Eurotronics

Eurotronics - a world-wide circuit and design idea competition, with over £10,000 worth of electronic equipment to be won! Note that the closing date for the competition is 31st March, 1979.
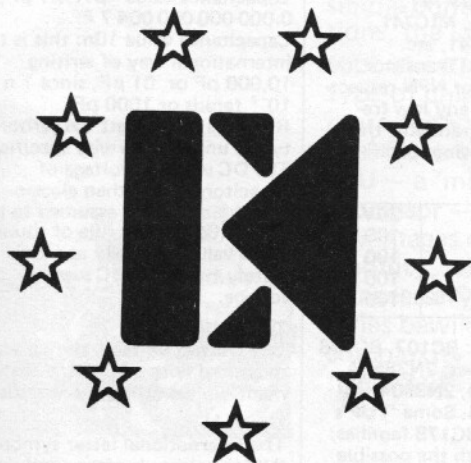
See this issue for further details

international circuit and design idea competition

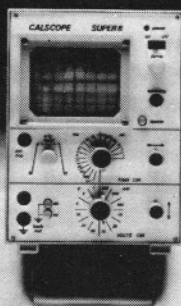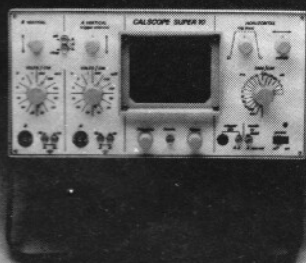# The professional scopes you've always needed.

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CALSCOPE

elektor 47 decoder

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 respect-
  ively) stand for any low fre-
  quency silicon transistor that
  meets the following specifi-
  cations:

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: BC177 and BC178 families;
BC179 family with the possible
exeption of BC159 and BC179;
2N2412, 2N3251, 2N3906,
2N4126, 2N4291.

- 'DUS' or 'DUG' (Diode Univer-
  sal, 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,
BA218, BA221, BA222, BA317,
BA318, BAX13, BAY61, 1N914,
1N4148.
Some '**DUG**'s are: OA85, OA91,
OA95, AA116.

- 'BC107B', 'BC237B', 'BC547B'
  all refer to the same 'family' of
  almost identical better-quality
  silicon transistors. In general,
  any other member of the same
  family can be used instead.

BC107 (-8, -9) families:
BC107 (-8, -9), BC157 (-8, -9),
BC207 (-8, -9), BC237 (-8, -9),
BC317 (-8, -9), BC347 (-8, -9),
BC547 (-8, -9), BC171 (-2, -3),
BC182 (-3, -4), BC382 (-3, -4),
BC437 (-8, -9), BC414

BC177 (-8, -9) families:
BC177 (-8, -9), BC157 (-8, -9),
BC204 (-5, -6), BC307 (-8, -9),
BC320 (-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 electro-
lytics) is normally assumed to be
at least 60 V. As a rule of thumb,
a safe value is usually approxi-
mately twice the DC supply
voltage.

Test voltages
The DC test voltages shown are
measured with a 20 kΩ/V instru-
ment, 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 modifi-
cation may be required.

Technical services to readers
- **EPS service.** Many Elektor
  articles include a lay-out for a
  printed circuit board. Some — but
  not all — of these boards are avail-
  able ready-etched and predrilled.
  The 'EPS print service list' in the
  current issue always gives a com-
  plete 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.

Eurotronics — a world-wide circuit and design idea competition, with over £ 10,000 worth of electronic equipment to be won! Note that the closing date for the competition is 31st March, 1979.

p. 3-19

For some relatively simple control applications, the µP is really too sophisticated and a new type of chip may prove more suitable: the Industrial Control Unit. **The ICU — a 'mini' microprocessor** — offers the advantages of programmability, without the unnecessary (and sometimes bewildering) complexity of a fully-fledged µP.

p. 3-28

A relatively large proportion of the 'fan mail' addressed to our Technical Queries department runs along the lines of: 'I have built your . . ., and it works beautifully, but could you please suggest a suitable power supply circuit, preferably with a p.c. board?' Apparently, there is quite a demand for **PSUs on PCBs!**

p. 3-36

Electronics, as a hobby, used to be purely hardware-oriented. In recent years, however, software is gradually coming into the picture — as this month's cover symbolises!

contents

Supplement:
BASIC (part 1), an introduction to a simple computer language.

SELEKTOR

Printed passive components

A new method of producing capacitors, coils and resistors on foil has been developed by Siemens. Introduced as 'Sicufol' circuits, these passive components are produced as flat zones. The rectangular, spiral and meandrous shapes of these zones and the material used determine the capacitances, inductances and resistances. The first modules produced with this technology were used in television sets. The 'Sicufol' principle is based on plastic foils made of polyimide or Teflon, which are first coated with copper in webs with lengths of several hundred meters. Chrome-nickel layers are then deposited, from which capacitors and resistors are later produced. The windings of the coils are etched directly out of the copper layer. The passive circuits formed next to each other on the webs in this way are cut off to produce finished modules. Protective layers made of insulating material provide both protection and reinforcement.

