the fact that the input and output procedures do not use the binary form but alphanumeric expressions, i.e. letters and digits, which are easy to understand.
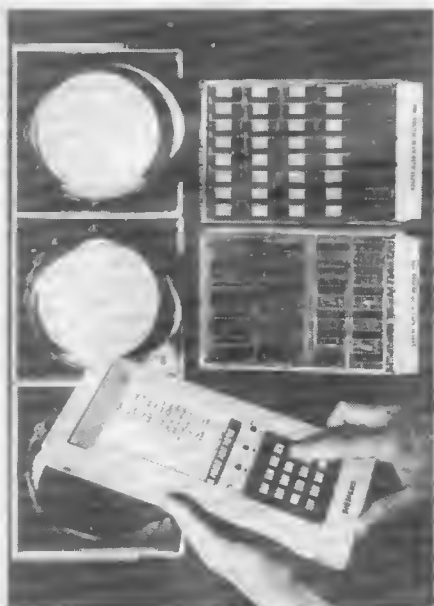
With 'M' equipment, not only the operation but also the design of large-scale signal networks is particularly rational and economical. A new transmission system makes it possible for this equipment to interoperate with traffic computers via a single conductor pair, so that the number of control wires normally required (often 20, 30 or more), has been drastically reduced. This permits multiple utilization of existing lines, resulting in considerable cuts in installation and maintenance costs of the cable network.

Siemens AG
Postfach 103
D-8000 München 1
West Germany

(283 S)

Sortie planning

The Ferranti Autoplan 2081 systems will be used by RAF operational squadrons to speed up the process of planning and producing on the ground the necess-

ary detailed flight navigational information required by aircrew prior to a sortie. For example, a sortie involving 20 turning points can be planned in as little as five minutes including changing from an en route map to a 1:50,000 scale map for the precise plotting of the initial point and target.

The problem

Pre-flight planning, especially of low-level combat missions, is a very demanding task — particularly for single-seat aircraft. Missions have to be planned taking into account evasive routing, constantly changing intelligence, and the need to avoid conflicts with other strike aircraft on similar tasks. Planning must be performed quickly and accurately often under difficult operational conditions, and may have to be repeated several times a day. Manual flight planning 'against the clock' induces high stress and, with battle fatigue added, it becomes increasingly difficult to maintain the required accuracy. It is to alleviate this problem that Ferranti developed Autoplan 2081 — a digitising and computing system used in conjunction with current military maps to produce navigational data accurately and quickly. It consists of a map digitiser table with associated cursor, a computer, a fast output printer and a control panel. Autoplan is rugged, inexpensive and easy to use, and no special training is required.

Autoplan operation

Autoplan may be used with Universal Transverse Mercator charts at scales between 1/50,000 and 1/25,000, and Lambert conformal charts at scales between 1/500,000 and 1/2,000,000. The map is placed on the digitiser table and the co-ordinates of two datum points are entered, in turn, on the Autoplan keyboard and related to the corresponding positions on the map by placing the cursor over each one in sequence and operating a 'record' button. From this information the computer calculates chart scale, projection, and orientation on the board. Basic mission planning information is then entered via the keyboard. This is done by a "question and answer" procedure with the printer producing the requests for information. The cursor is then moved around the required route from turning-point to turning-point. The computer performs the necessary navigational calculations and the results in the form of tracks to steer, time to turning-points or target, fuel states and so on are printed out in a standard form on a paper strip. Autoplan is a simple, fast, highly accurate operational data preparation system that provides a very consistent method of flight planning under difficult operational conditions. Several routes may be planned on the same chart without the need to re-insert basic mission data.

At the end of the planning phase the printer can produce as many copies of the flight plan as are required. Other equipment and devices may be used in association with Autoplan to extend its usefulness. One is a small (less than six cubic inches) solid-state portable data store (PODS). Flight planning information produced by Autoplan can be recorded directly in PODS which is then carried by hand to the aircraft and plugged into its digital navigation system. The pilot, therefore, does not have to spend valuable time inserting turning-point co-ordinates and, in addition, the risk of transcription errors occurring is eliminated. Furthermore the storage capacity of the aircraft's automatic navigation system is enhanced.

A minimum of 32 turning-points can be handled instead of the more usual eight or ten.

The rapid and secure transfer of information from Autoplan via PODS can be taken one stage further for aircraft fitted with the Ferranti COMED (Combined Map and Electronic Display). In addition to the basic flight plan information, such systems can store current intelligence information on gun-defended areas, surface-to-air missile sites forward edges of battle area (FEBA) and so on. This is displayed pictorially, on demand, to the pilot by electronic superimposition on a topographical map. This has tremendous advantages when the rapid turn-round of aircraft is required. Cockpit rebriefing of the pilot is possible, mission and intelligence information being stored in a replacement PODS which is handed to him.

PODS may also provide in-flight storage facilities for reconnaissance data. On landing, this information can be transferred to Autoplan and the latitude and longitude of significant locations printed out for intelligence purposes.

(280 S)

experimenting with the SC/MP (5)

Elbug

Elbug is the monitor software for the Elektor SC/MP microcomputer.

By monitor software is meant a programme, usually resident in ROM, which provides the user with the control functions needed to operate the system satisfactorily. A monitor programme typically contains a number of routines which perform such chores as programme loading, debugging and general housekeeping.

As has already been emphasised, before Elbug can be used, it is essential that all the system software which has been published so far should function without fault. A further preliminary to using Elbug is the transfer of the CPU card from page '1xxx' to page 'Øxxx' of memory. This is done by changing the position of the appropriate wire links on the memory extension board (see Elektor 33) to 'CPU Øxxx'. The page address of the RAM I/O (as long as it remains in use) then becomes 1ØØØ.

The Elbug programme is fairly long, and occupies all the 1½ k of memory which was reserved for this purpose. The memory hardware consists of three EPROMs, two of which (IC3 and IC2) are mounted on the CPU card, with the third (IC14) on the memory extension card.

The listing for the monitor programme is given in a condensed form in tables 1, 2 and 3. Only the machine code is listed. The first column in each of the tables consists of addresses, whilst all the remaining figures represent data. For example, the data byte Ø8 is contained in the location with address ØØØØ. The next figure, i.e. C4, is the contents of the following address, i.e. ØØØ1. The programme is written into the three EPROMs such that tables 1 and 2 represent the contents of IC3 and IC2 respectively on the CPU card, whilst table 3 is written into IC14 on the memory extension card.

In order to write data into an EPROM a special PROM-programmer is required, and, unfortunately, these are rather expensive. There are firms who operate a PROM-programming service, however that of course involves the prospective user recording the programme in question on papertape, cassette or PROM before it can be sent. For this reason it is the intention to make pre-programmed

This part of the series introduces 'Elbug', the monitor programme for the SC/MP system. It takes a close look at the various command routines provided by Elbug, as well as examining the software used to control the cassette interface.

H. Huschitt

EPROMs containing Elbug available direct from Elektor.

In addition to the three PROMs, Elbug also requires a section of RAM (STACK) in which to store variables. The section of memory from address ØFC9 up to and including ØFFF is reserved for this purpose. The rest of RAM present on the CPU and memory extension boards (address ØCØØ to ØFC9) and the ¼ k RAM on the RAM I/O card (address 1ØØØ up to and including 1ØFF) are left available for the user's programme. This amounts to a total of more than 1 k of RAM, which should prove more than sufficient for the 'apprentice' programmer. If desired, the memory capacity of the system can be expanded by incorporating one or more of the 4 k-RAM cards, details of which are contained elsewhere in this issue. However, before one sets about considerably expanding the memory of the system, one should ensure that the supply is capable of delivering sufficient current. A suitable power supply is also described elsewhere in this issue.

How to use Elbug

With the arrival of Elbug, the SC/MP system has acquired 'intelligence'. However before starting to use Elbug one must first know which command key initiates which control software routine and what the significance is of the various statements Elbug outputs on the displays.

Elbug splits the displays into three separate formats:

• Displays Ø and 1 (those furthest to the right) are reserved for data (data field)
• Displays 2 to 5 (the 4 middle displays) indicate addresses (address field)
• Display 6 and 7 (the 2 left-hand displays) indicate the instructions (command field)

The command keys enter the following control routines:

    Key C7 (code FØ): RUN
    Key C6 (code EØ): MODIFY
    Key C5 (code DØ): SUBTRACTION
    Key C4 (code CØ): CASSETTE
    Key C3 (code BØ): BLOCK-
                      TRANSFER
    Key C2 (code AØ): CPU REGISTER
    Key C1 (code 9Ø): DOWN
    Key CØ (code 8Ø): UP
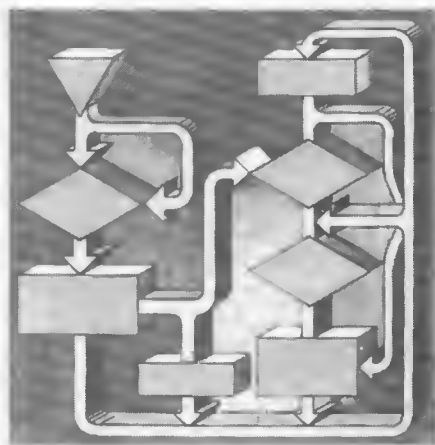
The UP- and DOWN keys are not in fact genuine command keys, but rather suffix keys, as will become clear further on.

MODIFY

Once Elbug has been installed, and the power turned on, pressing the Halt/Reset key should result in the word '.. Elbug' appearing on the displays. The two decimal points which should also light up indicate that the programme is waiting for one of the command keys to be pressed.

Once the MODIFY key has been pressed the text 'MO . . . .' will appear on the since it enables the user to examine the contents of any location in memory, and if so desired, to directly alter the contents of that location (assuming it is RAM of course).

Once the MODIFY key has been pressed the text 'MO . . . .' will appear on the displays, indicating that the programme is waiting for an address to be entered via the data keys (keys ∅ . . . F). When the last (hexadecimal) digit of the address has been entered, the contents of that address will also appear on the displays. To give an example; if address ∅CC9 is selected, the contents of which is A1, the displays will now read 'MOOCC9A1'. The user now has a number of different possibilities:

* The contents of the addressed location can be altered by using the data keys to enter the desired data-byte. When the first key is pressed the corresponding digit appears on display 1, the code generated by the second key appears on display ∅. It goes without saying that the above procedure is invalid if the address in question is located in PROM or does not reference memory at all. In the latter case the data field will display 'FF', whilst (as their name suggests) the contents of a location in PROM can only be read, and hence cannot be altered by means of the data keys.

* If the UP-key is pressed, the address and contents of the following location will appear on the displays. The contents can again be altered in the above-mentioned fashion.

If, whilst in the course of entering new data, a mistake occurs and the wrong key is pressed, this can be rectified simply by entering the correct byte immediately after the false data, since the latter is then lost.

* The contents of the previous address can also be examined by pressing the DOWN-key.

* The MODIFY routine can only be exited from by means of the NRST key. The word '.. Elbug' will then reappear on the displays.

Within the MODIFY routine it is only possible to access addresses on one page, i.e. if the UP-key is pressed at address 4FFF the programme simply returns to the top of the same page and address 4∅∅∅ appears. In order to 'turn the page' one must press the NRST, re-enter the MODIFY routine, then enter the address of the next page (5∅∅∅).

Table 1.

0000	08	c4	15	c8	f1	c4	e0	c8	f7	c4	0f	c8	f2	c4	00	c8
0010	e9	c8	e9	90	3d	c0	e9	31	c0	e5	35	c5	01	c8	de	c5
0020	01	c8	db	c5	01	37	c5	01	33	c5	01	36	c5	01	32	c5
0030	01	c8	c4	c5	01	c8	c1	c5	01	07	c5	01	01	c5	01	c8
0040	b8	c0	b4	35	c8	b9	c0	b0	31	c8	b5	b8	ad	c0	aa	3f
0050	90	04	90	4d	90	bf	c8	a1	c0	a6	33	c8	9b	c0	a0	37
0060	c8	95	c4	ff	31	cf	fc	c4	0f	35	cf	ff	01	cb	03	06
0070	cb	02	c1	f9	cb	04	32	cf	ff	36	cf	ff	c1	f8	cf	ff
0080	c1	f7	cf	ff	c1	fe	cf	ff	c1	fd	cf	ff	37	c9	ff	c1
0090	fe	33	c9	00	a9	fa	e1	fb	9c	04	c4	ff	c9	fc	3f	90
00a0	b3	c4	00	31	c4	07	35	c4	e0	32	c4	0f	36	c4	2f	33
00b0	c4	01	37	c4	08	ca	0b	c7	01	cd	01	ba	0b	9c	f8	c4
00c0	0a	ca	1d	c4	02	ca	1c	c4	00	37	c4	55	33	3f	c4	80
00d0	cd	fd	cd	ff	cd	ff	cd	ff	c4	00	cd	ff	c2	08	01	40
00e0	e4	e0	98	53	40	e4	f0	9c	07	c4	01	37	c4	a0	33	3f
00f0	40	e4	d0	9c	07	c4	03	37	c4	ea	33	3f	40	e4	c0	9c
0100	07	c4	02	37	c4	f1	33	3f	40	e4	b0	9c	07	c4	05	37
0110	c4	49	33	3f	40	e4	a0	9c	88	c4	04	37	c4	35	33	3f
0120	06	5b	4f	66	6d	7d	07	7f	6f	77	7c	58	5e	79	71	00
0130	3d	1c	7c	38	79	80	80	c4	5c	c9	05	c4	54	c9	06	c4
0140	3e	ca	1d	3f	c2	01	33	c2	02	37	c3	00	ca	00	c4	a0
0150	ca	1d	c4	00	37	c4	55	33	3f	c4	0a	ca	1d	3f	c2	01
0160	33	c2	02	37	c2	08	e4	80	98	0a	e4	80	e4	90	9c	0e
0170	c7	ff	90	02	c7	01	33	ca	01	37	ca	02	90	c6	c2	07
0180	c9	00	c4	00	c9	ff	c2	09	1e	1e	1e	1e	01	c4	00	37
0190	c4	55	33	3f	c2	01	33	c2	02	37	c2	09	58	cb	00	90
01a0	a3	c4	50	c9	06	c4	1c	c9	05	c4	3e	ca	1d	c4	00	37
01b0	c4	55	33	3f	c4	0a	ca	1d	3f	c2	01	33	c2	02	37	c7
01c0	ff	c4	50	c9	00	c4	1c	c9	ff	3f	c4	0f	37	c4	ff	33
01d0	3f	c2	15	1c	ca	14	c4	ff	01	19	40	94	02	90	f7	c4
01e0	ff	01	c2	14	ca	0a	ba	0a	9c	fc	c4	08	ca	08	c2	15
01f0	ca	09	c4	16	8f	00	ba	09	9c	fc	19	ba	08	9c	ef	c2

Table 2.

0200	15	ca	09	ba	09	9c	fc	40	3f	90	c6	c4	14	33	c4	00
0210	37	c4	01	31	c4	07	35	c4	e0	32	c4	0f	36	c1	08	94
0220	fc	8f	1e	c1	08	ca	08	d4	0f	ca	09	01	c1	08	94	02
0230	90	fa	8f	1e	c4	1f	31	c4	01	35	c1	80	ca	07	3f	c4
0240	06	31	c4	07	35	c4	e7	32	c4	0f	36	c4	04	ca	f9	c4
0250	55	33	c4	00	37	c4	0a	cb	a8	c4	02	cb	a7	3f	c4	e0
0260	33	c4	0f	37	c3	07	cd	ff	c4	00	c9	ff	c9	fe	c9	fd
0270	c9	fc	c9	fb	c3	09	ce	ff	bb	00	9c	d3	c4	80	c9	ff
0280	c9	fe	c3	06	1e	1e	1e	1e	01	c3	05	58	cb	02	c3	04
0290	1e	1e	1e	1e	01	c3	03	58	cb	01	c4	00	37	c4	14	33
02a0	3f	c4	e0	33	c4	0f	37	c4	e0	32	c4	0f	36	c4	e3	31
02b0	c4	0f	35	c4	03	cb	0f	c2	00	d4	0f	cd	01	c6	01	1c
02c0	1c	1c	1c	cd	01	bb	0f	9c	ee	c4	1f	31	c4	01	35	c4
02d0	06	cb	0f	c6	01	01	c1	80	ca	05	bb	0f	9c	f5	c4	00
02e0	31	c4	07	35	c4	06	cb	0f	c6	01	cd	01	bb	0f	9c	f8
02f0	90	a8	c4	39	c9	06	c4	5f	c9	05	01	19	c4	ff	ca	00
0300	c4	00	37	c4	55	33	3f	c4	5f	c9	00	c4	5e	c9	ff	c2
0310	08	e4	e0	9c	1e	c4	54	c9	00	c4	5c	c9	ff	c4	3e	ca
0320	1d	3f	c2	01	ca	15	c4	0a	ca	1d	3f	c4	5f	c9	00	c4
0330	5e	c9	ff	c2	08	e4	80	98	2c	c4	3e	ca	1d	3f	c2	01
0340	ca	0b	c2	02	ca	0c	3f	c4	0a	ca	1d	3f	c2	08	e4	80
0350	9c	04	ca	00	90	0f	e4	80	e4	90	98	02	90	50	c4
0360	37	c4	e3	33	3f	c4	1c	c9	00	c4	73	c9	ff	c4	d0	33
0370	c4	01	37	c2	00	98	0e	3f	ca	0c	3f	ca	0b	3f	ca	02
0380	3f	ca	01	90	04	3f	3f	3f	3f	c4	20	ca	05	c4	00	ca
0390	06	02	c2	0b	31	c2	0c	35	3f	c9	00	f2	06	ca	06	35
03a0	e2	02	9c	11	31	e2	01	9c	0c	3f	e2	06	9c	21	c4	0f
03b0	37	c4	ff	33	3f	06	01	02	c2	0b	f4	01	ca	0b	c2	0c
03c0	f4	00	ca	0c	40	07	ba	05	9c	c8	3f	e2	06	98	ba	c4
03d0	01	31	c4	07	35	c4	00	c9	04	c4	79	c9	03	c4	50	c9
03e0	02	c9	01	c9	ff	c4	5c	c9	00	90	fe	c4	6d	c9	06	c4
03f0	76	c9	05	c4	3e	ca	1d	c4	00	37	c4	55	33	3f	c4	40

Table 3.

```
⊘4⊘⊘  c9 ⊘⊘ c4 ⊘⊘ c9 ff c9 ⊘6 c9 ⊘5 c2 ⊘2 ca 14 c2 ⊘1
⊘41⊘  ca 13 3f ⊘3 c2 13 fa ⊘1 ca ⊘1 c2 14 fa ⊘2 ca ⊘2
⊘42⊘  c4 ⊘a ca 1d 3f c4 a⊘ ca 1d 3f c4 ⊘⊘ c9 ff c9 ⊘⊘
⊘43⊘  c4 48 c9 ⊘5 9⊘ fe c4 39 c9 ⊘6 c4 73 c9 ⊘5 c4 3e
⊘44⊘  ca 1d c4 ⊘⊘ 37 c4 55 33 3f c2 ⊘1 ca ⊘e c2 ⊘2 ca
⊘45⊘  ⊘d 3f c2 ⊘1 31 c2 ⊘2 35 c4 3f c9 ⊘⊘ c4 71 ca 1d
⊘46⊘  c4 ⊘4 ca 1c c2 ⊘e ⊘1 c2 ⊘d 36 4⊘ 32 c6 ff c4 55
⊘47⊘  33 3e c4 e⊘ 32 c4 ⊘f 36 c4 d5 ca 1f c4 ⊘a ca 1d
⊘48⊘  c4 ⊘2 ca 1c c4 ⊘⊘ 37 c4 55 33 3f c2 ⊘8 ⊘1 c4 a⊘
⊘49⊘  ca 1d c4 ⊘1 31 c4 ⊘7 35 4⊘ e4 fa 98 16 4⊘ e4 fe
⊘4a⊘  98 15 4⊘ e4 f5 98 14 4⊘ e4 f1 98 13 4⊘ e4 f2 98
⊘4b⊘  15 9⊘ bf c2 ff 9⊘ 1c c2 fe 9⊘ 18 c2 fd 9⊘ 14 c2
⊘4c⊘  fc ⊘1 c2 fb 9⊘ ⊘5 c2 fa ⊘1 c2 f9 ca ⊘2 4⊘ ca ⊘1
⊘4d⊘  3f 9⊘ ⊘9 ca ⊘1 3f c4 ⊘⊘ c9 ⊘3 c9 ⊘4 c4 ⊘⊘ c9 ⊘⊘
⊘4e⊘  c9 ff 9⊘ cd c4 5e c9 ⊘⊘ c4 5c c9 ff c2 ⊘b 31 c2
⊘4f⊘  ⊘c 35 c4 d7 33 c4 ⊘5 37 c2 ⊘c 3f c2 ⊘b 3f c2 ⊘2
⊘5⊘⊘  3f c2 ⊘1 3f c4 2⊘ ca ⊘5 c4 ⊘⊘ ca ⊘6 ⊘2 c1 ⊘⊘ ⊘1
⊘51⊘  c2 ⊘6 7⊘ ca ⊘6 4⊘ 3f 35 e2 ⊘2 ⊘1 4⊘ e2 ⊘2 35 4⊘
⊘52⊘  9c ⊘8 31 e2 ⊘1 98 19 e2 ⊘1 31 ⊘6 ⊘1 ⊘2 31 f4 ⊘1
⊘53⊘  31 35 f4 ⊘⊘ 35 4⊘ ⊘7 ba ⊘5 9c d2 c2 ⊘6 3f 9⊘ c4
⊘54⊘  c2 ⊘6 3f c4 ⊘f 37 c4 ff 33 3f c4 7c c9 ⊘6 c4 38
⊘55⊘  c9 ⊘5 c4 3e ca 1d c4 ⊘⊘ 37 c4 55 33 3f c2 ⊘1 ca
⊘56⊘  1⊘ c2 ⊘2 ca ⊘f 3f c2 ⊘1 ca ⊘e c2 ⊘2 ca ⊘d 3f c4
⊘57⊘  ⊘a ca 1d 3f ⊘3 c2 ⊘1 fa 1⊘ ca ⊘c c2 ⊘2 fa ⊘f ca
⊘58⊘  ⊘b 94 29 c2 1⊘ 31 c2 ⊘f 35 c2 ⊘1 33 c2 ⊘2 37 c5
⊘59⊘  ⊘1 cf ⊘1 c5 ff 31 e2 ⊘e ⊘1 4⊘ e2 ⊘e 31 4⊘ 9c ⊘8
⊘5a⊘  35 e2 ⊘d 98 9e e2 ⊘d 35 c5 ⊘1 9⊘ e3 c2 ⊘e 31 c2
⊘5b⊘  ⊘d 35 c5 ⊘1 ⊘3 c2 ⊘e f2 ⊘c 33 c2 ⊘d f2 ⊘b 37 c5
⊘5c⊘  ff cf ff 31 e2 1⊘ ⊘1 4⊘ e2 1⊘ 31 4⊘ 9c f1 35 e2
⊘5d⊘  ⊘f 98 d⊘ e2 ⊘f 35 9⊘ e7 ca ⊘7 c4 ⊘b ca ⊘8 c4 ⊘⊘
⊘5e⊘  ⊘1 19 ⊘1 ba 2⊘ c2 ⊘7 ⊘1 c4 ⊘b 8f ⊘⊘ c2 15 ca ⊘9
⊘5f⊘  ba ⊘9 9c fc 19 4⊘ dc 8⊘ ⊘1 ba ⊘8 9c eb 3f 9⊘ d8
```

RUN

Once one or more user's programmes have been stored in memory using the MODIFY routine, the RUN-key allows the user to select and then run one of these programmes.

After pressing the NRST and RUN keys the text 'RU . . . . ' will appear on the displays. The decimal points again indicate that Elbug is waiting for data to be entered, in this case the start address of the user's programme. Once this has been done programme execution can be commenced by pressing one of the data- or command keys. The displays will then continue to show 'RU address RU' provided that the user's programme does not require any data to be displayed.

If an XPPC 3 instruction occurs in the user's programme before pointer 3 has been reloaded, then the SC/MP will leave the user's programme and return to Elbug. The displays will indicate this fact by once more showing ' . . Elbug', thereby telling the user that the MPU is awaiting fresh instructions. This feature can be quite useful, since an interrupt call causes the SC/MP to automatically execute an XPPC 3 (3F).

SUBTRACTION

This routine can be used to calculate displacement values when developing one's own programmes. After pressing the SUB-key, ' SH . . . . ' (=Subtraction Hexadecimal) will appear on the dis-

Tables 1, 2 and 3 give the condensed listing for Elbug, the monitor software for the Elektor SC/MP system.

Photo 1 shows two of the three EPRoms in which Elbug is stored.

plays. A four-digit hexadecimal number should then be entered. When the last digit of this number has been punched in, displays 6 and 7 are blanked whilst a '−' sign appears on display 1. The subtrahend of the first number (which should also be a four-digit number) should then be entered. The result of the subtraction is obtained by pressing one of the data- or command keys, the difference will then appear on the display preceded by an ' = ' sign. If the difference is a negative number then it is expressed as the two's complement.

After a difference has been calculated the CPU enters a loop which can only be exited from via NRST.
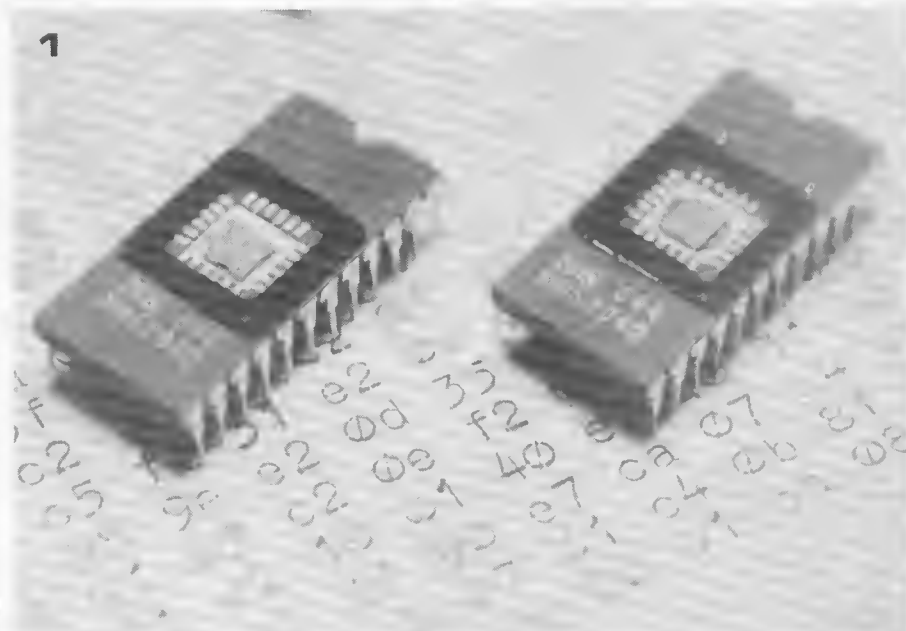
BLOCK-TRANSFER

When developing one's own software it will often occur that several instructions have to be inserted into the middle of a longish programme. In such an event it is possible to spare oneself the chore of having to re-enter great chunks of programme by employing the BLOCK-TRANSFER routine.

This routine allows the contents of any section of memory to bc transferred elsewhere in memory. After an NRST the transfer key is pressed, causing the text ' BL . . . . ' to appear on the displays. The first address of the block of data to be transferred should then be entered (the displays then read ' BLxxxx . . '), immediately followed by the last address (' BLyyyy . . '). Once that is done, the initial address of the section of memory to which the data is being transferred can be entered (' BLzzzz . . '). Pressing one of the data- or command keys then results in the BLOCK-TRANSFER being executed. The word ' . . Elbug' will reappear on the displays to indicate that the transfer has been completed.

As long as neither the block of data to be transferred nor the position to which it is to be transferred contains a page boundary, then the block-transfer routine can be used to copy data from one

page to another. In the event of a page boundary occuring in the data block or the new position the transfer will not be executed. This is only to be expected since programmes which contain such a page boundary cannot be executed directly, but must first contain a number of extra instructions (XPPC) which make the page jump possible.

CPU-REGISTER COMMAND

This is another routine which offers considerable assistance when developing, and, in particular, debugging one's own programmes. It allows the contents of the CPU registers to be examined on the displays at any stage during the user's programme. The only proviso is that the programme in question must be stored in a section of RAM.

After the NRST- and CPU-keys have been pressed, the text ' CP . . . . ' will appear on the displays. The start address of the programme to be checked should then be entered (the display will read ' CPxxxx . . '), followed by the address which immediately succeeds the last instruction to be executed (' CPyyyy . . '). After pressing any of the data or command keys the user may then examine the contents of the accumulator by pressing key A (' CP (A) '), the contents of the extension register (' CP (E) ') by means of key E, the status register by key 5, and pointer registers 1 and 2 by keys 1 and 2 respectively. The above registers can be examined in any order and as often as desired. This section of the CPU-routine can only be left via an NRST instruction.

Since this routine itself utilises pointer 3, care should be taken to ensure that the contents of this pointer are not altered in the section of programme under test, otherwise the CPU-routine will fail to function. In addition, the contents of the stop address following the section of programme being checked must be returned to their original state. This can be done by means of the MODIFY routine.

CASSETTE

When a programme has been completed it is normally first committed to paper, so that it can be re-entered later. The programme is, of course, loaded via the hexadecimal keyboard. However, as soon as one starts dealing with longish programmes, using a keyboard becomes a time-consuming business, whilst the chance of entering false data always exists where the human factor is involved. For this reason it is only natural to record the programme on a medium other than paper such as, e.g., magnetic tape, which can then be used to interface directly with the microcomputer.

In order to interface the microprocessor with a cassette recorder a certain amount of both hard- and software is required. The hardware consists of two parts, one to convert the digital information sup-
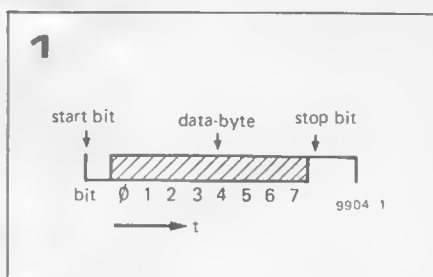

Figure 1. Whenever a byte is transferred from memory to a cassette it is prefaced by a single start bit and followed by two stop bits.
Figure 2. A diagrammatic illustration of the way in which Elbug reads a programme out of memory and onto a tape.

Table 4. This table shows how different transmission speeds can be obtained by entering the appropriate hexadecimal figures.
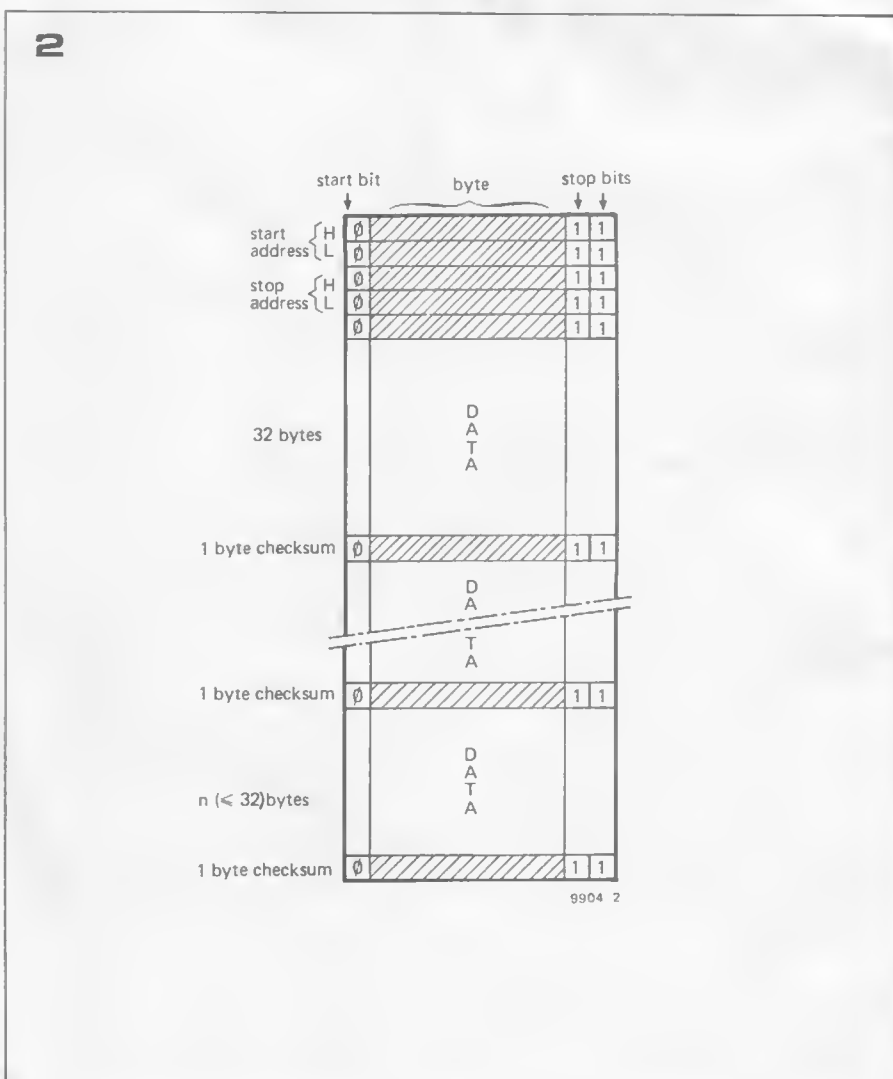
plied by the μP into signals which can be accepted by the cassette recorder, and another to do exactly the reverse. The cassette interface hardware for the SC/MP system (which can, however, also be used for any other microprocessor system) will be published in next month's article.

The cassette interface software, which ensures that data is read serially from and into memory is already contained in Elbug. This software allows a programme to be read from memory (PROM or RAM) onto a cassette, and programmes recorded on cassette to be written back into memory (RAM). Altough these routines cannot of course be used without the complementary hardware, they will nonetheless be discribed in this article on Elbug.

From memory to cassette

If a programme is to be transferred from memory to a cassette, first the NRST, then the CASSETTE key should be pressed. This results in 'CA . . . .' appearing on the displays. If any of the data or command keys, with the exception of the MODIFY-key, are then pressed, the displays will show ' CA . . . . AD ', indicating that the start address of the programme being read out can now be entered (' CAxxxx . . '), to be immediately followed by the stop address

Table 4.

desired speed	number (hex)	calculation
2400 Baud	0002	$1/2400$ s $= 417\ \mu s \approx 2 \times 66 + 285\ \mu s$
1200 Baud	0008	$1/1200$ s $= 833\ \mu s \approx 8 \times 66 + 285\ \mu s$
600 Baud	0015	$1/\ 600$ s $= 1667\ \mu s \approx 21 \times 66 + 285\ \mu s$
300 Baud	002E	$1/\ 300$ s $= 3333\ \mu s \approx 46 \times 66 + 285\ \mu s$
110 Baud	0085	$1/\ 110$ s $= 9091\ \mu s \approx 133 \times 66 + 285\ \mu s$

('CAyyyy . .'). The recorder is then connected up and started in the record mode.

The interface circuit will then produce a high-pitched tone which the recorder should be allowed to pick up for a short period (about 1 minute). The DOWN-key is then pressed, whereupon the μP will begin to output the desired programme. Each data byte which is read out is accompanied by one start bit (0) and two stop bits (1) (see figure 1). These control bits enable the data to be read back into memory again. When the process is complete the word Elbug will appear on the displays.

The start and stop addresses of the programme are also recorded on the cassette. In addition, after every 32 bytes the CPU calculates their arithmetical sum and records the last (i.e. lowest) eight bits of this sum (the checksum) on the tape. This procedure is illustrated diagrammatically in figure 2. At the end of every programme read out in this way there is a checksum of the last section of programme, regardless of whether it is shorter than 32 bytes.

There are no limits placed upon the size of programme which can be transferred to tape. Page boundaries can be crossed and it is even possible to read out the entire contents of memory from start address 0000 to stop address FFFF at one go.

Elbug outputs data for the cassette interface at a speed of 600 Baud, i.e. 600 bits (that includes control bits) per second. The data can also be read out at different speeds if so desired. In this case the operating procedure is slightly altered. After pressing the CASSETTE-key, the MODIFY-key should then be pressed, causing the text 'CA . . . . MO' to appear on the displays. The desired speed of transmission is now selected by entering the appropriate number ('CAXXXXMO'), whereupon after pressing any of the data- or command keys (with the exception of the MODIFY key) the transfer procedure can be executed in the above described fashion. The number which is entered to select the desired transmission speed can be found from table 4. The figures for 5 different transmission speeds are given in this table. Naturally enough other speeds can be obtained by entering different figures. Care should always be taken to ensure that the interface hardware is capable of handling the chosen transmission speed.

From cassette to RAM

To transfer a programme which is recorded on tape back into memory the procedure is as follows: One first presses NRST followed by CASSETTE. The recorder is started, and when the tone which is present at the beginning of each recorded programme can be heard, the UP-key is pressed. As soon as the programme begins it is written back into memory, commencing at the start address which was also recorded on the tape. When the transfer is complete '. . Elbug' reappears on the displays.

If anything should go wrong during the transmission, such as e.g. a damaged tape or a fault in the interface hardware, then the text 'CA ERROR' will appear on the displays; this means that the checksum calculated by the CPU during the transmission does not coincide with the checksum recorded on the tape. After an 'ERROR' statement the cassette routine can only be exited from by means of NRST. A second attempt can then be made to load the programme from cassette. It is, of course, also possible that an error occurred during the 'recording' of the programme onto tape, in which case a fresh recording must be made.

As already mentioned, since the start and stop addresses of the programme are also recorded onto the tape, the data is written back into the same section of memory from which it was read out. However there are cases where this may prove undesirable or (in the case of PROM) even impossible. In this instance the start and stop addresses must be entered which indicate the locations between which the data is to be stored. This is done as follows:

First NRST, then CASSETTE, and finally any of the data or command keys (with the exception of MODIFY, UP or DOWN) are pressed. This results in 'CA . . . . AD' appearing on the displays. The desired start and stop addresses are then keyed in one after another ('CAxxxx . .' and ('CAyyyy . .'). The recorder is then started and after pressing the UP-key the processor will initiate the cassette routine.

The start and stop addresses should be chosen such that the number of addresses between them exactly equals the number of addresses contained in the programme recorded on the tape. If the amount of memory between these two addresses is any smaller, then only a section of the programme on tape will be written back into memory. What is more, at the end of the transfer the text 'Error' will appear on the displays, even if the transfer itself was carried out correctly. The reason for this is that the CPU calculates the sum of a number of bytes before the stop address and com-

pares this with the last recorded byte, which will not normally be a checksum in this case.

Until now it was assumed that the programme was recorded onto the cassette at a speed of 600 Baud. If this is not the case, then, as when reading data out of memory, the desired speed can be selected by using the MODIFY routine. ◄

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missing link

Modifications to
Additions to
Improvements on
Corrections in
Circuits published in Elektor

Experimenting with the SC/MP

Part 4, E34 (February 1978), p. 2-28.
On the HEX I/O printed circuit board, R42 is connected to supply common instead of positive supply. This error only becomes apparent if a 'low-power' 74LS00 is used for IC6. R42 can either be omitted, or else connected to +5 V. This can be accomplished by connecting the 'top' of R42 (the end nearest to the keyboard) to the R5/C7 junction.

Formant — the Elektor music synthesiser

Part 3, E29 (September 1977) p. 9-42.
On the component layout for the power supply board shown in figure 12, the capacitor between IC1 and D1 should be C5 (not C15).
Part 5, E31 (November 1977), p. 11-41.
Several readers have requested information on how to extend the frequency range of the VCOs above 10 kHz. There are two possibilities: R12 can be reduced to 47 k, or C2 can be reduced to 2n7 (or even 2n2).

CMOS noise generator

E33, January 1978, p. I-05. The pink noise filter shown in figure 1 is not as accurate as it might be. A slope of 3 dB/oct. ± 0.2 dB can be achieved using the following component values:
Resistors: R2 = 10 k; R3 = 4k7;
R4 = 2k2; R5 = 1 k; R6 = 470 Ω;
R7 = 220 Ω; R8 = 100 Ω; R9 = 47 Ω;
R10 = 22 Ω.
Capacitors: C2 = 1 μ; C3 = 470 n;
C4 = 220 n; C5 = 100 n; C6 = 47 n;
C7 = 22 n; C8 = 10 n; C9 = 4n7;
C10 = 2n2; C12 = 1 n.
The same changes can, of course, be incorporated if the pink noise filter is used in conjunction with the TTL noise generator (E21, January 1977, p. 1-23, figure 7).
The characteristic of the filter mentioned in the 'Stop Press' at the end of the CMOS noise generator article is 3 dB/oct. ± 0.5 dB. ◄

SC/MP power supply

As has already been mentioned earlier in the series, the NMOS version of the SC/MP in particular places fairly high demands upon the stability of the supply ($V_{CC} = 5$ V $\pm 5\%$). Although a 5 V stabiliser IC would normally prove adequate for this purpose, it could happen that a 'worst case' IC together with the voltage loss in the supply lines and board tracks would result in the voltage on the chip dropping below minimum. For this reason it is desirable to have a stabilised supply which can be adjusted so that the IC voltage can be set exactly. A complete SC/MP system consisting of RAM I/O, CPU and memory extension cards, HEX I/O and 4-k RAM draws a current of approximately 2.5 A from the 5 V supply. The power supply must therefore have no

Although this power supply is primarily intended for use with the SC/MP system, its general-purpose design renders it suitable for other microcomputer systems as well.

trouble delivering this current, whilst keeping something in reserve for possible expansion of the system. In addition to the +5 V a negative voltage of −12 V must also be provided for the PROMs.

Circuit

A power supply which meets all the above requirements is shown in figure 1. A 723 (IC1) is used to stabilise the +5 V supply. By means of the preset potentiometer P1 the output voltage can be varied between 5 V and 5.5 V. T1 and T2 are external current booster transistors, the output current being limited to approx. 3 A. If, for the purpose of system expansion, more current is required, then the value of the current sense resistor R5 can be lowered to 0.1 Ω/4 W. The maximum current will

1
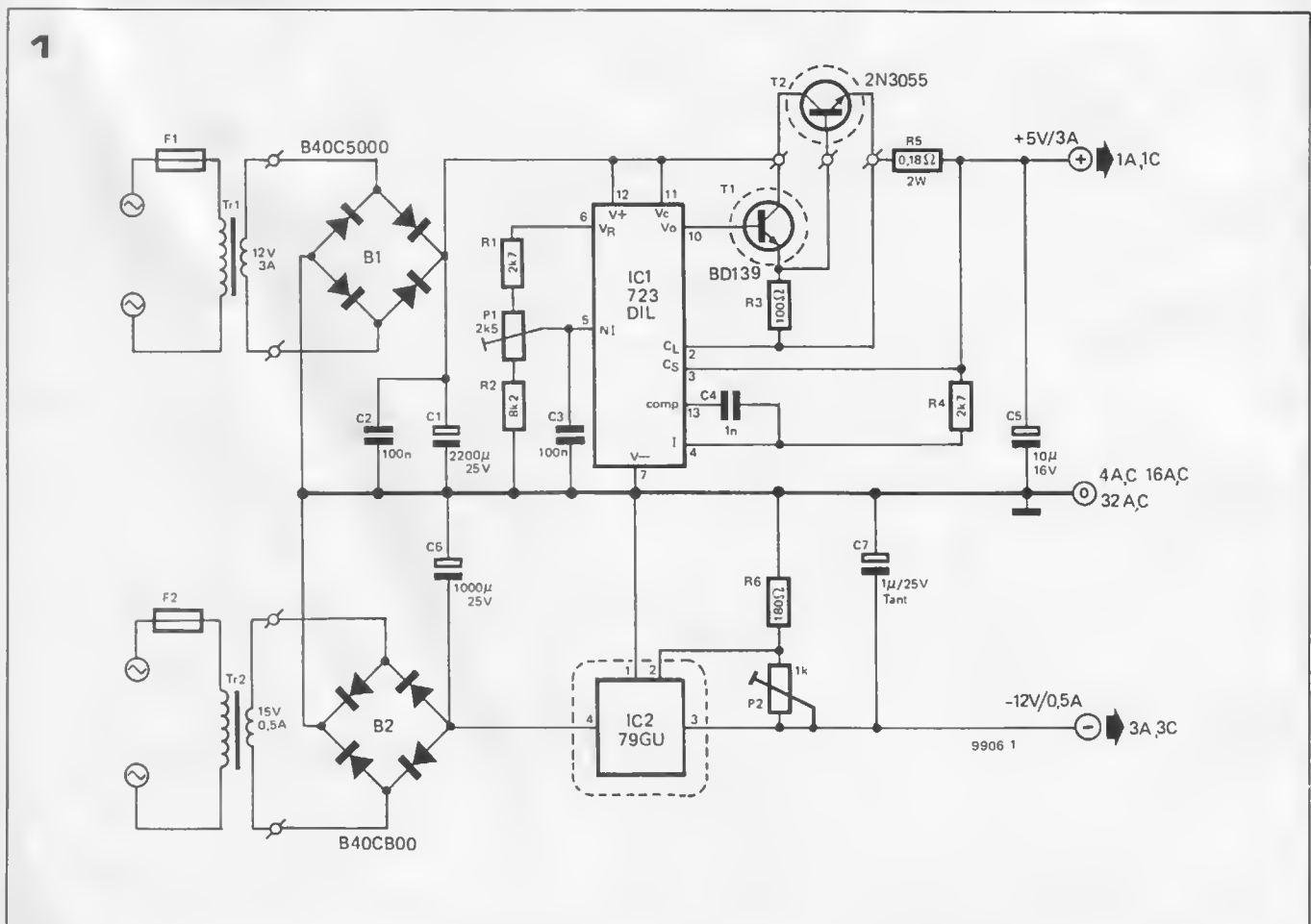
Parts list to figures 1, 2 and 3

Resistors:
R1,R4 = 2k7
R2 = 8k2
R3 = 100 Ω
R5 = 0,18 Ω/2 W
     (see text)
R6 = 180 Ω
P1 = 2k5
P2 = 1 k

Capacitors:
C1 = 2200 μ/25 V
     (see text)
C2C3 = 100 n
C4 = 1 n
C5 = 10 μ/16 V
C6 = 1000 μ/25 V
C7 = 1 μ/25 V tantalum

Semiconductors:
IC1 = 723
IC2 = 79G
T1 = BD 137, BD 139
T2 = 2N3055
B1 = B40 C5000 40 V
     5 A bridge rectifier
     (see text)
B2 = B40 C800 40 V
     800 mA bridge rectifier

Miscellaneous:
Tr1 = Transformer 12 V,
     3 . . . 4 A secondary
     (see text) parts list contd.
Tr2 = Transformer 15 V,
     0.5 A secondary
     (see text)
F1,F2 = 300 mA slo blo
     fuse

Figure 1. The circuit diagram of the complete power supply.

Figure 2. Track pattern of the printed circuit board for the power supply (EPS 9906).

Figure 3. Component layout for the printed circuit board of figure 2.

4

64-flexible connecting wires
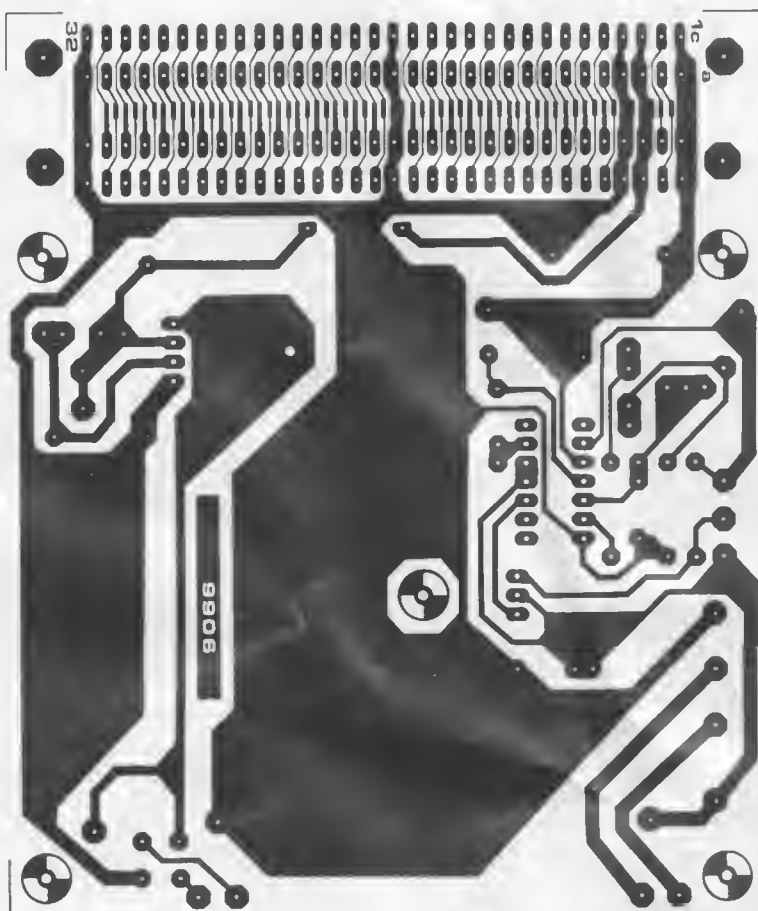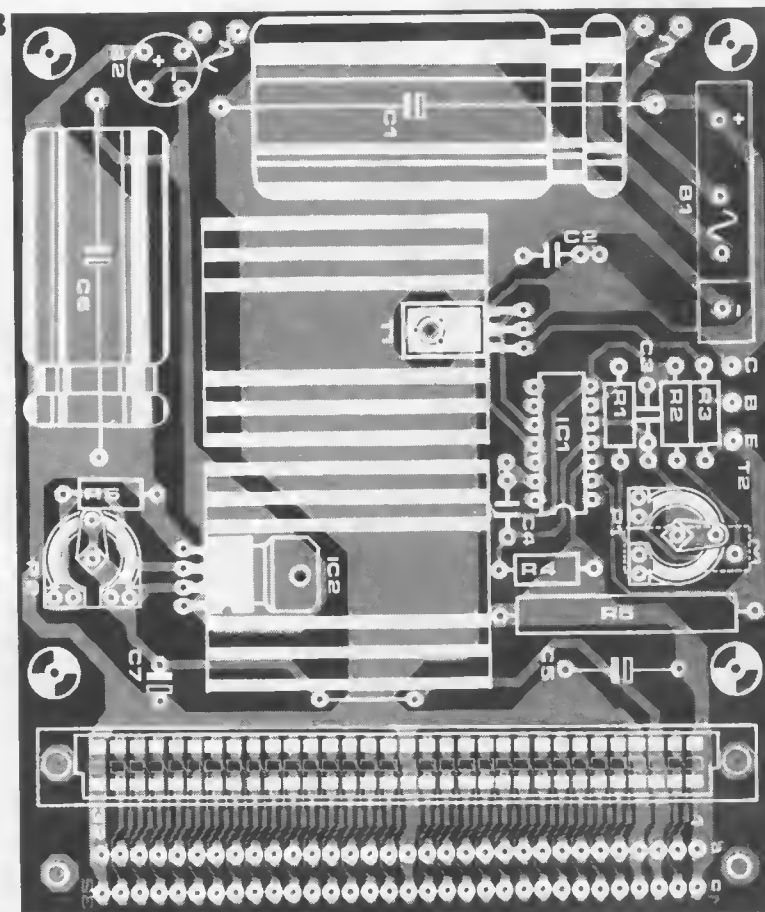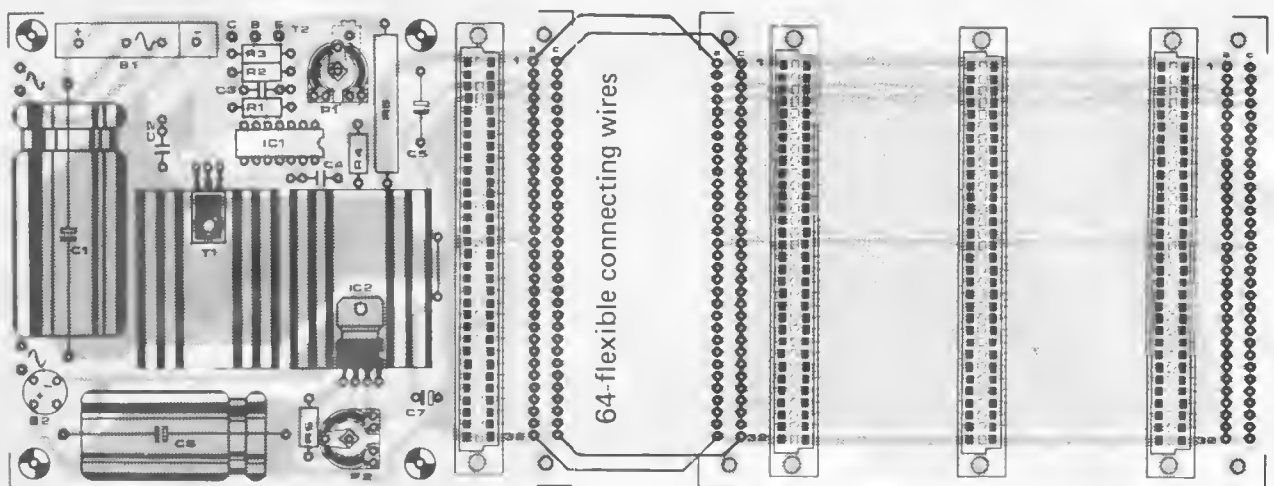
then be approx. 6 A. In that case the transformer, bridge rectifier and smoothing capacitor must, of course, also be uprated proportionally.

The negative supply (−12 V) is stabilised by a 79G IC variable regulator. This IC can supply a maximum current of 0.5 A, which will be more than sufficient for the SC/MP system. By means of preset potentiometer P2, the output voltage can be set to exactly −12 V. As is apparent from the circuit diagram, a separate transformer is used for the negative supply. It is of course quite possible to use a single transformer for both supply voltages; however in that case a transformer with two separate windings is required.

Figure 4. This figure illustrates the connections between the bus- and power supply boards.

Printed circuit board and construction

The entire power supply, with the exception of the transformer(s) and transistor T2, is mounted on a single printed circuit board (see figures 2 and 3). T2 should be mounted on a heat sink with a max. thermal resistance of $1.5\,^\circ$ C/W, for I = 3 A. For currents greater than this the thermal resistance should be correspondingly decreased. T1 and IC2 can be fitted with a heat sink on the board.

The dimensions of the board for the power supply are the same as those of the previously published bus board (EPS 9857, Elektor 33). In addition to the 64 termination points (see figure 2) to connect the supply board to the bus board, the former also contains a second series of connection holes which are designed to accomodate the female half of a connector. This means that the supply board can be used to hold e.g. an extra 4-k RAM card. Figure 4 shows how the supply- and bus boards are connected. The connecting wire between the two boards should be fairly flexible, although for the supply lines, it is advisable to make the wire as thick as possible.