In contrast to conventional circuit board technology, the components are deposited on both sides of the actual carrier, the plastic webs being coated on both sides with Cu and Cr-Ni. External ancillary devices such as potentiometers, filters and active integrated circuits are subsequently inserted; their contacts

already constitute part of the finished 'Sicufol' circuits.

The designers have paid particular attention to very close tolerances of the resistance variations with temperature and climatic conditions. It is claimed that the fluctuations measured are without exception under 0.5%. The temperature coefficient determining the mechanical strength is lowest for a chromium content of between 53% and 58% and on the average less than 10 ppm/K. Layers comprising 20% chromium and 80% nickel have a

temperature coefficient of 600 ppm/K. The users of 'Sicufol' circuits have at their disposal a noteworthy range of R, C and L ratings. Surface resistances of between 20 and 300 ohm are possible, the resistance can be increased 3800-fold by using meanders. The load carrying capacity is 0.5 W/cm^2. Capacitors with a polyimide carrier foil as dielectric have a surface capacitance of 150 pF/cm^2. Finally, inductances of up to 10 μH can be produced using two spiral structures positioned directly one above the other on each side of the foil. Such an arrangement quadruples the inductance.

The low thickness of the insulating plastic carrier permits a variety of through-plating methods, which can greatly facilitate the accommodation of new circuit designs. Furthermore, conductors made of copper can be soldered, even in a flow solder bath just like circuit boards if a polyimide foil is used (300°C permanent temperature stability). The solderability and the additional reinforcement ensure that the components customary in circuit board technology can also be used without restriction for 'Sicufol' circuits.

Siemens AG
Zentralstelle für Information
Postfach 103
D-8000 München 1
Federal Republic of Germany   (385 S)

Energy from space

However much like science fiction it may sound, giant solar space power stations providing energy for domestic and industrial uses on Earth may be possible. If pilot studies to develop solar arrays into space power sources prove economically feasible, then by the end of the century giant orbiting solar power stations could be in use. Covering many miles, these would be constructed in space from basic units and materials transported from Earth by advanced launch vehicles. By using solar cells which convert the sun's rays to electrical energy, the large arrays of today will, over the next decades, emerge as the early stepping stones which could lead to the utilisation of space initiated by the forthcoming Space Shuttle era.

Under contract to the European Space Agency, Dynamics Group Electronic and Space Systems organisation at Bristol are already designing the huge 33 sq. metre (365 sq. ft.) 4 kW solar array that will power a space telescope for NASA. A 6 kW lightweight flexible fold-out array is also being developed for communication satellites of the next decade and proposals are in hand

to augment the Space Shuttle power using solar power modules of up to 60 kW. Other proposals exist to develop arrays up to 500 kW as space power sources. These could form modules for further development up to 2 MW to provide a space power station pilot scheme which, if proved economically feasible, would provide a basic source of energy for use on Earth.

British Aerospace Dynamics Group,
Filton House,
Bristol,
England.

(439 S)

Desirable residence for sale

'Situated in El Salvador in pleasant surroundings, modern detached fully equipped batchelor quarters with excellent facilities. Having an unusual roof design and an exceptionally good reception area, would suit a radio or electronics enthusiast. £ 6,000,000'. Actually, El Salvador, the smallest of the American states is the owner of this communications satellite ground

station. Its 32 metre diameter parabolic antenna is operating telephone and telex, both data and pictures, through 120 channels, to North America and Europe via the Intelsat IV-A satellite. It is capable of being extended although some of the channels now being used are leased to neighbouring countries. The installation, built by Siemens of West Germany, was completed and operational in 18 months at a cost of 23 million DM.

(437 S)

SELEKTOR

Laser gyro

Ferranti are to develop a laser gyro and to incorporate it in an experimental model of a strap-down inertial navigation system.

The aim is, first, to produce a system for installation in transport aircraft, followed, if tests and trials are satisfactory, by the development of a laser-gyro navigator for combat aircraft.

Interest in the laser gyro exists because, potentially, it could provide a more robust and mechanically simpler device for detecting movement than the existing spinning-mass gyro employed today. Because of the greater simplicity it is also expected that the total cost of ownership (initial capital cost plus maintenance costs) of a laser-gyro inertial navigation system throughout its service life would be much less than the equivalent conventional gimbal gyro system. Currently the Ferranti Inertial Systems Department has developed a gimbal-supported inertial platform incorporating conventional spinning-mass gyros. However, a simpler method of sensing motion would be to eliminate the gimbal support and mount the gyros permanently in a fixed-position — the so-called 'strap-down' configuration. In a gimbal system the platform is always maintained in a fixed orientation in space — the datum reference position. With a strap-down system the displacement of the gyro with respect to the starting datum is assessed and stored by a computer associated with the system.

The problem with the strap-down method is that the gyros used have to be mechanically robust and continue to perform with great accuracy even when subject to increased vibration and the higher angular and linear rates of accelerations implicit in being 'strapped-down'. The spinning-mass gyros in the current designs of inertial platform are shielded to a considerable extent from these harsh conditions by virtue of being gimbal supported.