The arrangement shown in figure 4 will accomodate four plug-in Eurocards, e.g. the CPU card, memory extension card and 2 RAM cards. The HEX I/O (and, if still in use, the RAM I/O) card is connected to the bus board using ribbon cable. Such a system will draw a total current of approx. 3.5 A, thus Tr 1 must be capable of supplying a current of 4 A and resistor R5 should then have a value of $0.15\ \Omega/4$ W. ◀
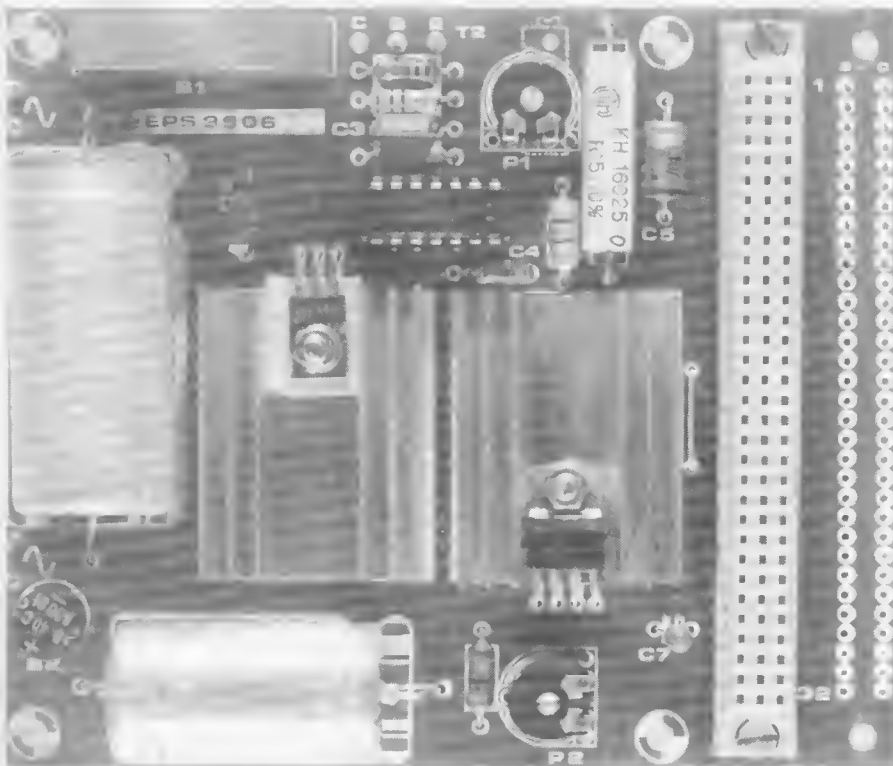
car lights failure indicator

It is often the case that the first a motorist knows of a failure in one of his car lights is when his attention is drawn to the fact by a policeman. The circuit described here, which consists solely of a single reed-relay, one LED and one resistor, should provide a more economical warning system.

A LED is mounted in a suitable spot on the dashboard, and is extinguished as soon the lamp concerned ceases working. It is of course possible to use several such circuits to monitor different lamps or groups of lamps.

The circuit (figure 1) works by feeding the supply current to a lamp or group of lamps through the operating coil of a reed-relay. If a particular lamp fails, the current falls, causing the relay to drop out and the LED to turn off. The number of turns in the operating coil should be large enough to pull in the relay at the normal operating current of the lamp, yet small enough to cause the relay to drop out in the event of lamp failure.

Generally speaking, a relay requires from 30 to 100 AT (ampere turns = current x no. of turns). Thus, in view of the relatively high currents drawn by car lamps, in this particular application the operating coil need consist of only a few turns. For example, the two headlamps draw a current of approx. 7.5 A (at 12 V). A reed-relay rated at 50 AT would therefore require only 7 turns to monitor the current of both headlamps. If one of the lamps fails, then the current through the operating coil falls to about half, causing the relay to drop out and the LED on the dashboard to be extinguished. The circuit shown in figure 2 is an alternative version which makes the LED light up when a lamp needs replacing. This provides a more prominent warning — particularly in the dark. However the circuit in figure 1 is failsafe; even electronic circuitry does not have a limitless life . . .

To ensure that the warning system operates satisfactorily, it is recommended that a separate reed-relay is used to monitor lamps of differing wattage, i.e. a different relay for the rear lights, brake lights, headlamps etc. It is also possible to use a single relay to monitor both right and left turning indicators by using a double winding round the coil. However, it is not advised to use one relay to monitor a circuit or combination of circuits in which more than two lamps can be 'on' simultaneously.

If the circuit of figure 2 is used then the supply to the LED should be taken from the switched side of the lamp supply. This ensures that when the relay drops out due to the lamp being switched off the LED does not light, since its supply is also disconnected.

It is important to note that the gauge of wire used to wind the relay coil should be at least as heavy as that used in the original car wiring, to minimise the voltage drop across the coil and possible overheating. ◀

1

2
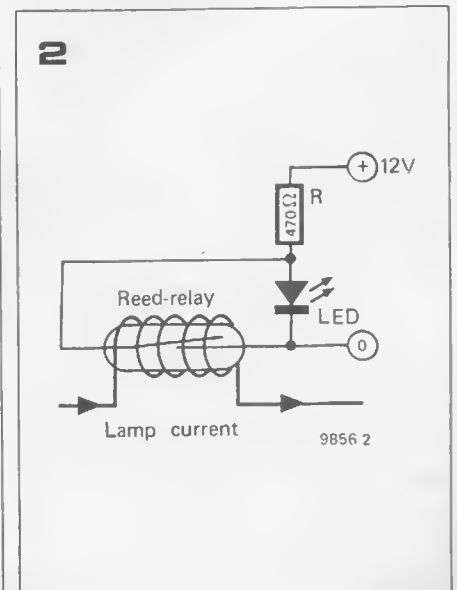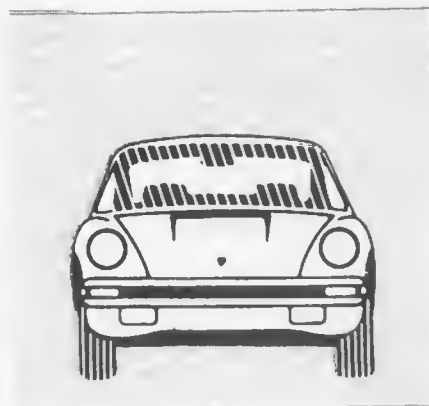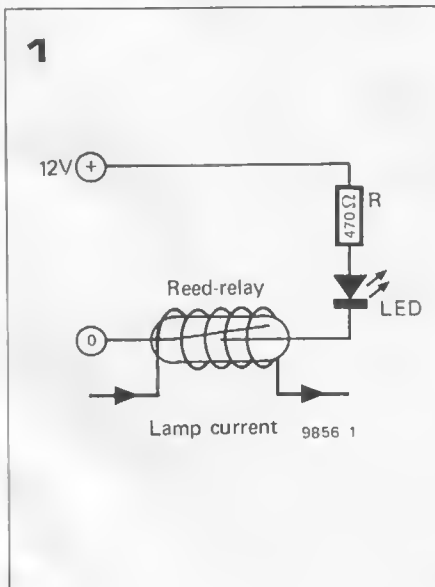
colour TV games

The oldest member of the family is the MM 57100, which was designed for use with the North American colour TV transmission system NTSC (National Television System Committee; an alternative interpretation is Never Twice the Same Colour). In several European countries, including Great Britain, the PAL (Phase Alternation Line, or Pay for Additional Luxury) system is currently employed for colour broadcasts, and National Semiconductor have introduced the MM 57105 for use with this.

Both 24-pin chips contain all the logic gating needed to generate the field of play, bats, ball, sound effects and score for three different games: Tennis, Hockey and Squash. In addition they supply the necessary chrominance information, so that in conjunction with the colour modulator IC LM 1889 (suitable for both NTSC and PAL) a colour picture is displayed on the screen. The circuit can equally well be used with a black-and-white receiver, although the picture obtained will, of course, not be in colour . . . . .

The third member of the family is the MM 57106. This IC is suitable for the NTSC system and offers a choice of six games. A PAL version of this chip is expected in the not-too-distant future, as well as a new NTSC IC which will offer 12 games. It should be noted that the 3, 6 or 12 games offered are fundamentally different: a 'practice' or 'solo' version of an existing game is not counted separately.

The descriptions given in this article are based mainly on the MM 57105, the PAL 3-game version. The modifications required for NTSC will be dealt with separately.

The vertical position of the bats is controlled by means of external slider- or rotary potentiometers. To vary the degree of difficulty of each game three different sizes of bat are available. For Hockey and Tennis, it is possible for one player to have a smaller sized bat than his opponent, thus providing an effective handicapping system for players of differing skill. In Squash, the size of the bat can also be modified, but in this case both players must use the same size of bat. To alter the size of

Playing games like tennis on a TV screen has become quite popular, and several manufacturers supply suitable integrated circuits. Regrettably, most of these ICs suffer from one drawback: built-in obsolescence! In a competitive market every manufacturer is bent on outdoing his competitor, either by offering a chip that will do the same job cheaper or by designing a chip that will offer more features for the same price: more games, on-screen scoring, sound, colour,... National Semiconductor have recently introduced a novel solution to this problem: a family of pin-compatible ICs, offering on-screen scoring, sound and colour (either NTSC or PAL), some interesting handicap features, and a growing number of games. This means that the same circuit and printed circuit board can be used with more versatile chips when they become available.
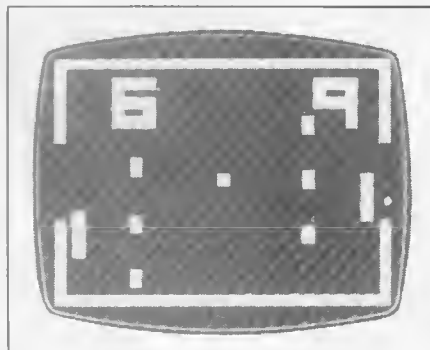
a bat it is first shifted to the extreme upper or lower edge of the screen and the reset button is then pressed. At each successive touch of the button the bat changes first from large to medium size, then from medium to small, and finally from small back to large. The reset button also has the function of zeroing the score counter (0 : 0).

A notable feature of this games chip is the amount of control afforded over the direction in which the 'ball' is struck. The bats are 'divided' into nine different sections, each of which reflects the ball at a particular angle (regardless of the angle that the ball was travelling before it hit the bat). The two sections in the middle of the bats will return the ball in the horizontal direction. The three sections above and below the centre of the bat reflect the ball towards the upper and lower side boundaries respectively. The nearer the ends of the bat the point of contact is, the steeper the direction of reflection becomes. Finally, the circuit has a last little trick, in that if one strikes the ball with the lower edge of the bat, then the ball is 'spun' upwards towards the wall at the top of the screen, simulating a 'wood' or handle shot.

When the ball strikes one of the boundaries or a machine-generated 'bat' as in Hockey, then the angle of reflection always equals the angle of incidence.

The circuit also generates bat/boundary 'hit' and scoring sounds, which are rendered audible via the audio stage and loudspeaker of the TV receiver. This means that a separate loudspeaker is not required.

The ball is always served by the player who won the last point. First the score is displayed for approximately 1.5 seconds; then it is automatically blanked and the ball is put into play. To allow for a more 'realistic' situation where the server can 'place' his shot, the ball is served from the bat. Note, however, that it leaves the bat at the same angle as the preceeding shot, so a certain amount of skill is required!

After the fourth stroke of a 'rally' the difficulty of the game is automatically increased by the speed of the ball being doubled.

When the score reaches 15 the game is

Both coils should be close wound. In order to be able to tune the oscillators when using these coils, capacitors C17 (82 p) and C19 (100 p) should be replaced by trimmer capacitors (2 . . . 27 p).

The outputs of these oscillators contain harmonics extending up into the UHF band, and for this reason a bandpass filter is included, consisting of R19 . . . R22, C22 . . . C27, L4 and L5. These coils may also be self-wound: using the same diameter and wire as for L2 and L3, 3 turns are required for L4 and 6 turns for L5. The passband of this filter lies between 50 and 70 MHz, which is just wide enough to allow through only channels 3 and 4 in the

ended and the automatic service is stopped. A new game can be started by pressing the 'reset' button.

A different game can be selected at any time by means of the 'game select' button. When this button is pressed repeatedly the chip steps through the possible games. This is one of the reasons why conversion at a later date to a 6- or 12-game version can be accomplished by simply inserting a new IC.

The circuit

Figure 1 shows the circuit diagram of the TV games system. The existing number of games can be extended to include 'solo' or 'practice' by moving switch S2 into the 'synchronous' position. Potentiometer P1 then ceases to affect the corresponding (right-hand) bat, both bats now being controlled synchronously by potentiometer P2. In this way it is possible to play against oneself.

In addition to the video-signal, the MM 57105 supplies the necessary colour information such as, e.g. the chroma and colour burst signals. The LM 1889 is a video modulator IC which combines all the functions of a colour signal mixer/modulator, reference frequency oscillator, sound channel oscillator/ modulator, composite video modulator and RF channel oscillator.

The stability of the chroma subcarrier frequency (which can be varied slightly by means of the trimmer capacitor C13) is maintained by the 4.433618 MHz crystal. The divide-by-3½ counter MM 53114 (IC2) divides down the oscillator frequency to 1.266748 MHz. (Note that for the NTSC version this IC will be replaced by the pin-compatible type MM 53104). This signal and its inverted form are then fed to clock inputs 13 and 15 respectively of IC1, where they are used to derive the line and field sync pulses.

The tunable oscillator coils L2 and L3, details of which are given in the parts list, may be replaced by self-wound air coils. The diameter of these coils should be 6 mm, with 9 turns of enamelled copper wire (0.9 mm dia., or 20 SWG) for L2 and 7 turns for L3.
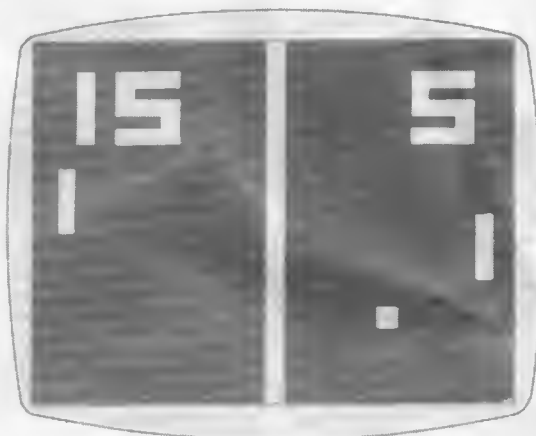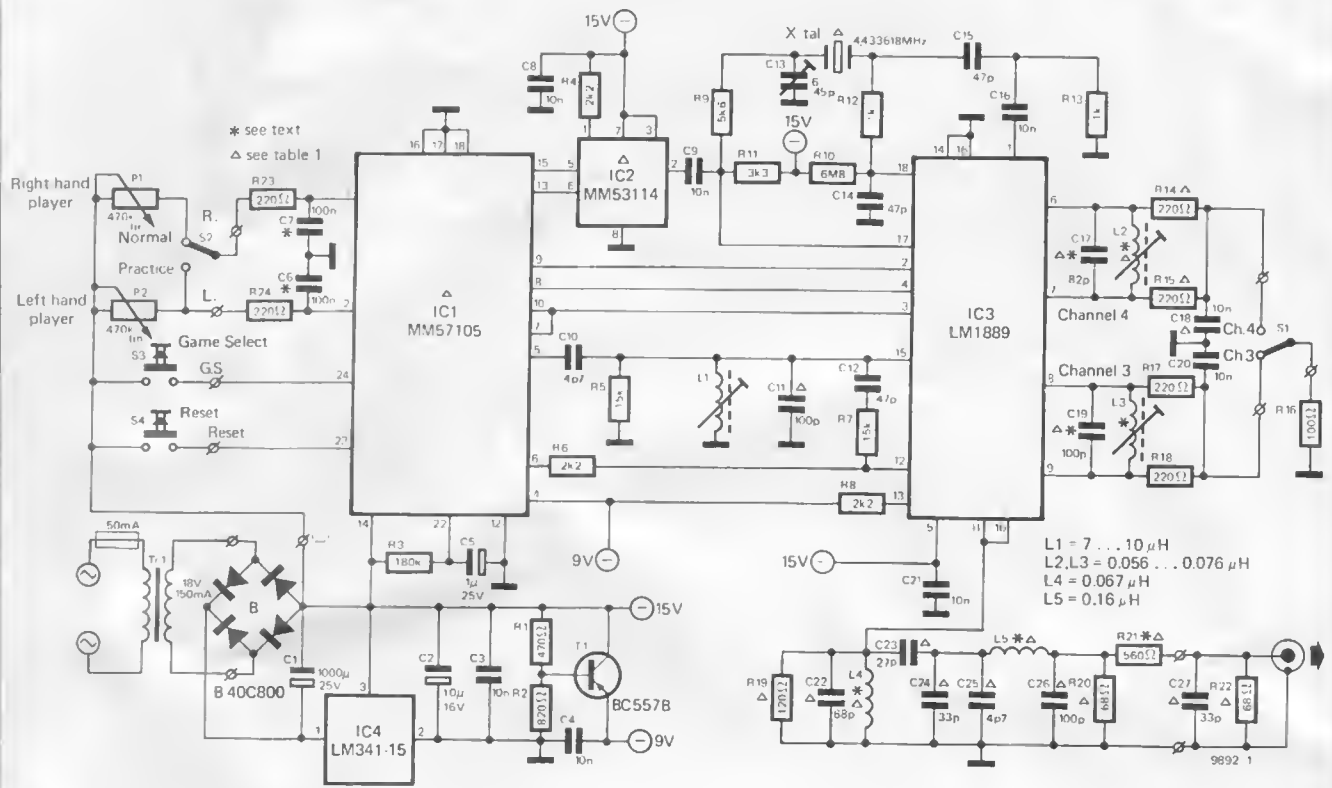
1

Figure 1. Complete circuit diagram of the basic (PAL VHF) version of the colour TV game.

Figure 2. Printed circuit board and component layout for the PAL TV game (EPS 9892).

Table 1. Component values and IC type numbers, insofar as they differ for the three versions of the game.

Table 1			
	PAL VHF	NTSC VHF	PAL UHF
R14,R15	220 Ω	220 Ω	—
R19	120 Ω	120 Ω	—
R20,R22	68 Ω	68 Ω	—
R21	560 Ω	560 Ω	w.l.
C11	100 p	150 p	82 p
C17+	82 p	68 p	—
C18	10 n	10 n	—
C19+	100 p	82 p	100 p
C22+	68 p	68 p	—
C23+	27 p	27 p	56 p
C24	33 p	33 p	180 p
C25	4p7	4p7	—
C26+	100 p	100 p	—
C27+	33 p	33 p	—
L2	as L3	as L3	—
L4	0.067 μH	0.067 μH	0.22 μH
L5	0.16 μH	0.16 μH	w.l.
IC1	MM 57105	MM 57100 or MM 57106	MM 57105
IC2	MM 53114	MM 53104	MM 53114
crystal	4.433618 MHz	3.579545 MHz	4.433618 MHz

— = omit;

w.l. = wire link.

+ All capacitors marked + should be NPO types. Note that C17 and C19 should be 2 ... 27 p trimmers if self-wound air coils are used for L2 and L3 (see text); for the PAL UHF version C19 is 33 p (fixed) in this case.

2
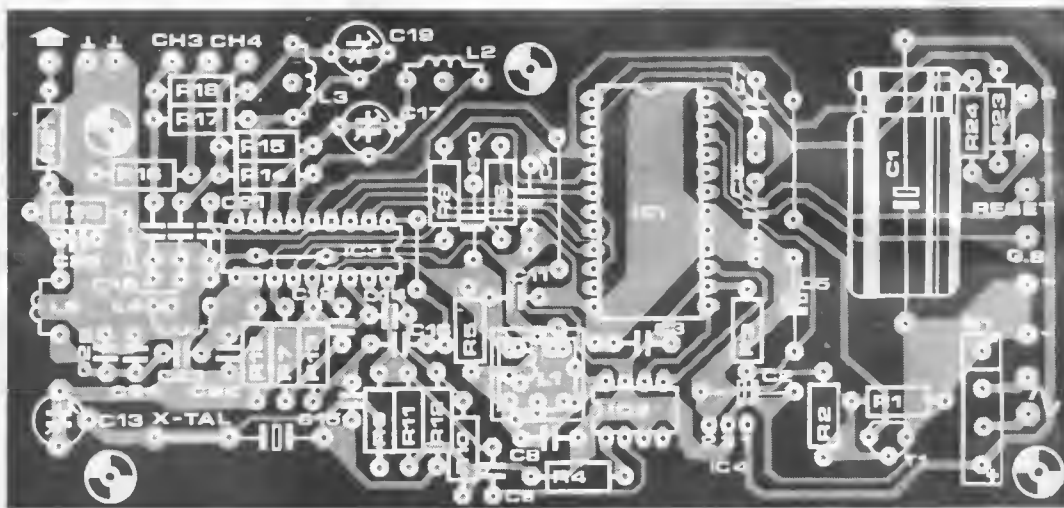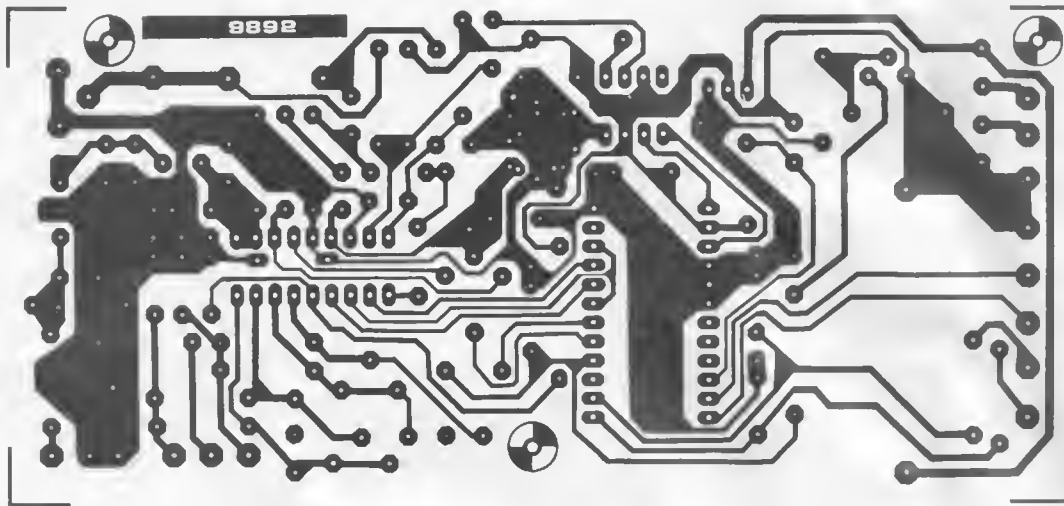
Parts list to figures 1 and 2:

Resistors:
R1 = 470 Ω
R2 = 820 Ω
R3 = 180 k
R4,R6,R8 = 2k2
R5,R7 = 15 k
R9 = 5k6
R10 = 6M8
R11 = 3k3
R12,R13 = 1 k
R14,R15 = see Table 1
R16 = 100 Ω
R17,R18,R23,R24 = 220 Ω
R19,R20,R22 = see Table 1
R21 = see text and Table 1
P1,P2 = 470 k (lin) potentiometer

Capacitors:
C1 = 1000 μ/25 V
C2 = 10 μ/16 V
C3,C4,C8,C9,C16,
C20,C21 = 10 n
C5 = 1 μ/25 V
C6,C7 = 100 n (see text)
C10⁺ = 4p7
C11⁺ = see Table 1

C12⁺ = 47 p
C13 = trimmer 6 . . . 45 p
C14⁺,C15⁺ = 47 p
C17⁺,C19⁺ = see text and Table 1
C18,C22⁺,C23⁺,C24,C25,
C26⁺,C27⁺ = see Table 1

Coils:
L1 = 7 . . . 10 μH (Toko 7 A6199
    or equ.)
L2 = see Table 1
L3 = 0.056 . . . 0.076 μH (Toko
    M 20070 or equ.) or self-
    wound air coil (see text)
L4 = 0.067 μH (Toko 521
    GN-3T or equ.) or self-
    wound air coil (see text and
    Table 1)
L5 = 0.16 μH (Toko 521 GN-6T
    or equ.) or self-wound air
    coil (see text and Table 1)

Semiconductors:
T1 = 8C 557B, BC 1778, or equ.
IC1,IC2 = see Table 1
IC3 = LM 1889
IC4 = LM 341-15
8 = B 40C800 (bridge rectifier)

Miscellaneous:
Tr = transformer 18 V/150 mA
S1,S2 = switch SPDT (S1 not
    required for PAL UHF
    version)
S3,S4 = pushbutton switch SPST
coaxial socket 60 Ω (or 75 Ω)
quartz crystal, see Table 1
fuse 50 mA

Note: capacitors marked ⁺ should
preferably be NPO types.

3
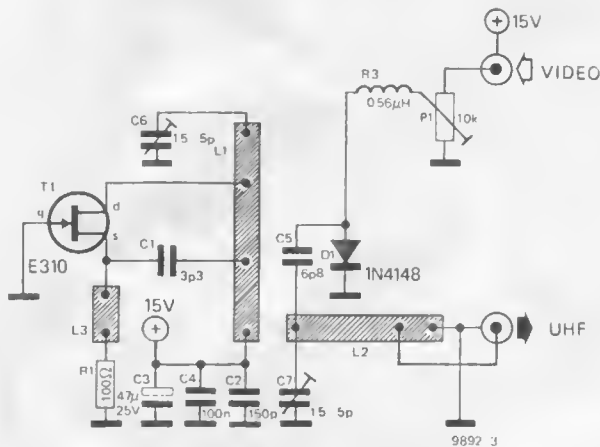
Parts list to figures 3 and 4:

Resistors:
R1 = 100 Ω
R2,R3 = 3k9
P1 = 10 k preset
P2 = 1 k preset

Capacitors:
C1 = 3p3
C2 = 150 p
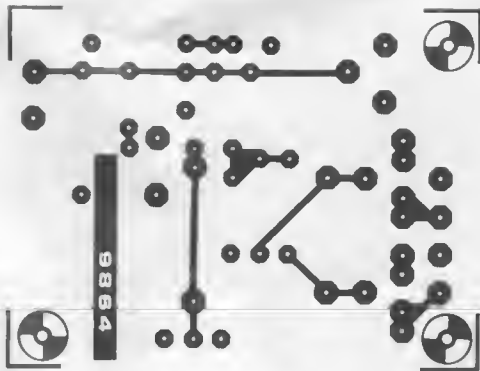C3 = 47 μ/25 V
C4 = 100 n
C5 = 6p8
C6,C7 = trimmer 1.5 - 5 p

Semiconductors:
T1 = FET E 310
D1 = 1N4148

Miscellaneous:
L1,L2,L3 = striplines on p.c.board

4
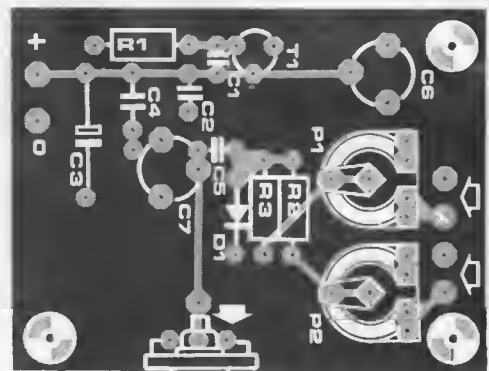
VHF band. This output is suitable as it stands for use on the European continent. However, in Great Britain 'up-conversion' to the UHF band (channels 21 ... 68) is required, and a suitable circuit will be described further on.

The frequency of the sound carrier is determined by the resonant circuit L1/C11, and can be tuned exactly by means of L1.

By lowering the value of capacitors C6 and C7 it is possible to reduce the range over which the bats may be moved up and down on the screen.

The −15 V and −9 V supply voltages which are needed for IC1 ... IC3 are obtained by means of a 15 V voltage regulator (IC4) and transistor T1. The regulator should be fitted with a heat sink. The metal housing of the game can also be used as a heat sink if the tab of the regulator is insulated using a mica washer. At 150 mA, the current consumption of the circuit is relatively small. Any transformer with a secondary voltage of 18 V will prove suitable.

Construction, general comments

A suitable printed circuit board design is given in figure 2. Regrettably, there is a minor error in the component layout: the indications 'GS' (Game Select) and 'Reset' at the right-hand edge of the board are transposed. When constructing the circuit the use of IC sockets is strongly recommended. IC2 is particularly sensitive to static charge and the appropriate precautions should be taken.

To prevent the circuit producing too much RF interference it should be housed in a screened metal case. The only earth connection between the board and the metal case should be at the coaxial output socket (see photo 1). The leads between the socket and the RF output on the board should be as short as possible. If the basic VHF version is used then R22 and C27 should be soldered direct to the socket. The cables to the control handsets and the 'Reset' and 'Game Select' switches are not critical, so they need not be screened. A 60 Ω coaxial cable should

be used to connect the output socket to the TV aerial input.

The description given so far has been sufficiently general to be basically valid for all versions of the game. However, when it comes to actually getting it to work in various parts of the world each version must be dealt with separately. For most of the European continent (with the notable exceptions of U.K., Ireland and France) the basic PAL VHF system is required. For the United States and Canada there is a similar NTSC VHF system. The U.K. and Ireland, however, need a PAL UHF version. All three versions will now be dealt with individually.

PAL VHF version

The circuit diagram given in figure 1 is valid for the PAL VHF version of the game. The various frequencies required are as follows:

Sound channel: 5.5 MHz;
Colour frequency: 4.43361875 MHz;
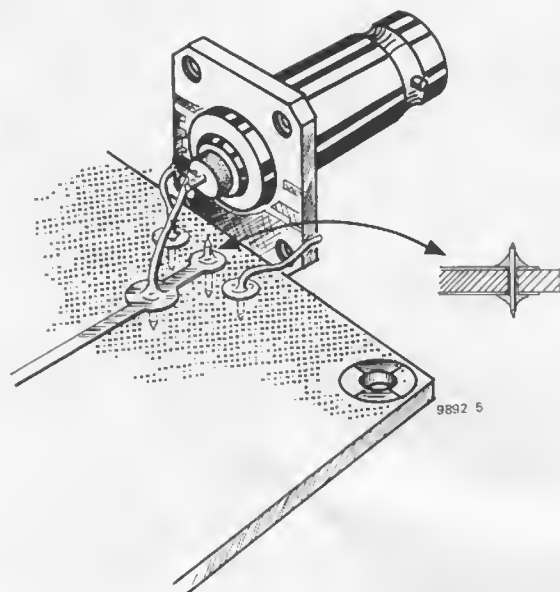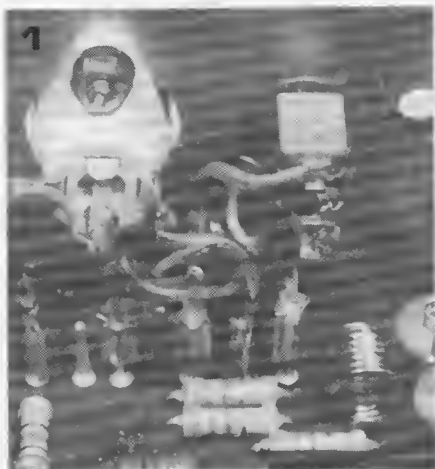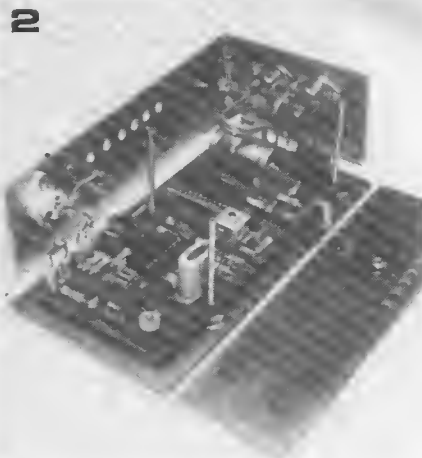Channel 3: 55.25 MHz;
Channel 4: 62.25 MHz.

The necessary IC types and component values can be found from the parts list and Table 1.

Tuning the circuit should not present too much of a problem:

● First tune the TV receiver to channel 3 in the VHF waveband, switch S1 to 'channel 3', then adjust L3 (or C19) until the picture appears on the screen. The TV channel control can then be used to provide fine adjustment.

● If the input sensitivity of the receiver proves insufficient (so that there is too much noise or 'snow' in the picture), then the value of resistor R21 should be reduced.

● Adjust C13 until a colour picture is obtained.

● Tune the TV receiver to channel 4 in the VHF waveband, switch S1 to 'channel 4', then adjust L2 (or C17) until the colour picture appears on the screen. Once again, the TV channel control can be used for fine adjustment.

Note that if a strong local broadcast transmitter is operating on the same frequency, then this may cause 'ghosting' or even poor synchronisation. To check for this, switch off the TV games unit, leaving it connected to the receiver. If a (weak) picture from the broadcast transmitter is now visible, the TV channel control can be used to tune it out. The TV games unit is then switched on again and L2 or L3 (or C17 or C19) is readjusted until the colour picture is once again obtained.

● To tune in the sound carrier, the volume control on the receiver is turned up a little and L1 is then adjusted until the noise from the loudspeaker is reduced to a minimum.

NTSC VHF version

For the NTSC version, the circuit diagram shown in figure 1 is basically correct. However, several component values and IC types should be modified as detailed in Table 1. The various frequencies required in this case are as follows:

Sound channel: 4.5 MHz;
Color frequency: 3.579545 MHz;
Channel 3:   61.25 MHz;
Channel 4:   67.25 MHz.

The alignment procedure is identical to the procedure outlined above for the PAL VHF version.

A special problem exists in the United States: the FCC regulations. These are among the most stringent in the world, and in order to comply with them extreme care must be taken when constructing the unit. Extensive details are given in the National Semiconductor publication number FEPM-0034/377 (CN-1) and only a brief summary can be given here.

The complete unit, with the possible exception of the player handsets and Game Select and Reset pushbuttons, must be housed in an RF-tight enclosure. This enclosure can be made from galvanized or tin-plated steel, or from printed circuit board material. All corners should be tightly formed and preferably soldered, allowing no gaps which could result in RF leakage; a tight-fitting lid is absolutely necessary. Feed-through capacitors should be used in the connections to the player control

handsets, Game Select and Reset pushbuttons, and power supply connections.

To fully comply with FCC regulations, a TV game antenna switchbox should be used. This is basically a selector switch, bc means of which it is possible to select either the TV game signal or the normal antenna; it must provide a minimum of 60 dB isolation to the non-selected input. These units can be purchased as a sub-assembly from various suppliers, however for the home constructor a much cheaper solution is to plug the desired programme source into the TV set . . .

The only other regulation that needs to be considered here states that all RF signals appearing more than 3 MHz outside the standard TV channel band must be attenuated by at least 30 dB relative to the peak envelope power of the wanted RF signal. There are two ways of meeting this demand. The first (and easiest) is to tune the unit approximately 1.5 MHz high with respect to the standard TV channel frequencies. The channel 3 and 4 outputs are thus tuned to 62.75 MHz and 68.75 MHz respectively. The second possibility is to replace the output filter (R19 . . . R22, C22 . . . C27, L4 and L5) by a so-called Surface Acoustic Wave filter and one or two other components. Full details of this modification are given in the National Semiconductor publication mentioned earlier.

PAL UHF version

For use in the UK and Ireland, a few modifications are required to the basic PAL VHF version. Furthermore, a VHF-to-UHF converter must be added. The required frequencies are as follows:

Sound channel: 6.0 MHz;
Colour frequency: 4.43361875 MHz;
Output frequency: 470 . . . 500 MHz
                (channels 21 . . . 25).

The necessary IC types and component values can be found from the parts list and Table 1. Components R14, R15, C17, C18, L2 and S1 may be omitted; the top of R16 is connected to the R17/R18/C20 junction by means of a wire link (in place of S1). L3 may be set in the middle of its range; if a self-wound air coil is used (as described earlier) C19 may be replaced by a 33 p fixed capacitor, since the VHF output frequency is unimportant and need not be adjusted.

The output filter can also be simplified: R19, R20, R22, C22 and C25 . . . C27 are omitted, L5 and R21 are replaced by wire links, L4 becomes 0.22 μH (or a self-wound air coil consisting of 9 turns), C23 becomes 56 p and C24 becomes 180 p.

A suitable circuit for a VHF-to-UHF converter was published in Elektor 32, December 1977, p. 12-20: the UHF TV modulator. One or two minor modifications are required: R3 is replaced by

C19 = 100 p, L3 = 0.056 . . . 0.076 μH
or
C19 = 33 p, L3 = selfwound air coil
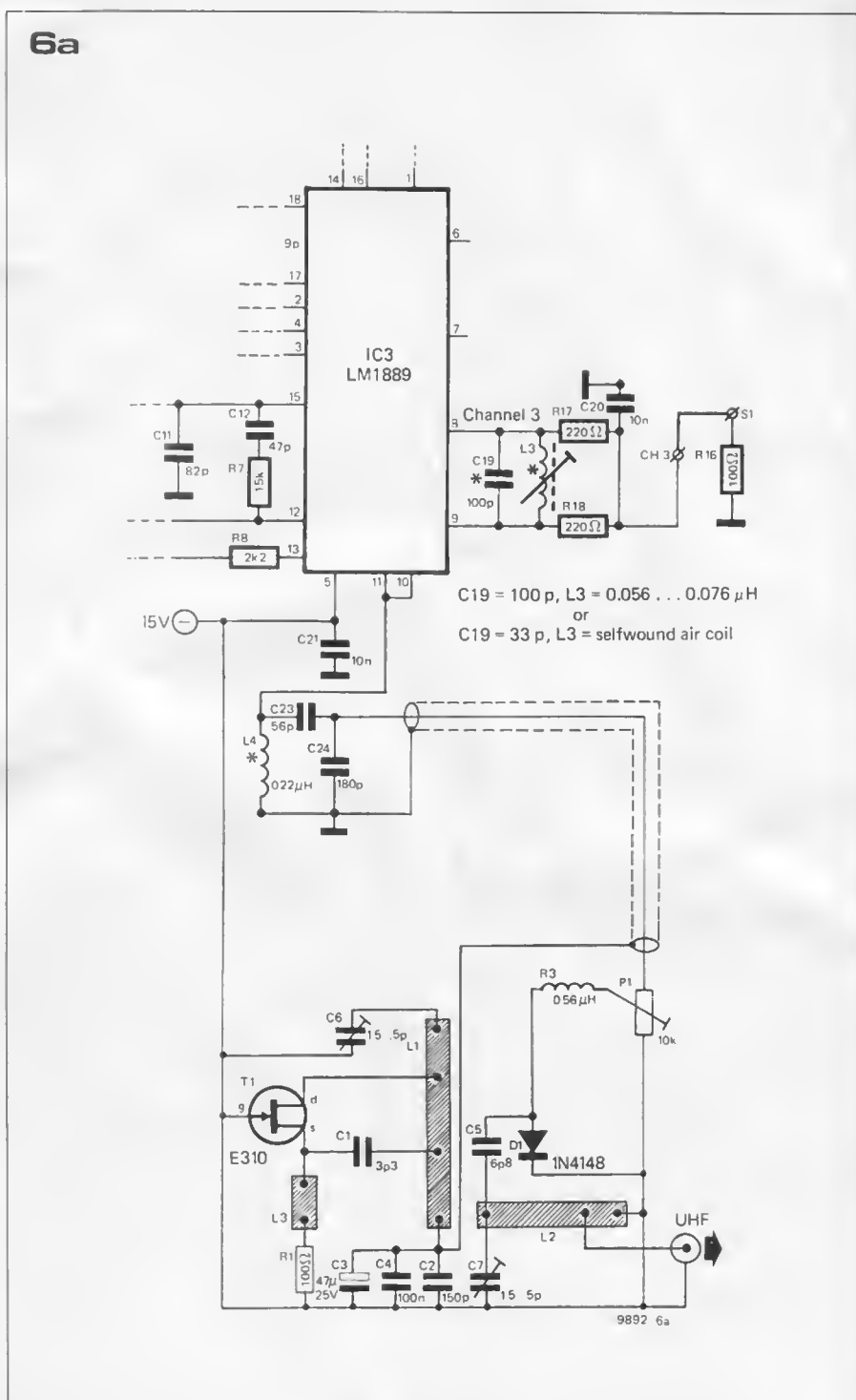
a 0.56 μH inductor and R2 and P2 may be omitted. The modified circuit is shown in figure 3, and the printed circuit board and component layout are given in figure 4. As stated in the original article, home production of this p.c.board is not recommended. It should also be noted that the components are mounted on the same side of the board as the copper track pattern. It is absolutely essential that all component leads should be as short as possible.

One important detail could not be made clear on the component layout: the right-hand end of stripline L2 should be connected to supply common on the board, as shown in figure 3. This is achieved by inserting a piece of wire in the hole underneath the coaxial socket, and soldering it to both sides of the p.c.board (see figure 5). It is strongly recommended to do this *before* mounting the socket!

When interconnecting the boards, careful attention should be paid to the power supply connections. The TV games board has 'supply common' and '−15 V' outputs, whereas the UHF modulator requires 'supply common' and '+15 V' inputs. To achieve this, the supply common output from the TV games board must be connected to the '+15 V' input on the modulator board, and the '−15 V' output from the TV games board must be connected to 'supply common' on the modulator board. In other words, supply common on one board is *not* 'supply common' on the other!

6b
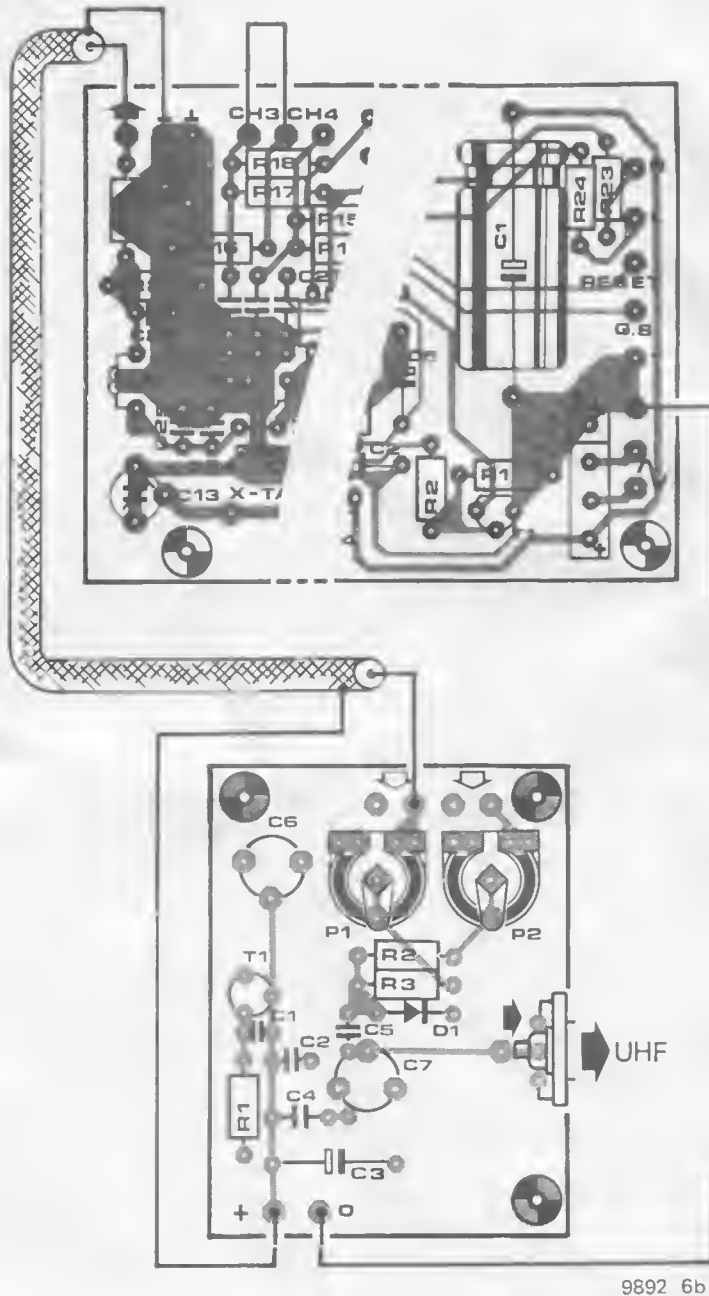
9892 6b

The correct way to interconnect the two boards is shown in figure 6. In figure 6A, the upper part of the circuit shows IC3 and the modified output filter section on the TV games board; the lower part is the (modified) circuit of the UHF modulator. The three connections between the two boards are shown in figure 6B: the output of the TV games board is connected to one input of the modulator board via coaxial cable; the screen of the coax is connected to supply common on the TV games board and *to the '+' input of* the modulator board; the '−' output of the TV-games board is connected to the '0' input of the modulator.

Both units should be mounted inside a screened box. A 75 Ω BNC or TV coaxial socket can be used as the UHF

output connector, and it should be mounted directly on the modulator board in the position shown. The ground connection between the circuit and the screened box must be made only at this output socket. Note that this implies that the box is connected to the '−15 V' supply of the TV games board, not its 'supply common'!

The alignment procedure in this case is as follows:

● Tune the TV receiver to an unoccupied frequency at the 'low' end of the UHF band — i.e. near channel 21.

● Set P1 on the modulator board to maximum (fully anti-clockwise).

● Starting from the minimum capacitance setting of C6 on the modulator board, adjust this trimmer slowly

until a clean TV games picture appears on the screen. Note that the modulator produces two strong sidebands, a strong carrier, and several weaker sidebands. Only one of these is the correct signal!

● Adjust C7 on the modulator board for maximum signal strength.

● If necessary, turn back P1 on the modulator board to reduce the signal strength.

● Adjust C13 on the TV games board until a satisfactory colour picture is obtained.

● To tune in the sound carrier, turn up the volume control on the receiver and adjust L1 until the noise from the loudspeaker is reduced to a minimum.
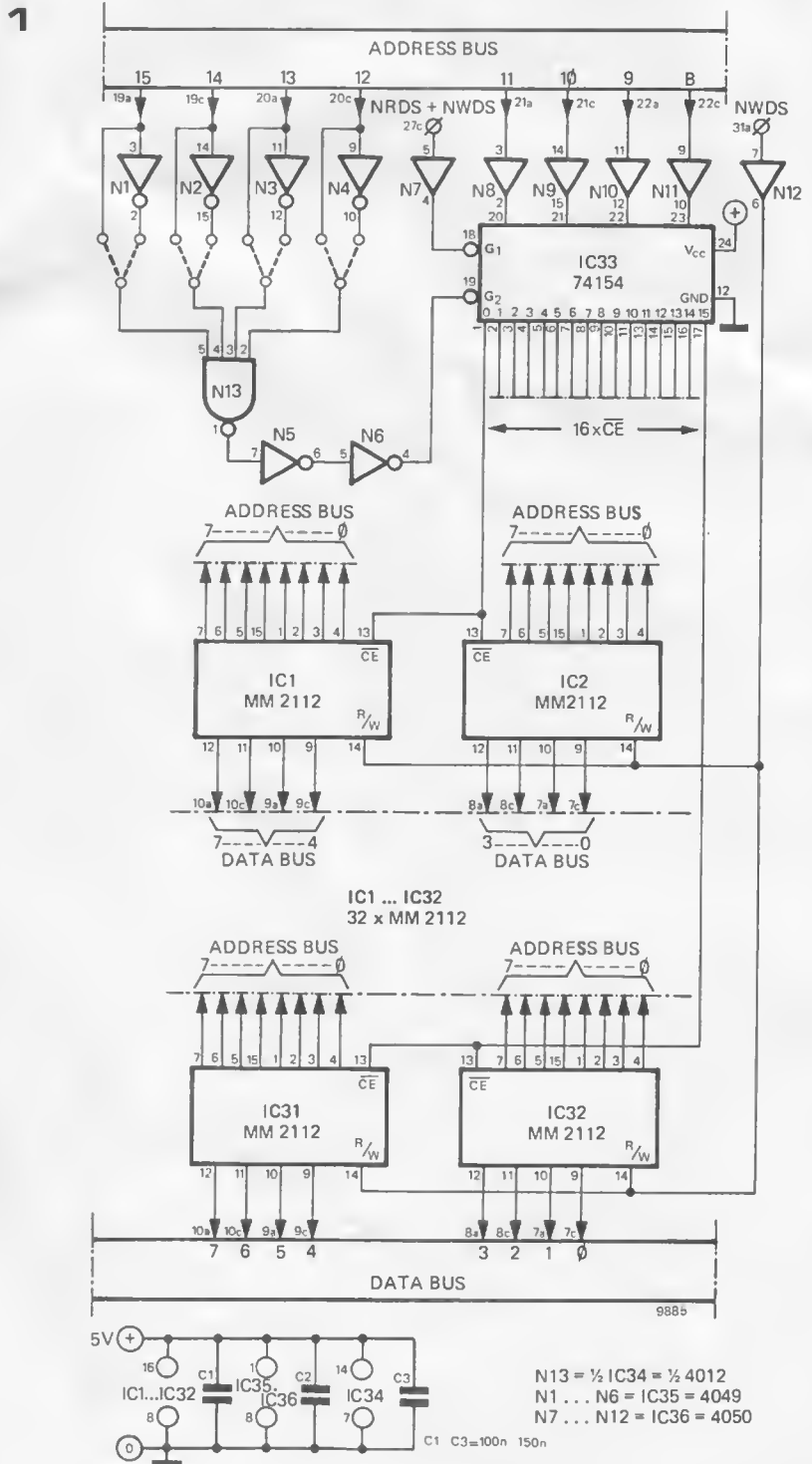
4-k RAM card

In order to expand the memory capacity of microcomputers use is often made of plug-in memory cards. The RAM card described in this article is primarily intended as an extension of the SC/MP system, however it can also be used with any 8-bit microprocessor.

The memory card consists of up to 32 RAMS, type 2112. This is a 256 x 4 bit memory, i.e. to obtain a 4-k RAM (4096 x 8 bits) all 32 ICs would be required. The circuit diagram of the memory card (see figure 1) shows only the first two (IC1 and IC2) and last two (IC31 and IC32) RAMs. The chip-enable inputs of the RAMs are activated by the outputs of a binary to hexadecimal decoder (IC33) which functions as an address decoder. In order to reduce the loading on the address bus to a minimum, MOS buffers are used on the lines to the address decoder. Of the two chip-enable inputs of the address decoder (G1 and G2 of IC33), one is activated by the read- or write strobe (NWDS + + NRDS), the other by the four highest address bits. These four address bits, whether inverted or not, are fed to the NAND gate N13. In order to address the RAM card all four inputs of this gate must be at logic 1. If the address of the RAM card when used in a particular system is, e.g. 2000...2FFF, that means that inputs 5, 4 and 2 of N13 should be connected to the outputs of N1, N2 and N4 respectively, whilst input 3 of N13 is connected direct to bit 13 of the address bus. Thus by altering the 'wiring' in this way the RAM card can occupy any desired page in memory.

The entire RAM card can be powered from a 5 V supply; the current consumption of the card is approx. 1 A.

Printed circuit board

A printed circuit board was designed to accommodate all the various com-
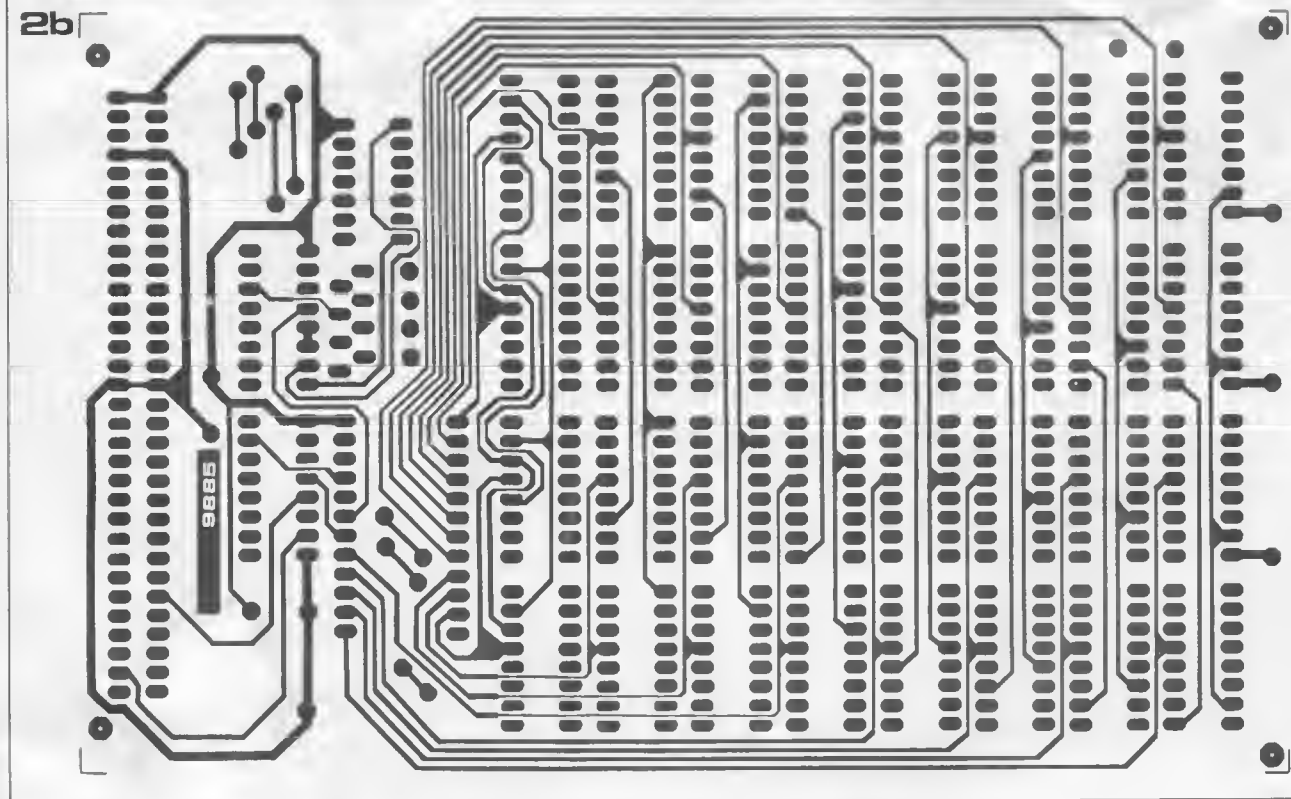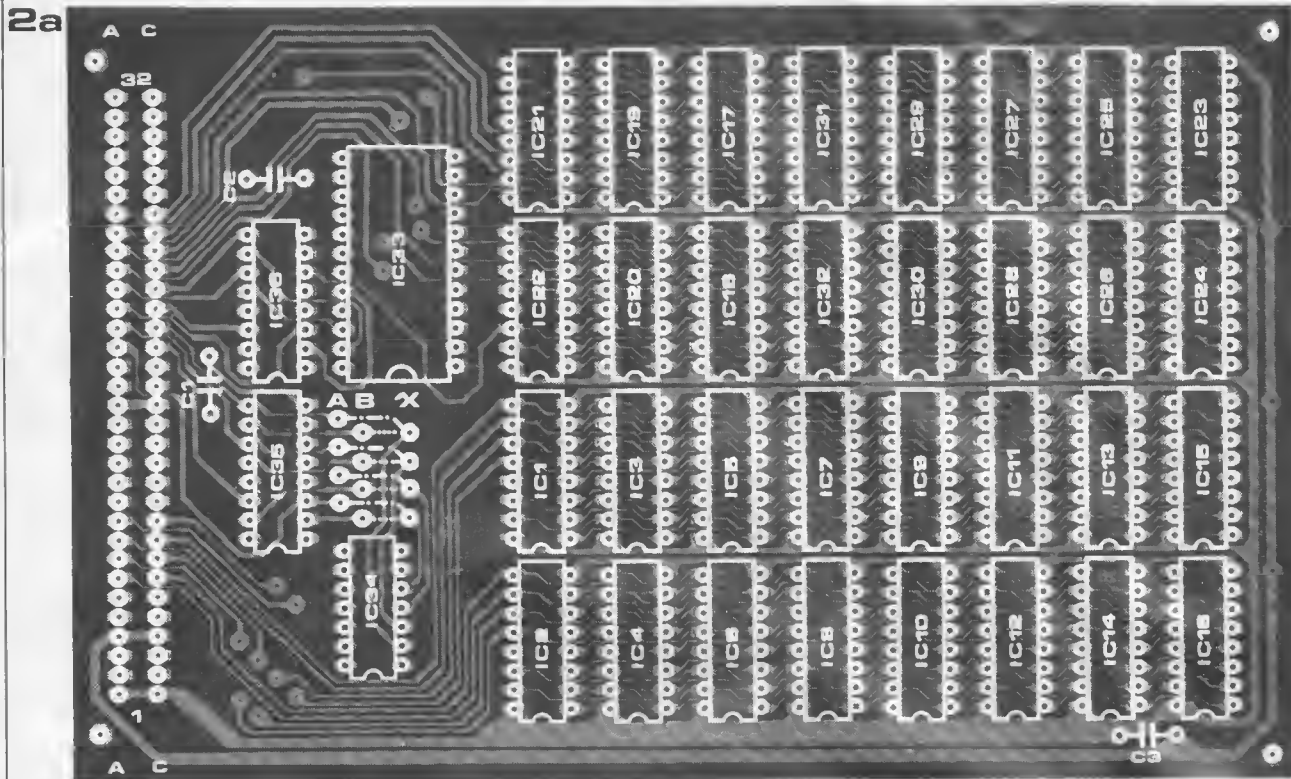

1

2a

2b

Figure 1. The circuit diagram of the 4-k RAM card. For the sake of clarity only four of the possible total of 32 RAMs are shown here.

Figure 2. The top (2a) and bottom (2b) sides of the printed circuit board for the RAM card (EPS 9885). The board conforms to Eurocard dimensions.

Parts list

Semiconductors:
IC1 . . . IC32 = 2112 (National, Intel, Texas Instr. etc.)
IC33 = 74154
IC34 = 4012
IC35 = 4049
IC36 = 4050

Capacitors:
C1 . . . C3 = 100 . . . 150 n

Miscellaneous:
DIN 41612 connector (64 way, 3 rows, rows A and C loaded)

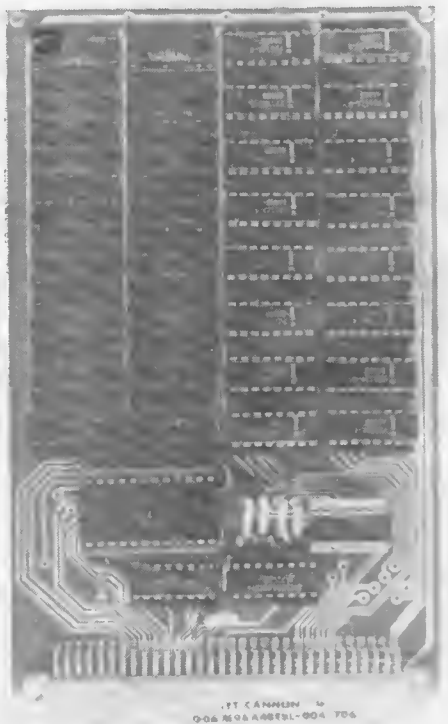Figure 3. The RAM card housing 2 k of RAM.

fun with a RAM

(M. de Bruin)

ponents on the card along with a 64 way connector (DIN 41612). Figures 2a and 2b show both sides of the board. As with the majority of the SC/MP p.c.b.s, this board is also double-sided with plated-through holes. Figure 1 shows the connections for the address-, data- and strobe-inputs and outputs. The positive supply rail is connected to pins 1a and 1c of the connector, whilst the earth rail goes to pins 4a, 4b, 16a and 16b.

The choice of page address can be made on the board by means of wire links. The solder pads below the 'A' are connected direct to the address bus. Points 'B' connected to the address bus via inverters N1 . . . N4, whilst points 'X' coincide with the inputs of N13. Depending upon the address which is required, each of the points below 'X' is connected to a point under either 'A' or 'B'.

Finally, figure 3 shows a prototype of the card. As is apparent from the photograph, the card need not be completely filled with RAMs, since it is unlikely that such an extensive memory will prove necessary (to say nothing of the cost involved).

With 16 RAMs, the card in figure 3 represents a 2 k memory. It is possible to fill the card in steps of 1/4 K. The only point to notice is that the numbering of the memories shown on the component layout should be adhered to.

The following circuit is intended as a simple illustration of how to interface peripheral 'hardware' with a RAM.
Random Access Memories (RAMs) are usually used in microprocessor applications where the data to be stored must be changed or modified easily. Static RAMs, like the one used in this circuit, use the inherent storage capability of a bistable device such as the flip-flop. A static RAM will store information until the information is changed or until the power to the device is switched off.

Basically this circuit lights up four LEDs in a predetermined (programmed) sequence. There are 16 steps in this sequence, since the RAM (IC3) is a 16 x 4 bit device. The BCD address inputs, pins 1, 13, 14 and 15, are connected to the outputs of a four-bit binary counter (IC2). The clock input to the counter is driven by an oscillator circuit (T1, N1). Each time this 'clock' generates a pulse, the binary counter steps to the next higher BCD number which in turn steps the RAM to the next address location. The speed with which the unit steps through the

address locations is determined by the clock frequency; this can be adjusted by P1. The RAM outputs are open collector and hence can drive the LEDs directly.

To programme the RAM, switch S1 is put in the 'write' position. The new programme is determined by the setting of switches S4 . . . S7. A binary one ('1') corresponds to an open switch, due to the pull-up resistors R7 . . . R10.

When S3 is pressed the binary counter is reset to zero (BCD: 0000). The programme switches S4 . . . S7 are now set to the desired positions for the first step in the sequence. Pressing S2 causes the counter to advance one step, after which the new programme switch settings should be set. Each time S2 is pressed the counter steps to the next address location.

After the programme is completed (all 16 steps of the desired sequence have been written into the RAM) switch S1 should be switched to 'read'. This will start the programme.

As is always the case with RAMs, when the power is switched off the programme is lost.
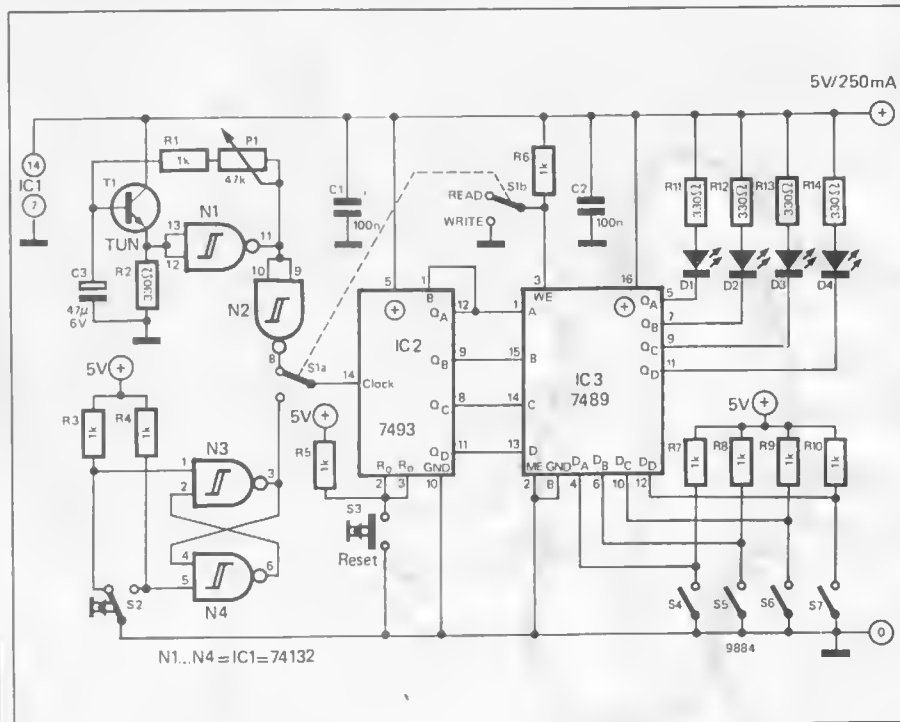
electronic maze

The problem in most mazes is simply to find the way out, with no account being taken of the number of false steps made. Part of the novelty of this electronic labryrinth is that it counts the number of incorrect steps made. The maximum number of errors permitted can be preset to 10, 20, 40 or even 80. If the hapless victim has failed to find his way out of the maze before reaching the preset limit, an audio tone sounds to indicate that he has lost. The number of steps taken to escape from the labyrinth is indicated on a digital display so that successful contenders can compare their scores, the one with the lowest score obviously winning.

The maze itself consists of a matrix of drawing pins or furniture tacks on the playing board. All pins that lie along the correct path are linked and connected to positive supply, whilst other pins are grounded. The path through the maze is traced using a probe wired to the input of the error counter. So long as the correct path is followed the counter input will remain high, but whenever a false step is taken the counter input will receive a low-going pulse and will advance.

Complete circuit

The major part of the maze circuit consists of a two decade counter, which is shown in figure 1. The probe, which can be a 'banana' plug or may be made from an old ballpoint pen, is connected to the input of Schmitt trigger N2. So long as the probe input is high or floating (not grounded) the input of N2 will remain high. If the probe is grounded the input of N2 will be pulled low. The output of N1 will then go low, clocking the counter IC4. The filter network R4/C2 connected at the input of N2 helps suppress noise generated by 'contact bounce' between the probe and the drawing pins. This bounce could cause the counter to advance several counts for only one wrong step.

When the counter reaches a predetermined number, selected by S1, the appropriate output of the second decade counter (IC3) will go high. The oscillator constructed around N4 will then produce an audio tone to indicate that the contestant has lost. This tone is amplified to loudspeaker level by T1

Whether they are formed by garden hedges or walls, galleries of mirrors or simply lines on paper, mazes have always proven a popular pastime for all ages. The 'electronic maze' described in this article provides an extra 'twist' to the problem of finding the correct path through the maze.

D. Neubert
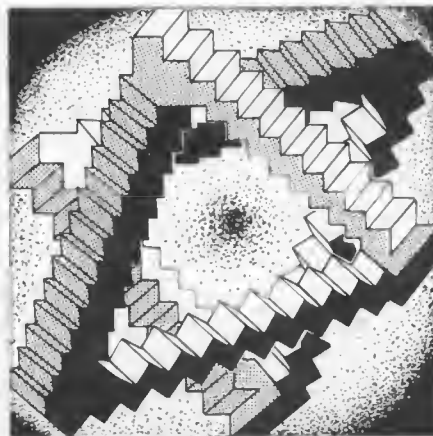
and T2. The volume can be adjusted by changing the value of resistor R3. The counter is reset to zero at the start of the game by a pushbutton switch, S2.

Two 7447 BCD-to-seven-segment decoders (IC1 and IC2) drive the seven-segment displays which indicate the number of errors made.

Multiple exits

A maze with only a single path would quickly lose its entertainment value. This can be avoided by providing multiple exits from the maze. To achieve this, several paths are provided to exit points around the periphery of the maze. However, these are not permanently wired to positive supply, but each path is linked to positive supply only when it is in use, and all other paths are grounded. Light-emitting diodes mounted around the edge of the playing board indicate which exit is being aimed for.

The switching circuit used to select the paths of a four-exit maze is shown in figure 2. When exit D1 is selected, for example, then output D1 of the switching circuit is high. All points in the path leading to exit D1 only are linked to output D1. Provision is also made for connecting points that are common to two paths. For example, output A is high when output D1 is high and when output D4 is high (see table 1). Any points common to both these paths should be linked to output A. Output B performs a similar function for outputs D2 and D3. It is important that any points common to two paths should be linked to A or B and not back to any of the D outputs, as this would mean that one of the outputs would be trying to pull these points low while the other was trying to pull them high.

Provision is not made for connecting points that are common to three or more paths. Such points should be avoided when drawing the maze, but if any such points are unavoidable they should be treated as 'dead' points and left floating.

Constructing the maze

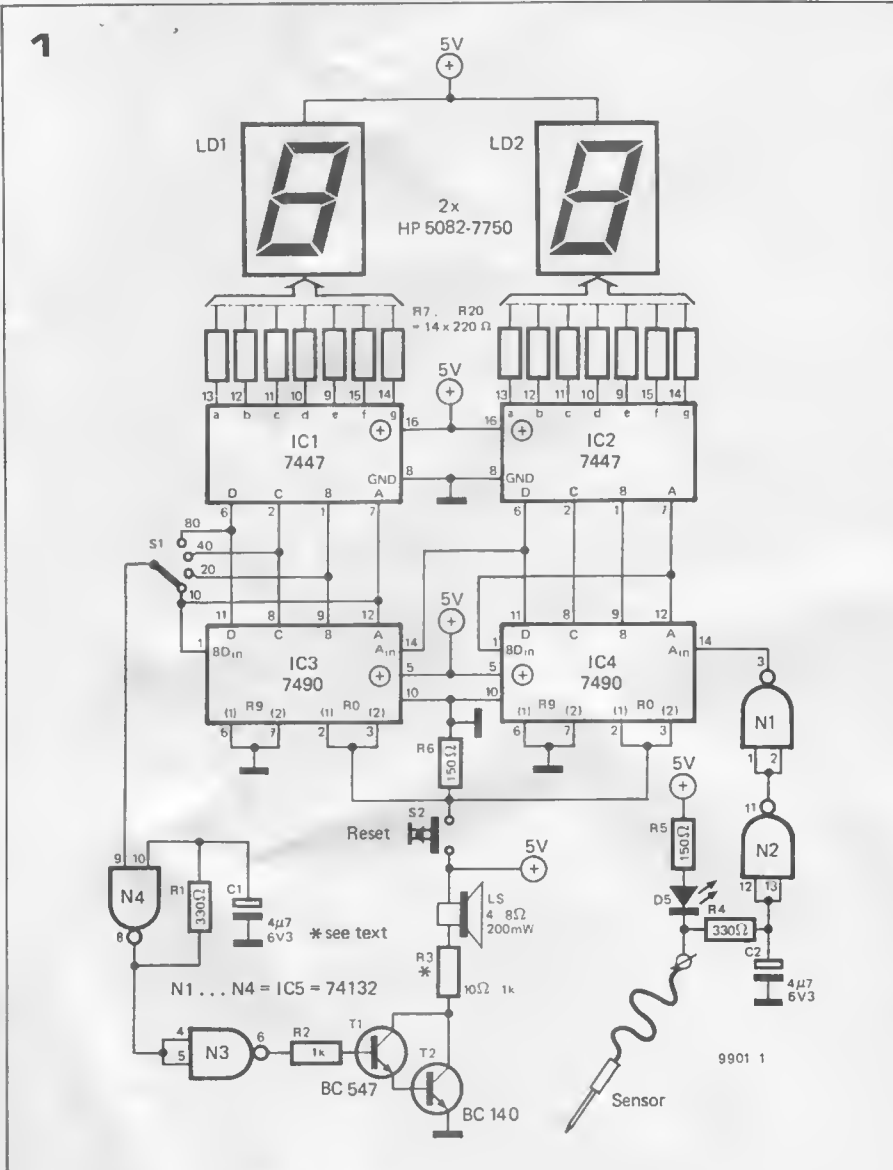The construction of a 14 x 14 point maze is illustrated in figure 3. To con-

Figure 1. Circuit of the counter and audible warning oscillator, which forms the major part of the maze electronics.

Figure 2. This gating circuit provides four different exits from the maze by taking the required path high and all other paths low.

Figure 3. A typical layout for a 14 x 14 maze, with the four exits at the corners.

Figure 4. Mains power supply for the maze circuit.

Table 1. This table illustrates the four possible combinations of S3 and S4, and the state of the outputs that define which path through the maze is active.
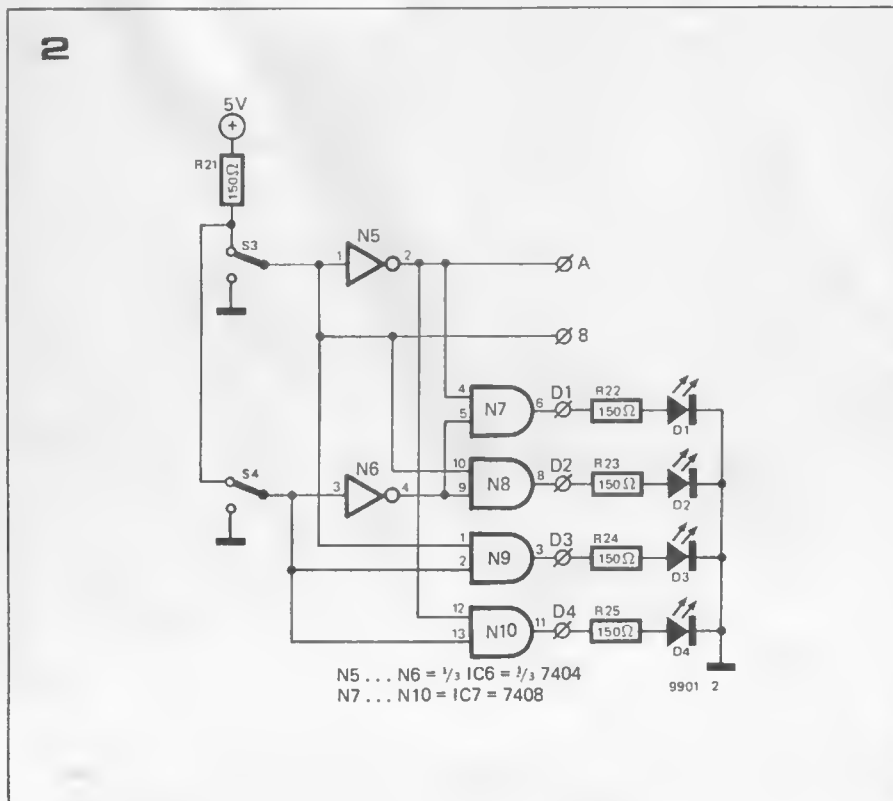
struct the maze a sheet of squared (e.g. graph) paper is glued to a playing board made of suitable material such as strong card (Bristol board) or thin plywood. Drawing pins or furniture tacks are then pushed through the paper and the baseboard to form a matrix. It is important that the spacing between the heads of the tacks should be such that it is not possible to move the probe from one to the next without breaking contact.
On the underside of the board all tacks which form part of a path through the maze should be linked together and connected to the appropriate points (D1 to
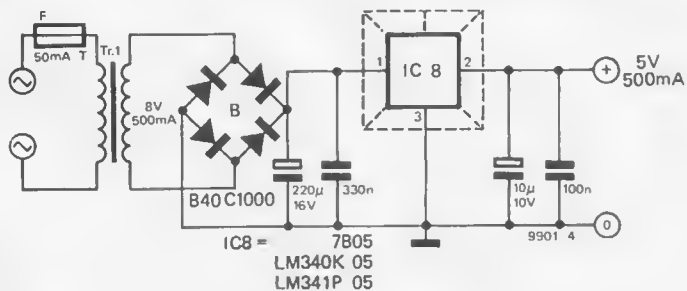
3

9901 3

4

IC8 = 7805
LM340K 05
LM341P 05
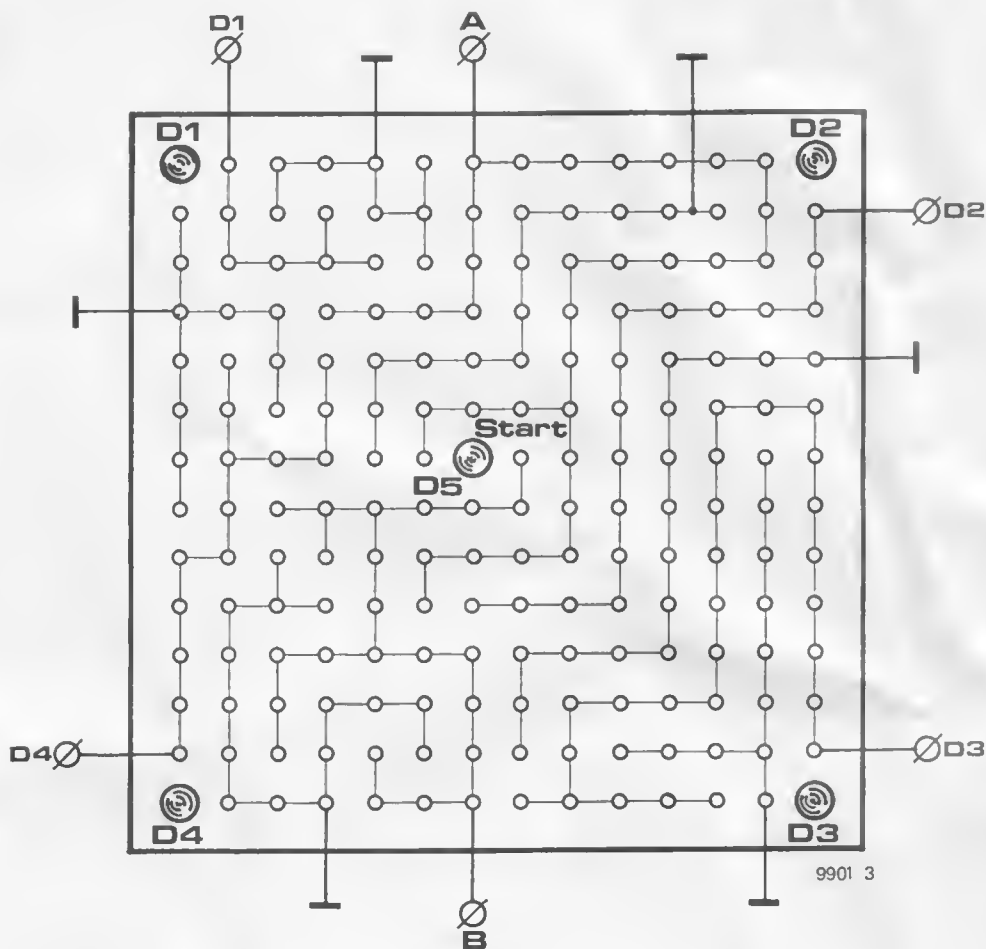
Table 1.

S3	S4	D1	D2	D3	D4	A	B
0	0	1	0	0	0	1	0
1	0	0	1	0	0	0	1
1	1	0	0	1	0	0	1
0	1	0	0	0	1	1	0

D4, A or B). Points not forming part of any path are permanent blind alleys and should be connected to ground.

How to play the game

A maze usually is nothing more than a complicated pattern of lines drawn on paper, and there is normally only one correct way through the maze with a large number of blind alleys leading off from the main path.

However, if 'walls' are drawn for this electronic maze it becomes a fairly simple task to find the proper way out. The game becomes much more interesting (or frustrating) if no lines are drawn, so that the path must be found in true 'hit or miss' fashion by the player. LED D5 indicates each false step, and the player must remember each step taken — otherwise the 'wrong step counter' will quickly reach the maximum permitted setting!

An alternative possibility is to construct a truly complicated maze, including lengthy and involved blind alleys, and draw in the walls alongside the rows and columns of the matrix. In this case the 'wrong step indicator' D5 and displays LD1 and LD2 should obviously not be visible to the player, as he would then be aware that he was wandering off the correct path.

Power supply

A suitable power supply circuit for the maze is given in figure 4. Care should be taken to ensure the electrical safety of the circuit, especially if it is to be used by children. All mains wiring should be extremely well insulated from the low-voltage circuits.

formant
the elektor music synthesiser (9)

Mention has already been made of the fact that conventional instruments exhibit more 'life' and variation in tonal character than electronic instruments due to the way in which they are played. For example, string instruments and woodwind instruments can exhibit marked tremolo and/or vibrato due to variations in the bowing or blowing. The keyboard of a synthesiser provides a relatively inflexible and expressionless means of playing that does not allow these nuances to be introduced into the sound, and in order to make the sound more 'lively' amplitude and frequency modulation must be introduced using the LFOs and noise source.

The noise source also provides the basic material to produce a whole spectrum of sounds that do not have a defined pitch. White noise can be used to produce sounds such as wind, rain and surf. 'Coloured' noise, which is white noise with the low frequency components boosted, is used for sounds having a strong bass content, such as the rumbling of thunder.

In addition to modulating the VCO signals, noise can also be added to these signals to simulate wind noise in organ pipes and woodwind instruments.

The LFO module

The Formant LFOs are basically low-frequency function generators that produce three different waveforms. Each LFO module contains three LFOs, two of which are identical and produce square, triangle and sawtooth waveforms. The third LFO produces a triangular waveform and two sawtooth waveforms in antiphase with each other, i.e. one with a positive-going ramp and the other with a negative-going ramp.

The circuit of LFO1 is shown in figure 1a; LFO2 is identical. The basic oscillator circuit consists of two op-amps IC1 and A3 connected respectively as an integrator and a Schmitt trigger. When the output of A3 is positive a potential of about +2.5 V (depending on the position of the wiper of P3) is applied to R9. The full positive output voltage of A3 is applied to P1, so a current (dependent on the wiper position of P1) flows into the integrator

The low frequency oscillators and noise generator described in this article are invaluable components in a synthesiser system. The LFOs allow amplitude and frequency modulation of the VCO outputs to provide tremolo, vibrato and other effects. The noise sources can be used for random modulation of the VCO signals, and in addition can be used as signal sources themselves.

C. Chapman
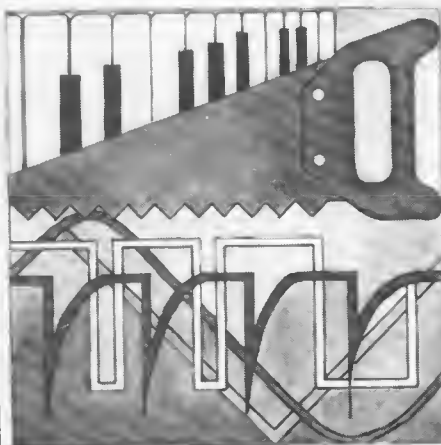
through R1. The output of IC1 ramps negative until it reaches about −2.5 V, when the voltage on the non-inverting input of A3 will fall below the voltage on the inverting input (zero volts) and the output of A3 will swing negative. The voltage applied to R9 is now −2.5 V, and the full negative output voltage of A3 is applied to P1. Current will flow out of the integrator through R1, and the integrator output will ramp positive until it reaches about +2.5 V, when the voltage on the non-inverting input of A3 will rise above zero and the output of A3 will swing positive. The whole cycle then repeats.

The output from IC1 is thus a triangular waveform with a peak-to-peak voltage of about 5 V, while at the wiper of P3 a squarewave of the same amplitude and frequency is available. P3 presets the trigger threshold of A3 and hence the signal amplitude. P1 is used to adjust the frequency of the LFO by varying the voltage applied to the integrator input, which alters the integrator input current and hence the rate at which the integrator ramps positive or negative.

The triangular wave output is taken direct from IC1 via R13, whilst the squarewave output is buffered by voltage follower A4. The sawtooth waveform is derived from the triangle by A2. When the output of A3 is positive and the triangle output is on its negative-going slope, T1 is turned on, grounding the non-inverting input of A2. A2 thus functions as a unity-gain inverting amplifier, producing a positive-going ramp. When the output of A3 is negative and the output of IC1 is positive going, T1 is turned off and A2 functions as a unity-gain non-inverting amplifier (voltage follower), again producing a positive-going ramp. The positive- and negative-going ramps of the triangular waveform are thus converted into a series of positive-going ramps. Since every half-cycle of the triangle is converted into a full cycle of the sawtooth, the frequency of the sawtooth is twice that of the triangle and square waveforms, as illustrated in figure 2.

To indicate that the LFO is functioning a LED indicator, constructed around A1, is connected to the triangle output.

Figure 1a. Circuit of LFO 1, which is identical to LFO 2 and produces triangle, sawtooth and square waveforms.

Figure 1b. LFO 3 also produces three waveforms, but instead of a squarewave output a negative-going sawtooth is provided.

The third LFO circuit, shown in figure 1b, is similar to the first circuit, with two exceptions. Firstly, no squarewave output is provided; secondly, a sawtooth with negative-going slope is provided by A8, which inverts the positive-going sawtooth from A6.

Construction of the LFO module

Figure 3 shows the printed circuit board and component layout of the LFO module, which of course contains three LFOs. The components for LFO2 are identical to those for LFO1, being distinguished on the board and in the components list by an apostrophe ('). The board layout is fairly cramped, and care should be taken when soldering components to avoid solder bridges. A front panel layout is given in figure 4.

Adjustment of the LFOs

Each LFO requires four adjustments:
- P3, P3' and P7 set the signal amplitude.
- P2, P2' and P5 null the offset of the integrators.
- R16, R16' and R17 must be selected to set the lowest frequency of the LFO.
- P4, P4' and P6 adjust the LED indicators.

The adjustment procedure, which is identical for all three LFOs, will be described for LFO1.

Amplitude adjustment

1. Monitor the triangle output on an oscilloscope; set P2 to its mid-position and P1 for maximum frequency.
2. Adjust P3 to give a peak-to-peak output of 5 V.
3. Check the amplitude and waveform of the other outputs.

Offset adjustment

1. Disconnect R1 from the wiper of P1 and ground it.
2. Monitor the output voltage of IC1 with a multimeter. It will probably exhibit a tendency to drift positive or negative, and the voltage will settle at +15 V or −15 V. Reset the
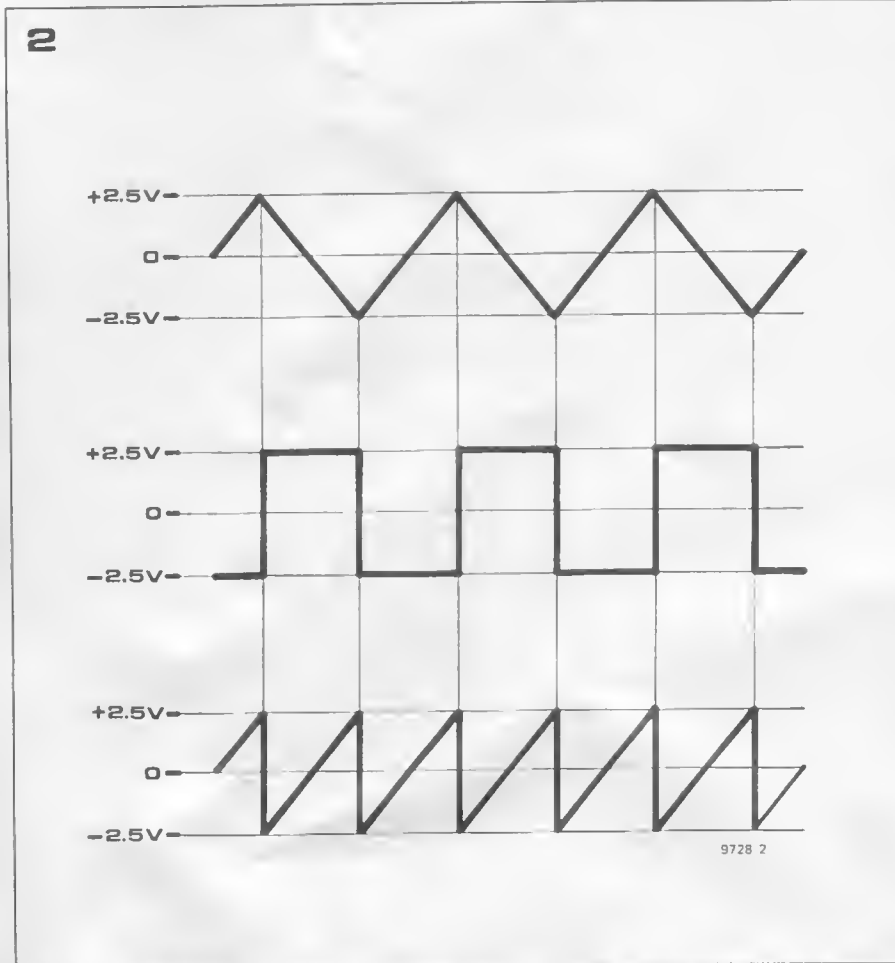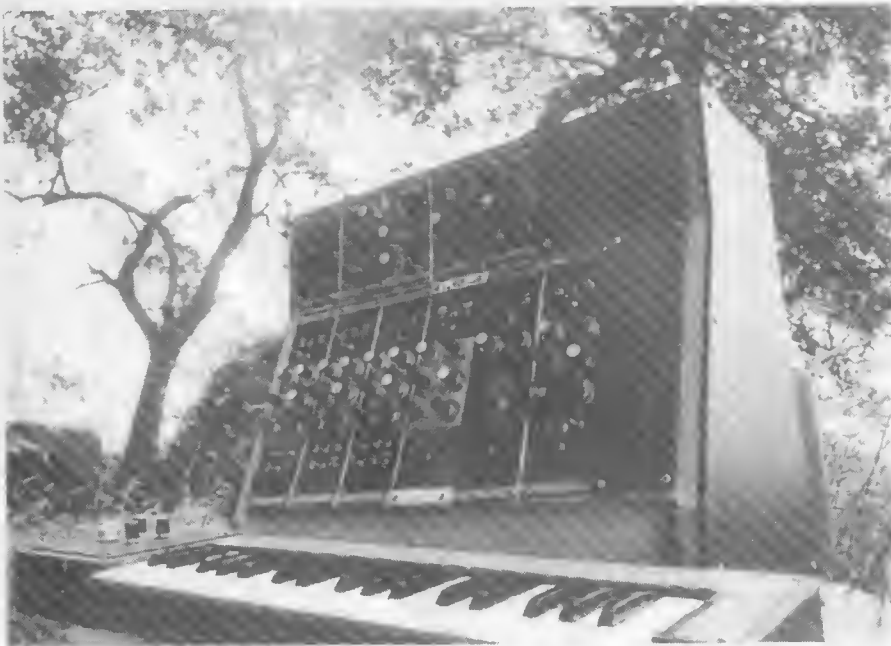
2
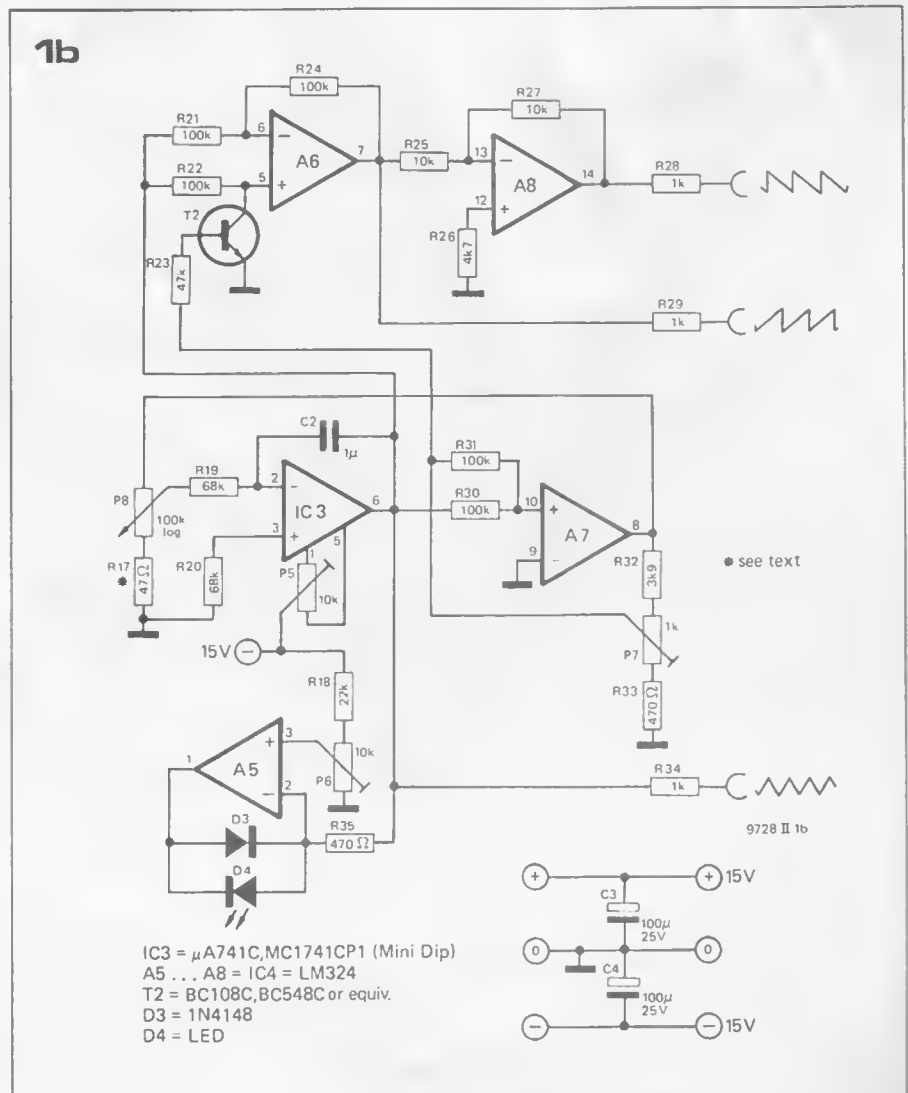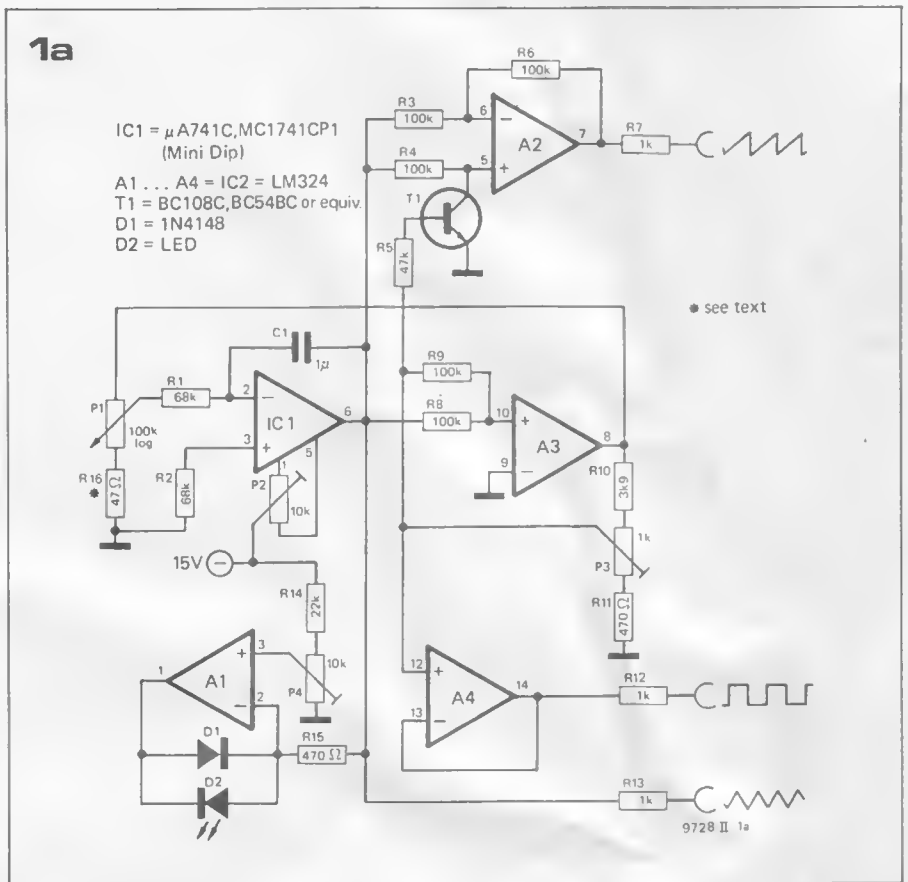
Figure 2. Showing the phase relationship of the triangle, square and sawtooth waveforms. Since the sawtooth is derived by inverting alternate half-cycles of the triangle waveform, its frequency is twice that of the other waveforms.

Figure 3. Printed circuit board and component layout for the LFO module (EPS 9727-1).

output voltage to zero by discharging C1 through a 1 k resistor. Adjust P2 until the voltage remains stable at zero volts for a period of several seconds (without the discharge resistor in circuit). Repeat this adjustment, progressively switching the multimeter to more sensitive ranges until the drift is only a few hundred millivolts in several seconds.

Careful adjustment of the offset is vital, as it determines the minimum frequency at which the LFO will operate reliably and the symmetry of the waveforms at low frequencies.

Selection of R16

The value of R16 determines the minimum integrator input voltage that can be set by P1, and hence the minimum frequency of the LFO. The value of R16 must not be chosen too high or the minimum LFO frequency will be too great. On the other hand it should not be chosen too low, or the integrator input current at the minimum setting of P1 will be comparable with the input currents of IC1. This will result in unreliable operation of the oscillator at low frequencies.

R16 should be chosen so that the minimum frequency of the LFO is about one cycle every three minutes, but the value of R16 should not be less than 10 Ω. If it is not possible to obtain this low frequency then the input currents of IC1 may be too high, or C1 may be leaky.

The maximum LFO frequency is about 20 Hz.

8727-1
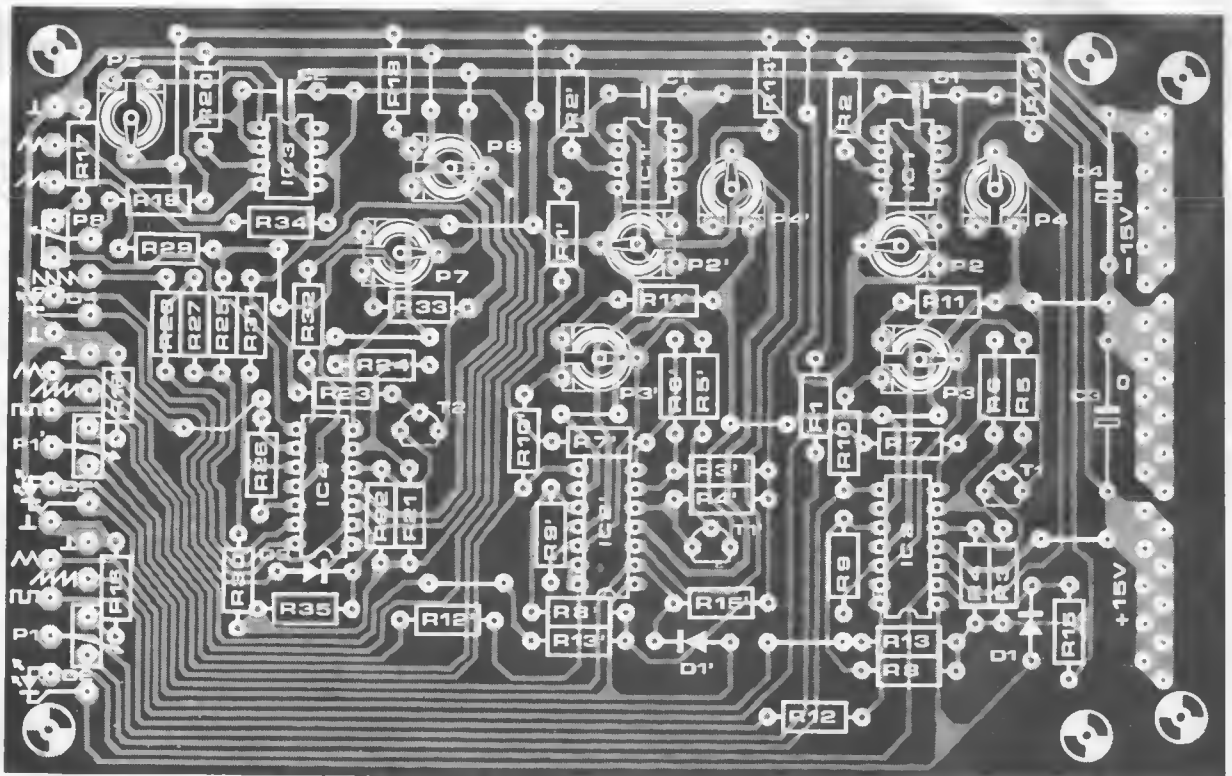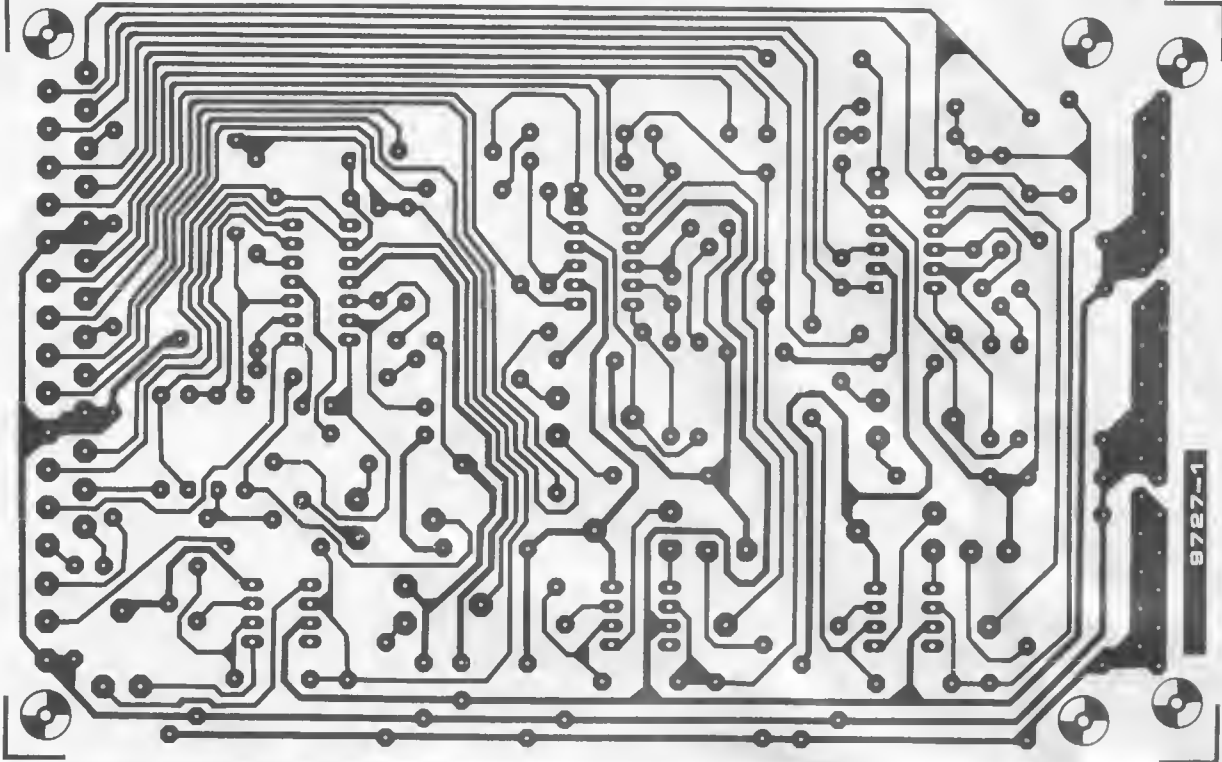
Parts list for LFO module

Resistors:
R1,R1',R2,R2',R19,R20 = 68 k
R3,R3',R4,R4',R6,R6',R8,R8',
R9,R9',R21,R22,R24,R30,
R31 = 100 k
R5,R5',R23 = 47 k
R7,R7',R12,R12',R13,R13',R28,
R29,R34 = 1 k
R10,R10',R32 = 3k9

R11,R11',R15,R15',R33,
R35 = 470 Ω
R14,R14',R18 = 22 k
R16,R16',R17 = 47 Ω (see text)
R26 = 4k7

Potentiometers:
P1,P1',P8 = 100 k log
P2,P2',P4,P4',P5,P6 = 10 k preset
P3,P3',P7 = 1 k preset

Semiconductors:
IC1,IC1',IC3 = µA 741C,
   MC 1741CP1 (Mini DIP)
IC2,IC2',IC4 = LM 324 (DIP)
T1,T1',T2 = BC 108C, BC 548C or
   equivalent
D1,D1',D3 = 1N4148, 1N914
D2,D2',D4 = LED (e.g. TIL209)

Capacitors:
C1,C1',C2 = 1 µ (polyester or
   polycarbonate)
C3,C4 = 100 µ/25 V

Miscellaneous:
31-way connector (DIN 41617)
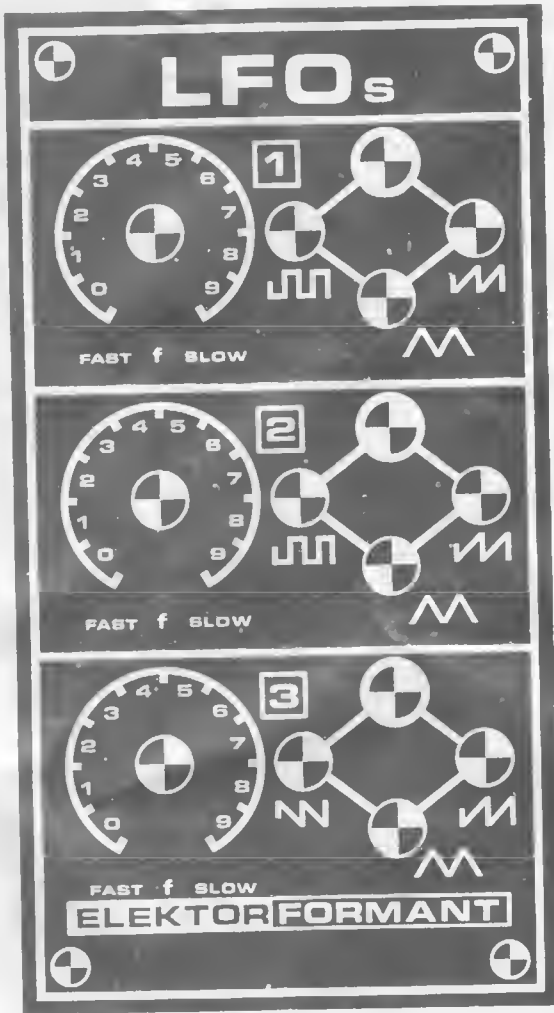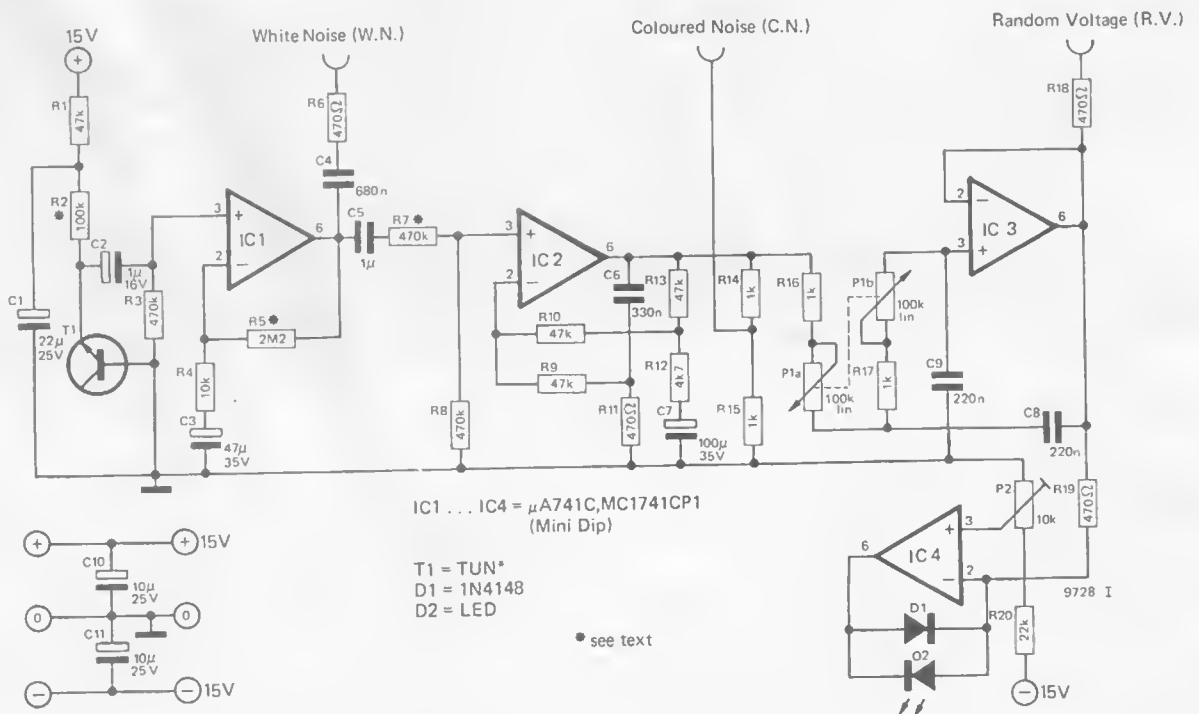9 x 3.5 mm jack
3 x 13 . . . 15 mm knobs

4

Figure 4. Front panel layout of the LFO module.
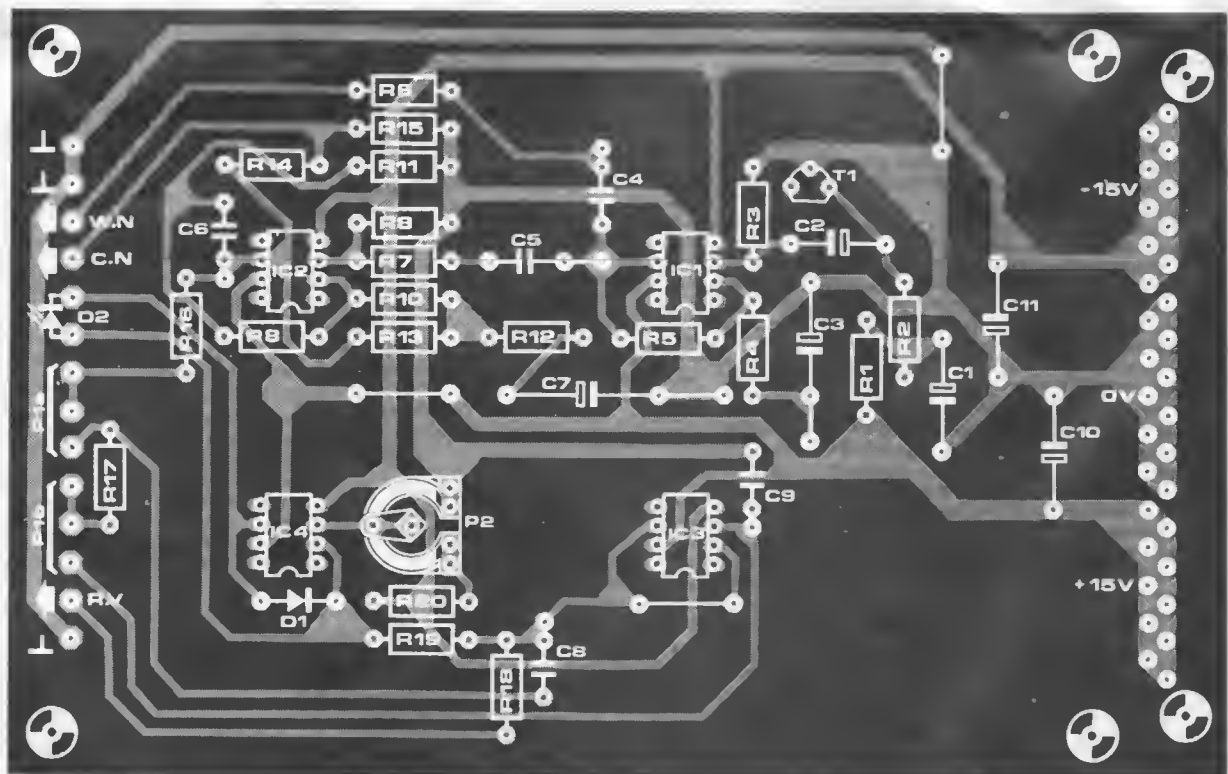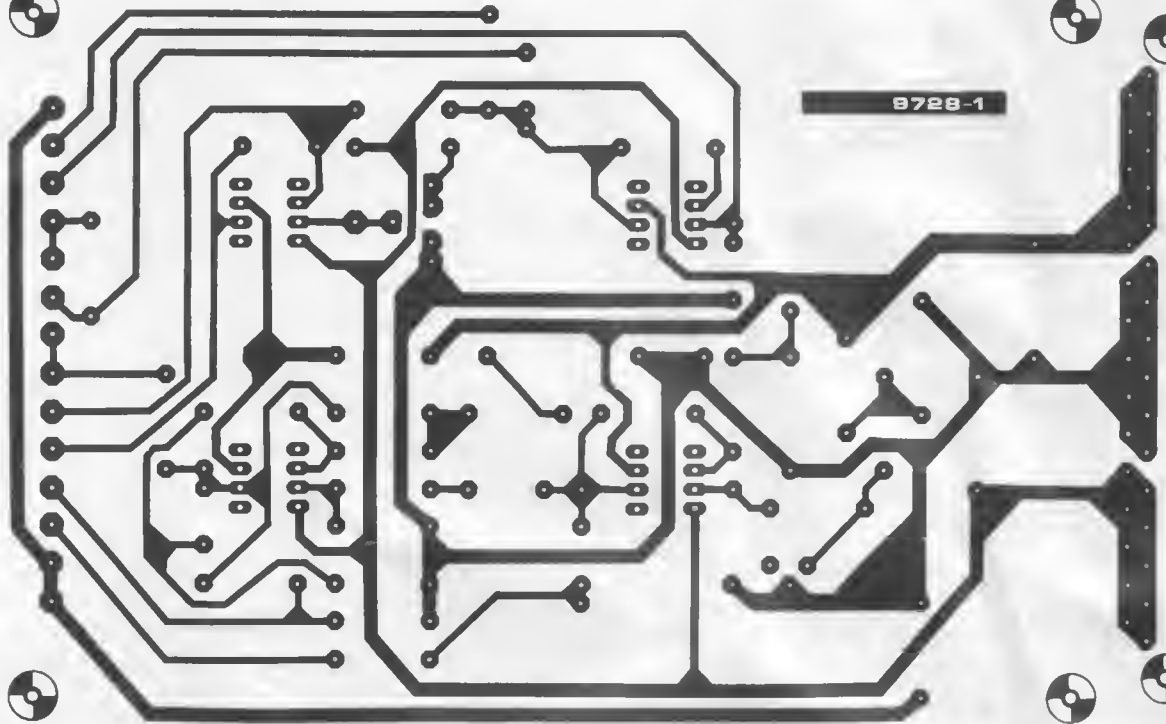
Figure 5. Circuit of the noise module.

Figure 6. Printed circuit board and component layout for the noise module (EPS 9728-1).

5

IC1 . . . IC4 = μA741C, MC1741CP1 (Mini Dip)

T1 = TUN*
D1 = 1N4148
D2 = LED

* see text

6

9728-1

Parts list for noise module

Resistors:
R1,R9,R10,R13 = 47 k
R2 = 100 k (see text)
R3,R7,R8 = 470 k
R4 = 10 k
R5 = 2M2 (see text)
R6,R11,R18,R19 = 470 Ω
R12 = 4k7
R14,R15,R16,R17 = 1 k
R20 = 22 k

Capacitors:
C1 = 22 μ/25 V
C2 = 1 μ/16 V
C3 = 47 μ/35 V
C4 = 680 n
C5 = 1 μ (polyester or
        polycarbonate)
C6 = 330 n
C7 = 100 μ/35 V
C8,C9 = 220 n
C10,C11 = 10 μ/25 V

Semiconductors:
IC1,IC2,IC3,IC4, = μA 741C,
        MC 1741CP1 (Mini DIP)
T1 = TUN (selected)
D1 = 1N4148, 1N914
D2 = LED (e.g. TIL 209)

Potentiometers:
P1 = 100 k lin. ganged
        potentiometer
P2 = 100 k preset

Miscellaneous:
1 x transistor socket
1 x 31-way connector (DIN
                41617)
3 x 3.5 mm jack sockets
1 x 13 . . . 15 mm knob

Adjustment of the LED indicator

P4 should be adjusted so that the brightness of the LED follows the amplitude of the triangle output, i.e. the LED should be at minimum brightness when the triangle voltage is at its most negative, and at maximum brightness when the triangle is at its most positive. P4 should adjusted so that the LED brightness does not reach maximum before the peak of the triangle, but on the other hand it should not extinguish completely before the trough of the triangle.

The noise module

The complete circuit of the noise module is shown in figure 5. The noise is produced by the base-emitter junction of an NPN transistor T1, which is reverse-biased to breakdown. The noise is amplified to a level of about 2.5 V peak-to-peak. This white noise output is fed out via C4 and R6.

The white noise is also fed into a filter constructed around IC2, which has two frequency dependent elements in the feedback path. These two elements interact as follows. On its own, the feedback network comprising R10, R12, R13 and C7 would produce a 6 dB/octave rise in the gain of IC2, from 0 dB at zero Hz via 3 dB at 9 Hz to approximately 20 dB at 90 Hz. The feedback network R9, R11, C6, on its own would produce a 6 dB/octave fall in gain from 0 Hz to 1 kHz, above which the gain would remain constant at 0 dB.

The combined effect of these feedback networks is that below 90 Hz the 6 dB/octave rise and 6 dB/octave fall cancel out, giving a gain of 20 dB. Above 90 Hz the gain falls at 6 dB/octave to 0 dB at 1 kHz, above which it remains constant. The result is that the bass end of the noise spectrum is boosted, and 'coloured' noise is available at the output of IC2. The coloured noise output is taken from the junction of R14 and R15.

The coloured noise output is also fed to a second filter built around IC3. This is a 12 dB/octave lowpass filter with variable turnover frequency, which passes only the very low frequency components to produce an extremely low frequency 'random voltage'. The fluctuation rate of this random voltage is adjusted by means of P1, which varies the turnover frequency of the filter. Fluctuations of the random voltage are displayed on a LED indicator, which is identical to those used in the LFOs.

Construction and adjustment of the noise module

A printed circuit board and component layout for the noise module are given in figure 6, and the front panel layout is given in figure 7.

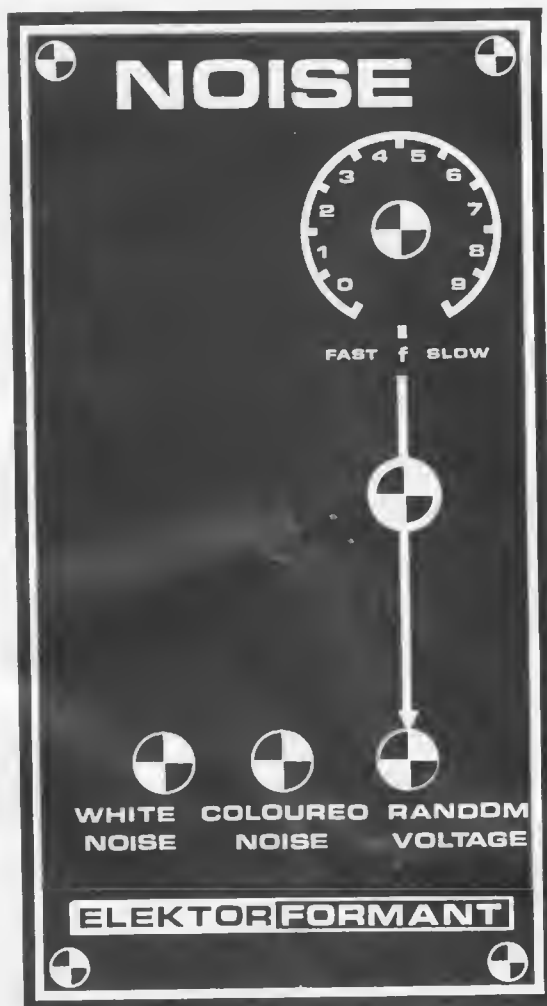As not all transistors are suitable noise generators, a socket should be fitted in

Figure 7. Front panel layout of the noise module.

the T1 position on the board so that different transistors may be tried. Measuring with a multimeter on a suitable AC voltage range at the white noise output, a voltage of 0.5 V to 0.8 V should be present. Alternatively, if an oscilloscope is used to monitor the output, a noise signal of about 2 V to 2.8 V peak-to-peak should be obtained. It may be necessary to try several transistors before a suitable one is found. Varying the value of R2 between 33 k and 150 k may also help.

If the transistor produces too high a noise level this can be reduced by making R5 smaller, thus reducing the gain of IC1.

The amplitude of the coloured noise output should also lie in the same range as the amplitude of the white noise output. If it is too small then R7 should be reduced and if it is too large R7 should be increased.

The random voltage output should vary between about +2.5 V and −2.5 V with P1 in the 'fast' position.

The final adjustment to the noise module is to set P2 so that the LED brightness indicates the amplitude of the random voltage output in a linear manner. This adjustment is carried out in exactly the same way as the adjustment of the LFO indicators.

Voltage comparison on a 'scope

There is frequently a need, when experimenting with circuits, to measure or compare several DC voltages at test points etc. Since most readers are unlikely to possess more than one multimeter this can be rather tedious. Using this simple circuit, up to four voltages can be compared or measured on any oscilloscope that has a DC input and an external trigger socket. The circuit uses only three ICs, five resistors and a capacitor.

The complete circuit of the voltage comparator is given in figure 1. The four voltages to be measured are fed to the four inputs of a quad analogue switch IC, the outputs of which are linked and fed to the Y input of the 'scope. N1 to N3 and associated components form an astable multivibrator, which clocks counter IC3. This is a decade counter connected as a 0 to 3 counter by feedback from output 4 to the reset input. Outputs 0 to 3 of the counter go high in turn, thus 'closing' each of the analogue switches in turn and feeding the input voltages to the 'scope in sequence.

Output 0 of the counter feeds a trigger pulse to the 'scope once every four clock pulses, so that for every cycle of the counter the 'scope trace makes one sweep of the screen. A positive-going

This simple circuit allows up to four DC voltages to be measured or compared by displaying them side by side on an oscilloscope.

(H. Spenn)

trigger pulse is available via R4, or a negative-going trigger pulse is available from the output of N4 via R5. The resulting display is shown in figure 2, four different input voltages being fed to the inputs in this case. The oscilloscope timebase speed should be adjusted so that the display of the four voltage levels just occupies the whole screen width.

The supply voltage $+U_b$ may be from 3 to 15 V, but it must be noted that the input voltage should be positive with respect to the 0 V rail and not greater than $+U_b$. If voltages greater than this are to be measured then potential dividers must be used on the four inputs.

Setting up

To calibrate the circuit, simply feed a known voltage into one input and adjust the Y sensitivity of the 'scope to give a convenient deflection (for example one graticule division per volt input). The unknown voltages may then be fed in and compared against each other and against the calibration.

The circuit can easily be extended to eight inputs by adding an extra 4066 IC and connecting IC3 as a 0 to 7 counter (reset connected to output 8, pin 9).
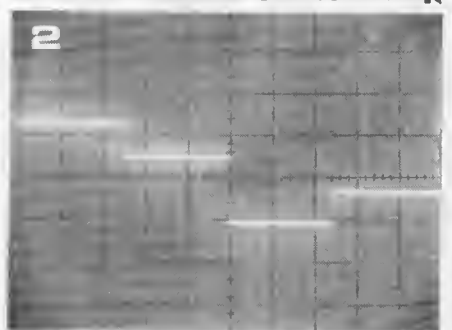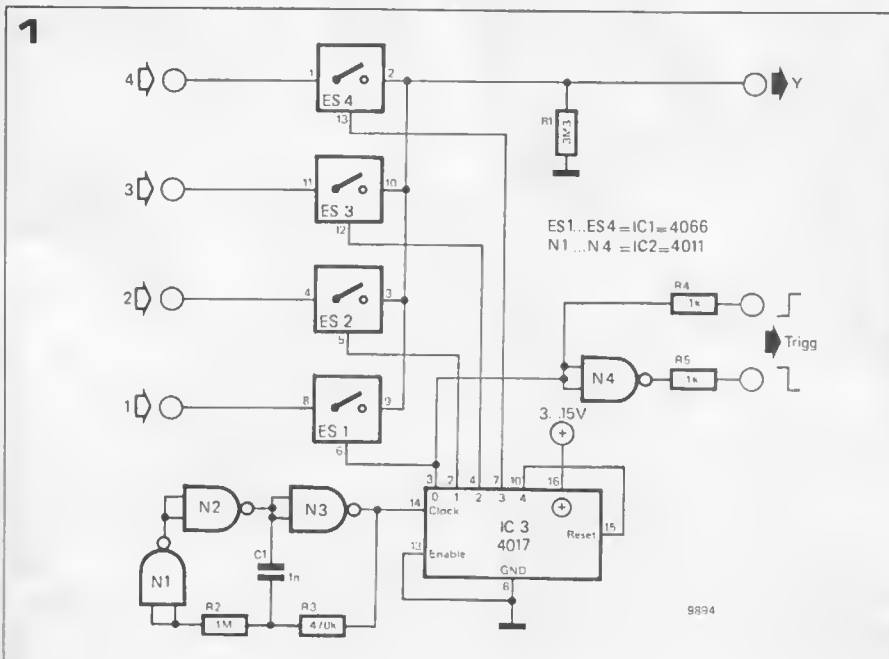

ES1...ES4 = IC1 = 4066
N1...N4 = IC2 = 4011

Figure 1. The circuit diagram of the voltage comparator.

Figure 2. An example of 4 random voltage levels displayed simultaneously on the 'scope.

safety first

Readers frequently ask why more explicit wiring details of the mains input side of mains powered equipment are not given in Elektor articles. There are several reasons for this seeming omission.

In the first place, this would entail a great deal of repetition every month, thus wasting space that could be put to better use. In the second place, Elektor is read in many English-speaking countries where wiring standards are different from those of the UK, and what is correct for the UK market may not be correct for these other countries. In the third place, anyone who understands the principles involved can wire up a mains powered circuit quite safely without any further details, whereas anyone who does not understand what he is doing should not attempt to build mains-powered circuits, no matter how explicit the wiring details. The only exceptions to this last remark are kits supplied by a reputable manufacturer, where the mechanical construction and mains wiring can be closely specified, and an industrial situation where unskilled personnel carry out mains wiring under supervision and subject to quality control checks.

The purpose of this article is to provide readers with the necessary information to enable them to wire and use mains-powered equipment safely.

Safety hazards

There are two principal hazards that may be encountered in electrical and electronic equipment, namely electric shock and fire hazards.

The currents required to cause physical injury or death are quite small compared to the currents that flow in many electrical and electronic circuits, and the effects of a 50/60 Hz AC current flowing through the body from arm to arm are listed in Table 1.

These figures are, of course, typical and the actual effect of a particular current will depend on the victim's state of health. A person with a weak heart is likely to succumb at a lower current than a healthy person.

The two most dangerous paths for current to take through the body are from arm to arm and from left arm to

The golden rule when confronted with mains powered electrical or electronic equipment is 'if you aren't 100% sure of what you are doing leave well alone'. In this article the steps taken to ensure the safety of home-built and commercial equipment are discussed, both from an electrical (shock hazard) and from a fire-risk point of view.

Table 1	
Current	Effect
Below 500 µA	Little or no sensation
500 µA to 1 mA	Tingling sensation
1 to 5 mA	Slight pain
5 to 10 mA	Severe pain
10 mA to 100 mA	Muscular contraction (inability to let go)
100 mA to 2 A	Ventricular fibrillation (uncoordinated contraction of the heart muscle) — DEATH.
Above 2 A	Burns and physiological shock, but good chance of recovery.

left leg, since in both cases the current passes directly through the region of the heart. A well-known safety rule is based on this: 'When working with high voltages, always keep your *left* hand in your pocket — even if you are left-handed!'.

Any current flow of more than a few milliamps through the body should be regarded as dangerous. Since the resistance of the body from arm to arm can be as low as 10 k if the palms of the hands are moist, this means that not only mains voltages, but also relatively low voltages can be dangerous. It is generally agreed that voltages in excess of 60 V DC or 42 V AC can constitute a shock hazard, since they could cause a current flow of some 5 or 6 mA through the human body.

Equipment housing

Electric shock can occur in a variety of ways. Current can flow through the body if contact is made with the supply and zero volt rails of a DC circuit or the two supply terminals of an AC circuit. This occurrence is prevented while equipment is in use by suitable physical construction, i.e. by a housing that prevents physical contact with any dangerous voltages.

If equipment must be ventilated to avoid overheating and consequent fire risk, the ventilation apertures must be
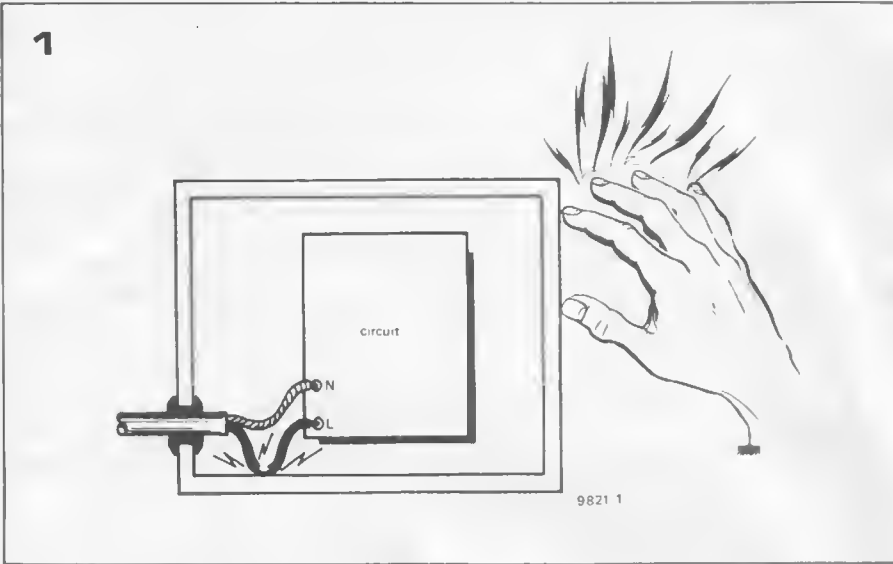
Figure 1. An unearthed metal case can become live in the event of an insulation failure.
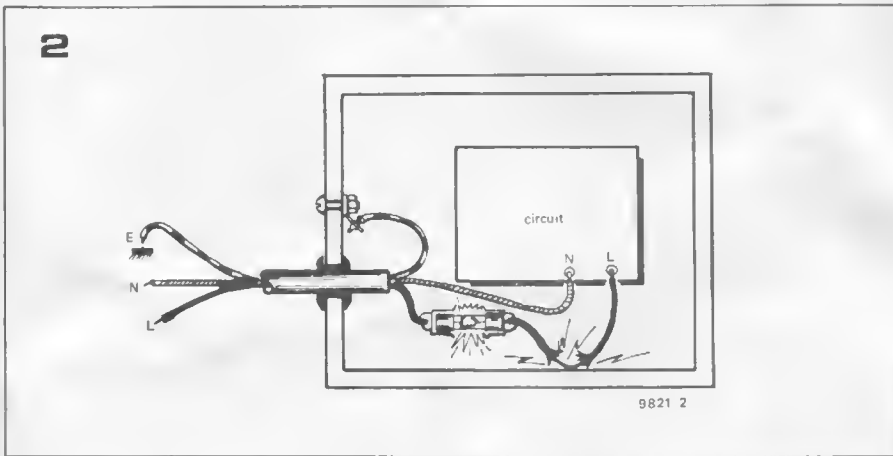
Figure 2. Earthing the case and placing a fuse in the live lead prevents a shock hazard, since the fuse will blow and disconnect the live input.

Figure 3. Correct wiring of three-pin mains plugs. If two-core cable is used then no connection is made to the earth terminal.

sufficiently small to preclude contact with dangerous voltages inside the housing.

Housings should be proof, not only against direct finger contact with dangerous voltages, but also against indirect contact via such things as necklaces which may inadvertently dangle through ventilation holes, or knitting needles wielded by tiny hands. British Standard tests for the safety of housings involve the use of a jointed test 'finger' of very slender dimensions and a thin chain 'necklace'. Only housings which have the ventilation holes covered with fine metal or plastic gauze can pass such tests.

When testing or repairing equipment with the housing removed the possibility of electric shock still exists. Obviously, power should be applied to unhoused equipment only for test purposes; for repair work the equipment should be unplugged, and in any case such work should be undertaken only by a competent person.

Earthing and double insulation

The second way in which electric shock can occur is by current flowing from a high-voltage point, through the body, to earth. In the U.K. mains system, the neutral lead of the mains wiring is at a voltage very close to true earth or ground potential (i.e. the
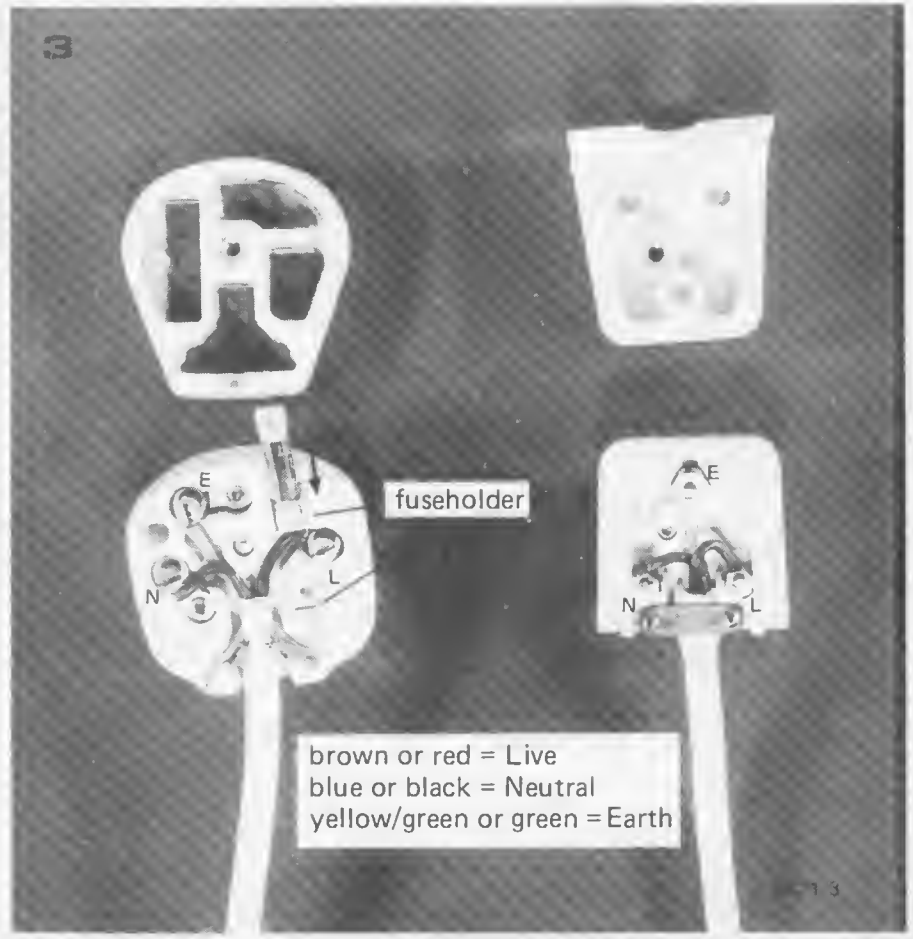

fuseholder

brown or red = Live
blue or black = Neutral
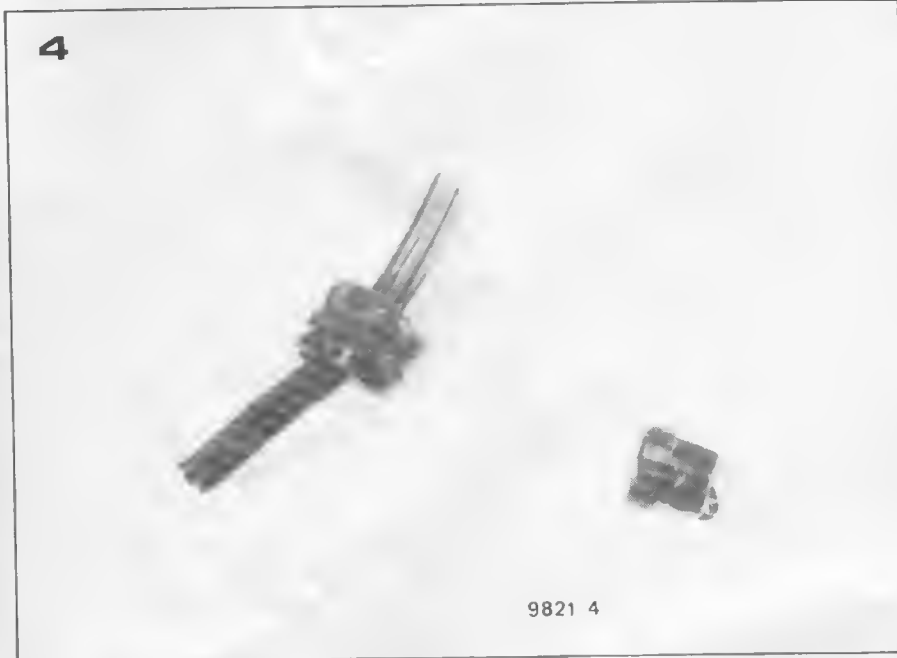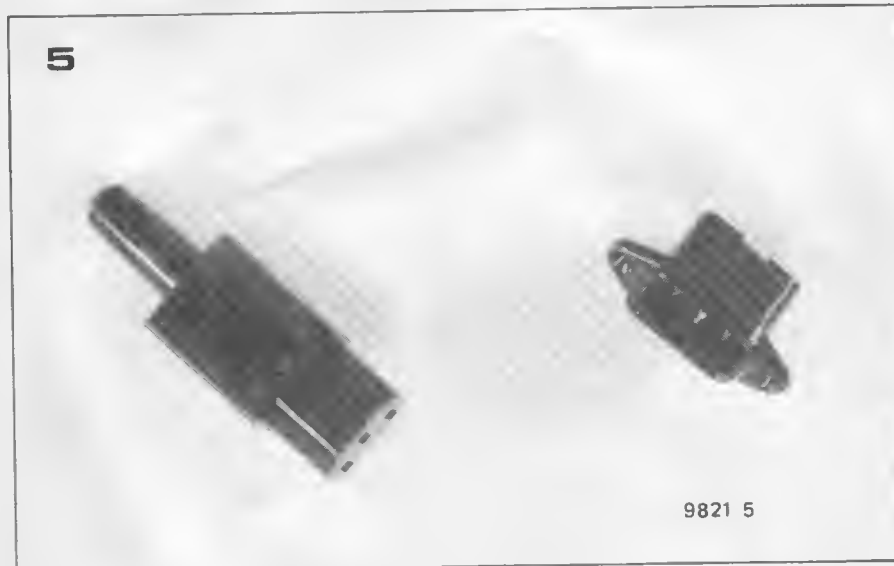yellow/green or green = Earth

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9821 5

Figure 4. A strain relief bush prevents damage to the cable, which could cause a safety hazard.

Figure 5. I.E.C. connectors may be used to feed mains power to equipment. In addition to preventing strain on wiring inside the equipment, there is also the advantage that the mains flex can be removed for storage of equipment, and cables of different lengths may be used if necessary.

Figure 6. Circuits powered direct from the mains supply (not via a transformer) must have current limiting resistors in series with any external connections. This is only feasible for very low current circuits.
Note that in the ioniser circuit (referred to in the text) the voltage is so high that resistor R must be replaced by a chain of 10 series resistors.

Figure 7. Low voltage circuits generally derive their power from a transformer which both steps down the voltage and provides electrical isolation from the mains input.

potential of the mass of the earth, which is taken as being zero volts) while the live lead alternates between positive and negative. If some part of the body is in contact with earth potential then electric shock may be incurred if another part of the body contacts the live lead. Electric shock from DC circuits may also occur in this way if the zero volt rail is tied to earth potential and the supply lead is inadvertently touched.

If the equipment is properly housed it will not be possible to touch the live lead or other high-voltage leads. However, if the equipment housing is of metal then an insulation breakdown within the equipment may cause the case to become live, as illustrated in figure I. The occurrence of a shock hazard by this means can be prevented in one of two ways.

The first method is to construct the housing of insulating material so that, even in the event of an insulation failure within the equipment, the insulated housing provides protection against electric shock. If any metal parts are used in the construction they should not pierce the insulation of the case.

This type of construction is known as 'double-insulated', and it can be seen in many small domestic appliances where it is identified by the symbol ▣. For the home constructor, this type of construction simply entails the use of plastic housings for equipment and the avoidance of metal hardware such as metal screws to fix components to the sides of the case. Items such as potentiometers with metal shafts and switches with metal fixing bushes or toggles should also be avoided.

Where a metal case must be used the second method of avoiding a shock hazard must be employed. This involves connecting the case to earth via the earth lead of the mains wiring, and placing a fuse in the live lead, as illustrated in figure 2. Should an insulation breakdown to the case occur, a large current will flow to earth, blowing the fuse and thus isolating the live lead. This method of construction, of course, means that a three-core mains lead must be used with live, neutral and earth conductors.

Earthed construction is frequently employed on larger domestic appliances such as washing machines and cookers.

It is perfectly possible to use a metal housing and double-insulated construction by having the electrical circuits surrounded by a second layer of insulation within the metal case. Even if there is a primary insulation breakdown this second insulation layer then prevents the case from coming into contact with high voltages.

This type of construction can be found in small domestic appliances such as food mixers, electric drills and some types of hi-fi equipment. However, it does require extreme care to make this type of construction totally safe, and it is not really suitable for the home constructor.

Care should also be taken to ensure that the mains wiring external to the equipment is safe. The mains lead used must be of a type having an outer sheath and two or three insulated conductors, depending on whether an earth lead is required or not. Twin core cable of the 'bell-flex' type, having only a single layer of insulation, should not be used for mains wiring.

The mains plug should be wired in accordance with figure 3, which shows both a 13 A fused plug and a 5/15 A unfused plug. Care should be taken to ensure that the cable strain relief clamp is gripping the outer sheath of the cable, to avoid any strain on the conductors. Where the mains cable enters the equipment the hole should be bushed with a plastic or rubber grommet

to avoid chafing, and the outer sheath of the cable should be clamped to avoid strain. These two functions may be combined in a strain relief bushing, as shown in figure 4.

Alternatively, connection to the equipment may be made via an I.E.C. chassis plug and cable socket, as shown in figure 5. In the event of the cable being tugged the plug and socket will simply disconnect.

## Equipment with external connections

The discussion so far has assumed that the equipment was totally enclosed within its housing, with no part of the circuit being accessible from the outside. However, there is frequently a need for a circuit to have external connections, for instance equipment such as power supplies, oscilloscopes and other instruments.

Equipment in which no part of the circuit is accessible from the outside may or may not contain a mains transformer, depending on the type of circuit. For example, a domestic appliance such as a hairdryer or foodmixer operates direct from the mains supply, whereas a digital clock or mains-powered transistor radio would probably contain a mains transformer to step down the voltage to that required by the electronic circuit.

However, if a piece of equipment has external connections then precautions must be taken to ensure that no dangerous voltage can appear on these connections, or if high voltages do appear then steps must be taken to limit the available output current to a safe value. An example of the latter practice is the ioniser circuit that appeared in Elektor 30, October 1977. The ioniser needle operates at a potential of around 7.5 kV, but a chain of series resistors limits the current to a few hundred microamps if the needle is inadvertently touched. This principle is illustrated in figure 6.

In a majority of cases, however, electronic circuits are low voltage circuits that derive their power from a mains transformer that steps down the mains voltage and also provides electrical isolation between the low voltage circuit and the mains input, as illustrated in figure 7. The transformer has independent primary and secondary windings, and there must be no direct electrical connection between them.

Of course, the possibility of an insulation breakdown between the primary and secondary must be considered, and there are two ways of preventing a shock hazard from this source. The first method is to use a transformer which is double insulated. This type of insulation makes the possibility of an insulation breakdown between primary and secondary virtually impossible. Transformers of this type generally have a two-section bobbin made of an insulating material, the primary being

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circuit

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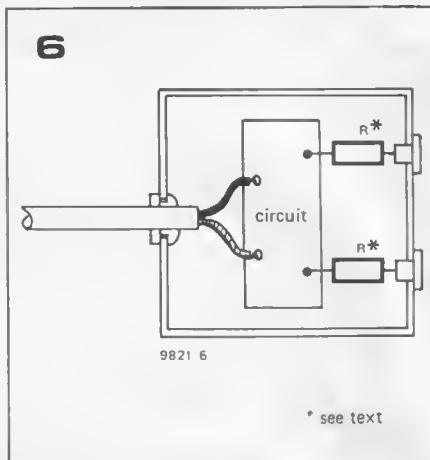
wound on one half of the bobbin and the secondary or secondaries being wound on the other half. An example of construction using a split bobbin transformer is shown in figure 8.

Provided care is taken to ensure that no high-voltage part of the circuit can contact the low-voltage circuit, no earth connection is required. This can be ensured by a physical barrier between the high voltage and low-voltage sides of the circuit, which prevents contact even in the event of a mains wire coming adrift, or by double insulation of the high-voltage wiring, as shown dotted.

If double insulated construction is employed on the high-voltage side of the circuit then a metal case may be used if desired.

Some types of transformer do not employ split-bobbin construction, but have both windings on a single bobbin in layers. Since the insulation in this case consists only of the enamel on the winding wire and thin paper or plastic interleaved between the windings, this type of construction is much more prone to insulation breakdown. This type of transformer should be provided with an interwinding screen, which is a layer of metal foil between the primary and secondary winding layers. This screen is earthed, thus forming a barrier between the primary and secondary windings. Any insulation breakdown will reach the screen before it reaches the secondary winding, causing a large

current to flow to earth and thus blowing the fuse in the live lead. An example of this type of construction is given in figure 9. If a metal case is used it must also be connected to mains earth. This type of circuit must always be used with the earth lead connected to the earth terminal of a three-pin mains plug.

Additional protection against electric shock due to the housing of equipment becoming live may be provided by having an earth leakage circuit breaker fitted to the house wiring. Any current flowing to earth will cause the circuit breaker to trip and disconnect the mains supply.

To summarise, electrical equipment can be made safe from a shock hazard point of view in several ways:

1. Any equipment in which high voltages are present should be suitably housed so that high-voltage points cannot be touched.

2. Protection against the housing becoming live should be provided in one of three ways:
   a. The housing may be of insulating material.
   b. The housing may be of metal, in which case it should be earthed.
   c. The housing may be of metal and not earthed, in which case the high-voltage sections of the circuit should be double-insulated from the case.

3. If the circuit has external connections then the supply to the circuit must come from a transformer with separate primary and secondary windings. Care should be taken to avoid any high-voltage points coming into contact with the low-voltage section of the circuit. To this end a double-insulated transformer or a transformer with an earthed interwinding screen should be used. The high-voltage wiring should also be double insulated or physically separated from the low voltage circuits. If double insulation and a double-insulated transformer are employed then the case, if metal, need not be earthed. If double insulated construction is not employed then the case should be earthed, if metal.

7

low voltage

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circuit

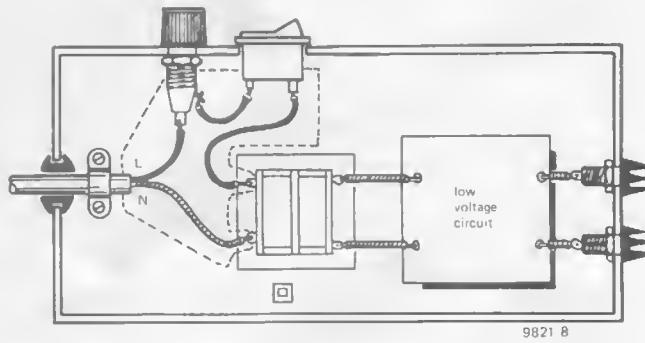external connections

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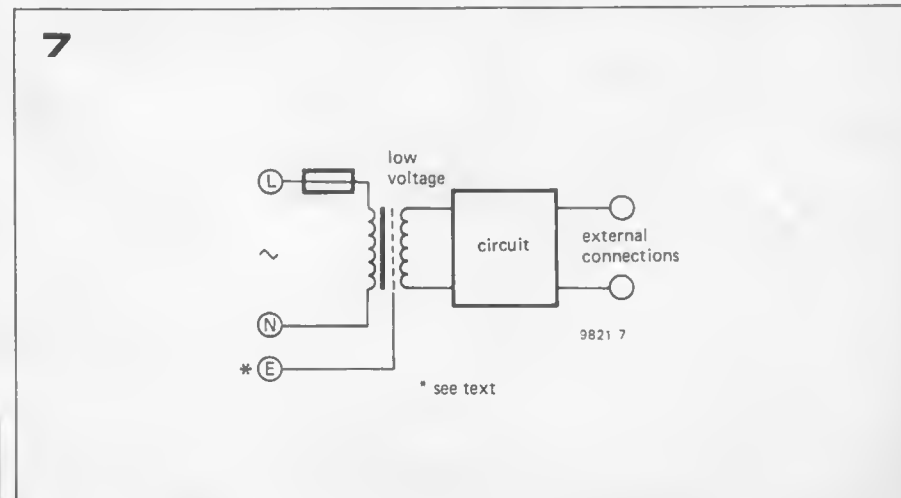
Figure 8. If double-insulated construction is employed, no earth lead need be provided. Care must be taken to ensure that no high-voltage point can contact the low-voltage circuit.

Figure 9. A single insulated transformer with interwinding screen requires an earth connection to the screen. Care should be taken to ensure that no high-voltage point can contact the low-voltage circuit. This can be achieved by physical separation of the high- and low-voltage circuits and clamping of leads to ensure that no contact can occur, by a physical barrier, or by double insulation of the high-voltage circuit.
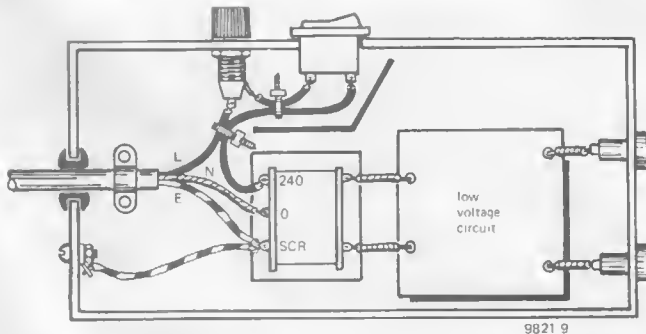
Fire hazards

Overheating of equipment can lead to fire hazards, since many of the plastics used as insulators in electronic components and assemblies are inflammable, as are wooden and plastic cabinets. Overheating usually occurs in one of two ways, either through inadequate ventilation under normal operating conditions, or through excessive current flow caused by a circuit malfunction or misuse.

Overheating due to inadequate ventilation is prevented simply by providing ventilation holes and/or cooling fans in equipment that produces a significant amount of heat. In commercial equipment, protection against excessive current flow may be provided in a variety of ways, but for the home constructor the humble fuse fulfils most needs.

The simplest form of protection is provided by a fuse in the live lead of the mains input. This fulfils two functions. If a live to neutral short-circuit occurs at any point in the circuit after the fuse, or any other malfunction occurs which causes excessive current flow then the fuse will blow.

If the equipment is in an earthed metal case the fuse will also blow in the event of a live to case short, thus preventing an electric shock hazard. Fuses may also be used in other parts of the circuit to protect particular sections (for example each channel of a hi-fi amplifier may have a fuse in the supply line) but these should be in addition to the mains fuse.

The ideal place for the mains fuse is in the mains plug, since it then also protects the mains lead to the equipment. However, this is not always feasible for

several reasons. Firstly, the domestic wiring may not be suitable for plugs of the 13 A fused type. Secondly, the minimum rating of fuse available for this type of plug is 2 A, which may be too high if only a low-power circuit is to be protected. In this case a fuse of suitable rating should be installed inside the equipment.

So that the fuse does not blow during normal operation of the equipment, its current rating must be greater than the maximum current consumption of the circuit. The current rating of the fuse must not be too great or it may not provide adequate protection. On the other hand, if the fuse rating is too close to the normal current consumption of the circuit it will eventually fail in normal operation due to premature ageing caused by the heating effect of the current flowing through it.

market

Multifunction calibrator

The Rotek 610 offers the highest accuracy available in a multi-function calibrator.
Based on the 600 Wide Band Calibrator the 610 shares the same full scale ranges:
10 mV . . . 1000 V AC and DC voltage, 10 μA . . . 1 A AC and DC current with AC operation to 50 kHz and resistance from 1 Ω to 10 MΩ. The model 650 High Current Adaptor extends current output to 10 A DC and 50 A AC. The 610 has a specified accuracy of 30 ppm (0.002% setting + 0.001% of range) up to 500 V DC and 0.03% (0.025% setting + 0.005% range) on AC voltage up to 1000 V over the range 400 Hz . . . 1 kHz for a minimum of 30 days.
AC frequency may be selected to a 2 digit resolution and the 610 offers an unparalleled combination of Volt-Hertz product and output current even into capacitive loads. A full 1000 Volts is available from 40 Hz . . . 10 kHz de-rating to 500 V at 20 kHz and 100 V at 50 kHz.
The 610 features Digital readout of error of the instrument under test to 0.001% — with a printer output for this information as an optional and very time-saving extra. Output values are settable to 5 decade resolution (0.10 V on the lowest range) with the deviation control providing vernier setting.
Rotek have produced in the 610 an instrument which caters for almost every meter calibration situation — from Dynamometers requiring 25 mA drive at 1000 V to the latest 5½ digit precision source the stability of the 610 is more than adequate for calibration work of the ultimate precision.
All the previous safety features of Rotek Calibrators, such as reversion to standby on overload, are retained and new ones added, as are operator instruction lamps. Front panel switching, mainly by push buttons for speed of operation, only operates logic to eliminate the problems of switch wear and contact resistance which arise if output signals are maually switched.
As with the 600, the 610 may optionally be programmed either by parallel BCD (TTL level) signals or via the IEC 66 (IEEE 499-1975) Interface. Both programming options may be added subsequent to initial purchase at no cost penalty. Response to programme command is very rapid to allow full use to be made of Automatic Calibration when the situation justifies it.
A universal calibration programme is available to enable users to calibrate any meter via the HP9825 Desk top computer and IEC Bus.

Datron Sales Limited
Penmark House
Woodbridge Meadows. Guilford
Surrey GU1 1BA, England

(652 M)
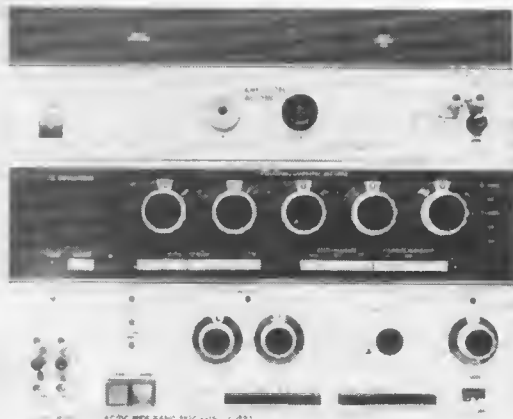
New type of power semiconductor

A new class of power semi-conductors known as transcalent devices has been introduced by RCA Electro-Optics & Devices. The new small, lightweight devices feature integral heat pipes bonded directly to large silicon wafers capable of handling currents of hundreds of amperes. The first devices available include rectifiers, thyristors and transistors.
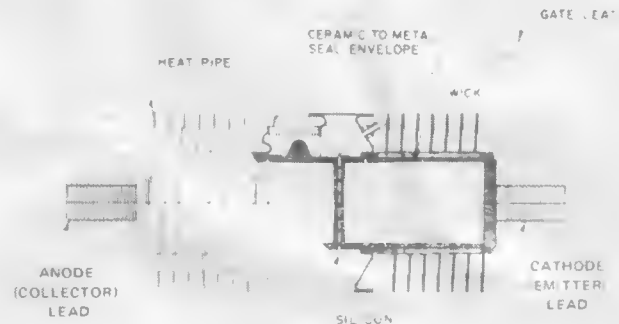The integral heat pipes in the devices minimise thermal resistance and increase radiator fin efficiency, thereby permitting RCA to produce devices signifi-

cantly smaller and lighter than conventional semiconductor/heat-sink assemblies of similar power ratings. Typical size reduction is by a factor of four and weight reduction by a factor of seven. Other advantages of RCA's heat-pipe/integral-fin construction include improved resistance against overloads and high-current surges, and the opportunity either to reduce the silicon-junction temperature for enhanced reliability or to operate at full ratings at high ambient temperatures.
Installation is also simplified by the elimination of separate heat sinks.
The first RCA transcalent devices available are the P95000EB Series of 250 A, 500 W rectifiers with blocking voltages up to 1200 V, the P95400EB Series of 400 A, 500 W thyristors with blocking voltages up to 1200 V, and the P95200EE4 100 A, 500 W NPN transistor.
The rectifiers and thyristors use compact radiator structures resulting in a weight of only 340 g and a volume of less than 230 cm³. The transistor uses a different radiator structure with a dissipation capability of 500 W, yet the device weighs less than 1 kg and occupies a volume of less than 1100 cm³.
Any of the devices can be supplied with radiator structures to accommodate either air or liquid cooling. Thermal resistances are of the order of 0.1-0.2 °C/W, and operating ambient temperatures at full ratings range up to 50°C.
The transcalent devices are appropriate for a wide range of commercial and military applications involving fixed, mobile or aerospace equipment. Typical uses are in welders, electro-chemical platers, power conversion and distribution systems, motor-speed controls, military-vehicle drivers, radar power supplies and aircraft power systems.

RCA Solid State—Europe
Sunbury on Thames
Middlesex TW16 7HW England

(649 M)

Paper-tape

A new paper-tape punch/reader unit for converting selected KSR (keyboard-send/receive) printer terminals to ASR (automatic-send/receive) is available from the Engineering Division of The Exchange Telegraph Company Limited (Extel). Designated the RP-30, the paper-tape unit can be used with approved 30 character-per-second terminals such as the DECwriter LA36.
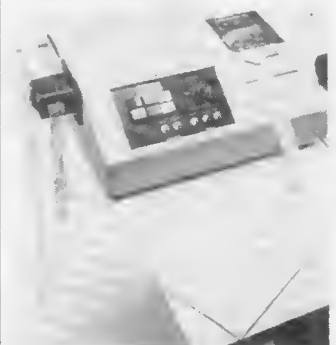
The RP-30 offers 20 mA or V24 input and output interfaces, and also the option of the Post Office approved output interface. The basic cost of the unit is £ 1050 plus V.A.T., and the PO-approved interface costs £ 45 plus V.A.T.

The Exchange Telegraph Company Limited,
*73-75 Scrutton Street,*
London, EC2A 4PB, England

(679 M)

market

Timer-counter

The TC321, a new universal timer-counter from Gould Advance Ltd., offers a comprehensive range of measurements including automatic and manual frequency measurement, manual and automatic multi-period averaging, single-period timing, two-line timing with mechanical start and stop facilities, pulse-width measurements, counting, totalising and counting events over a set period. The 5-digit instrument makes extensive use of low-power C-MOS and Shottky circuitry, thick-film resistor networks and open-plan construction to give easy access, reliability and low cost ownership.

The TC321 incorporates large, clear 7-segment Beckman-type displays for ease of reading, and covers frequencies up to 35 MHz with a maximum sensitivity of 10 mV r.m.s.
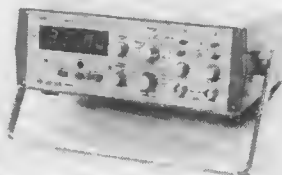
To complement the mechanical aspects of two-line timing on contact positions, a variable hold-off is provided to remove the effects of contact bounce. Hence mechanical measurements on relays or event timing can easily be carried out.

Up to ten of the seven decade steps of multiple-period averaging can be measured over a range of 500 ns to 100 ms overspill. For automatic period averaging, the periods counted are automatically selected from one to 10^4 in decade steps for maximum display resolution.

The high-impedance 10 mV input is enhanced by an automatic position for optimum triggering, as well as positive and negative slope selection with a variable sensitivity. Pulse-width measurements down to 2 μs can be made directly into input A. The instrument is housed in a rugged metal case measuring

88 mm high x 258 mm deep x x 280 mm wide, and weighs 2.3 kg without internal batteries. The battery-powered option uses five rechargeable nickel-cadmium cells giving 8 hours' operation. The batteries are trickle-charged during normal AC operation. A temperature-controlled crystal option is also available, which increases the crystal accuracy from one part in 10^6 to one part in 10^7 and the temperature stability from one part in 10^5 (0-35°C) to two parts in 10^6 (0-50°C).

*Gould Advance Limited, Roebuck Road, Hainault, Essex, England*

(677 M)

LCD multimeter

Gould Advance Ltd. announces the DMM9, a new 4½-digit multi-meter incorporating 7-segment liquid-crystal displays, a 0.05% measurement accuracy and true root-mean-square measuring facilities. The DMM9 features 28 different AC and DC voltage, current and resistance measurement ranges, including a separate 10 A current range, and is also available with optional probes for temperature, radio-frequency and high-voltage measurements.

The DMM9 has a maximum reading of 19999, and maximum resolutions on the current, voltage and resistance ranges of 10 μV, 10 nA and 100 mΩ, respectively. The liquid-crystal display incorporates separate positive or negative polarity indication plus a decimal point. Overrange is indicated by a flashing display, while 'battery-low' indication is provided by blanking the least significant digit.

An important feature of the DMM9 is the true r.m.s. sensing AC/DC converter, which can accept waveforms with a crest factor (ratio of peak to r.m.s. value) of up to 4 at full scale. A combined AC/DC facility is also available to measure AC waveforms with a DC content. Because true r.m.s. voltage measurement is the only accurate
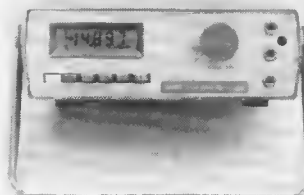
way of assessing the energy content of an AC waveform, the DMM9 is ideal for applications where power is the main parameter of interest, e.g. in the electricity supply industry or in applications involving thyristor control.

The electronic method of r.m.s. measurement used in the DMM9 involves squaring, averaging and square-rooting the input voltage, and gives a dynamic range greater than 1000:1. Feedback techniques allow the r.m.s. function to be synthesised with a single square-law device.

Options available include a temperature probe with a range of −20°C to +120°C, an r.f. probe and detector, a high-voltage probe for measurements up to 40 kV, and a printer interface offering a parallel BCD output.

The DMM9, which measures 227 mm x 72 mm x 260 mm and weighs 1.9 kg, may be operated from 90-130 V or 180-260 V AC supplies (45-400 Hz), or from four rechargeable 'C' cells.

Gould Advance Limited, Roebuck Road, Hainault, Essex, England

(686 M)

Sprocket-feed printer

A new version of the Extel M30/RO receive-only matrix printer, available from the Engineering Division of The Exchange Telegraph Company Ltd., incorporates a sprocket-feed system designed to ensure accurate registration when printing on labels, forms or preprinted stationery. The 30 character-per-second unit can handle roll or fan-folded paper or business forms.

A choice of 8-level ASCII or 5-level CCITT No 2 is available, and character sets of 64, 96 or 128 characters, upper or lower case can be supplied. Printing is by a 5 x 7 dot matrix impact via a ribbon onto plain paper. Vertical spacing is six lines per inch and the horizontal format is 72 characters-per-line.

The speed is switch-selectable, with three standard speeds, 10, 15 and 30 characters/sec available. The line interface is serial asynchronous to EIA RS232C Standard.

Selective-calling facilities are available, with or without positive/negative answer-back. The printer is a compact, typewriter-sized unit weighing only 16.2 kg and with a power consumption of between 25 and 65 W. Modular construction is used throughout.

The Exchange Telegraph Company Limited, 73-75 Scrutton Street, London, EC2A 4PB, England

(685 M)

8″ digital display

A new all-British range of large illuminated digit display modules is now available, the series 1620, intended mainly for numerical data display. However it also includes units with a partial alphabetic capability. Typical applications include data display on industrial processes; petrol price displays for filling stations; counting (and digital clocks); and scoreboards in sports stadia. The use of high-intensity lamps in an 8 inch high format gives clear viewing over long distances, with equally good visibility in areas of intense lighting such as TV studios.

Series 1620 comprises four display modules and six accessory packs. The 1620A and 1620S modules are full digits with partial alphabetic capacity. The former uses a 4-line BCD input, the latter a direct 7-segment input. The 1620B is a half digit with polarity indication, while 1620P is a punctuation module. Accessories include a power unit, controller, pulse counter, timer and an 18-line driver. Interconnecting trunking is also offered.
Newly-developed, low cost lamps, incorporating a vibration-resistant filament, have a minimum life of two years and are fitted with a high performance Fresnel lens. The lamps are easily replaced, being a push-in type, while access requires no tools, the front screen being simply slid upwards.

Display may be in red or white-on-black.
Power supplies may be either 12 V DC or 16 V AC with no need for switchover. The system is therefore fully adaptable for mobile use. The result is a highly flexible system with low cost (both first cost and maintenance) and long life.

Strainstall Limited
Harelco House
Denmark Road
Cowes
Isle of Wight, PO31 7TB

(645 M)

Mini Printer

G.M.T. Products Limited announce the availability of their low power Mini Printer – the 402. This compact stand-alone numeric printer has been specifically designed for use with digital voltmeters, frequency meters, etc. and for peripheral use with instrumentation systems.
Available as a standard 15 column parallel input unit, an interesting feature which greatly extends its capability is a range of low power board options which, used with a rechargeable battery power unit, allows the 402 to be ideal for electrically isolated, stand-by or portable applications.
With manual controls recessed to avoid accidental operation the

402 stands only 107 mm high, 157 mm wide with an overall depth of 314 mm. Power input is AC 230 V or 115 V ± 10% 48-62 Hz; DC 20-28 V. The 15 column parallel input boards offer independent loading of each of the two halves of a printed line (8 cols. and 7 cols.). A five digit counter is available for line/sample counting, batch counting, rate measurement etc. and is combined very handily on one board.
Parallel inputs on all versions have the important feature of a built in buffer memory for all data. This enables the data to be loaded prior to, or at the start of, the print cycle and eliminates the need to hold the data constant while printing takes place. Also provided is a synchronising input which enables data to be loaded by an external command after the manual print push button has been operated. The 'sync' input is in addition to the normal remote print input facility.

G.M.T. Products Ltd,
Woodlands Road,
Epsom, England.

(687 M)

Low profile keyboard

Low profile keyboard switches manufactured by Osmor Moulded Products ltd., are available individually or can be supplied mounted as complete Keyboards custom-made to individual specifications.
The chief advantage of this switch is its low profile, 0.450″ (11.45 mm). The keytops, which form an integral part of the switch, come in a wide range of colours.
The switch contacts, S.P.S.T. N/O, are gold-plated phosphor bronze with cross-bar switching reliability and are rated at 2.5 watts (50 V 50 mA).
These switches, with a life of 10×10^6 operations and their proven reliability, are particularly

suitable for microprocessor keyboards, computer peripheral and calculating equipment.

Osmor Moulded Products ltd.,
75 Bensham Grove
Thornton Heath, Surrey,
England

(680 M)

BOSS switches

True, low-cost programming of solid state equipment is offered by Binary Option Selection Switches from Molex Electronics' BOSS family. Designed for applications where manual programming is required, these switches can also be used to eliminate point-to-point hand soldering of wires on pc boards. Switch features include base ribs which raise it from the board so facilitating cleaning of flux residues. A low-stress, high-force contact is achieved by means of a double-lever design for the contacts. The switching interface provides a butting/wiping action. This minimises wear and, at the same time, ensures maximum contact integrity.
Brief electrical specifications
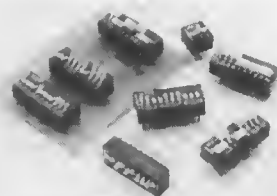
include switching rating at 30 V DC (open circuit) of 50 mA maximum, a non-switching rating of 100 mA rms at 50 V DC (maximum). Contact resistance, measured at a current flow of 10 mA is 100 milliohms. SPDT and DPST versions are available. Housing of both the standard and low-profile models is of polyester material providing both excellent mechanical and electrical characteristics. Terminals are of phosphor bronze, whilst finish is gold-alloy inlaid.
Up to ten circuits can be handled according to style ordered.

Molex Electronics Ltd.,
1 Holder Road, Aldershot,
Hants, GU12 4RH, England

(684 M)