The laser gyro, if it can be made to work with sufficient accuracy, offers a solution to this problem because it has no moving parts and is of rugged construction.

Principle of the laser gyro

The type of laser gyro Ferranti is developing is triangular in plan. It comprises a single block of vitreous ceramic material in which three cavities of circular cross-section have been drilled. The three cavities form a triangle in one plane. A mirror is positioned at the angular junction between each pair of cavities. The vitreous ceramic selected has a low temperature coefficient of expansion to ensure the mirrors remain accurately aligned with the cavities under all operational conditions. The cavities are filled with a lasing material and Ferranti have selected a helium neon gas mixture for this purpose. A cathode is situated midway along the length of one cavity and anodes are positioned towards the furthermost ends in the two remaining cavities. The helium neon mixture is excited to lase by electrical discharges occurring between the cathode and the two anodes. As a result, two independent coherent electromagnetic waves are generated — one travelling round the triangular resonating cavity in a clockwise direction, and the other in a counter-clockwise direction. If the assembly is now spun about a vertical axis perpendicular to the plane of the cavities the effective path around which one electromagnetic wave is travelling will appear to lengthen, and the other to shorten. To a detector placed at one of the reflecting mirrors the frequency of the electromagnetic wave propagated in one direction will appear to increase while that of the other wave will decrease. The difference in frequency between the two waves is directly proportional to the rate of rotation of the chamber about its perpendicular axis. The detector produces output pulses at a frequency proportional to the rate of rotation. Angular rates of acceleration can be determined by assessing changes in output pulse frequency. This device has all the characteristics of a gyro — hence the laser gyro.

The major technical problems that have to be solved before the laser gyro becomes a practical proposition are:
a) the generation of a truly linear output signal at extremely low rates of angular rotation (the two wave patterns tend to 'lock together' under these conditions)
and
b) to devise manufacturing techniques that enable the required high accuracies to be consistently achieved and maintained on a production basis.

Should the results attained in the new development programme be satisfactory it is expected that, from the mid to late 1980s onwards, laser gyros incorporated in 'strap-down' systems will be specified for many airborne applications.

Inertial Systems Department,
Ferranti Limited,
Silverknowes,
Ferry Road,
Edinburgh, EH4 4AD.

(440 S)
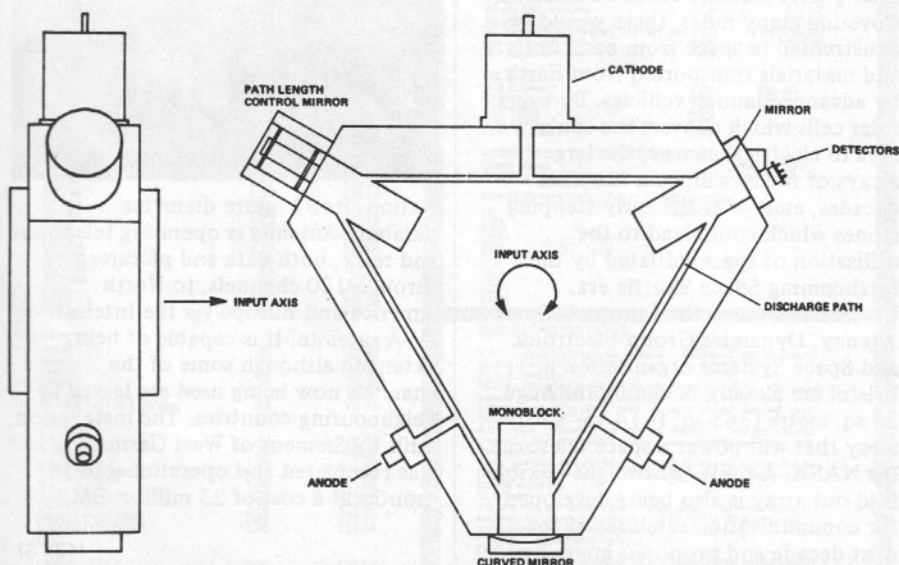
RCA enter the video disc market

Video recording is probably the biggest new innovation in home entertainment since the colour television and RCA are not alone in their view that video discs will be a multi-million dollar business in the 1980's. This company plan to achieve the earliest possible wide scale distribution of their 'Selecta Vision' video disc in the United States. The RCA system uses a grooved disc that is played with a diamond stylus at 450 revolutions per minute and contains one hour of programme per side. The player is designed for use with any television set, keeping the overall cost to a minimum. An unusual feature is the plastic sleeve resembling a record album cover, which deposits the disc on the turntable when inserted into a slot on the front of the machine. The disc is

SELEKTOR

removed by reinserting the empty sleeve back into the player. In this system the sleeve is a protection against environmental hazards such as warping, dust and scratches and also prevents the disc being touched by hand. RCA's initial catalogue will contain 250 titles, including feature motion pictures, as well as childrens, how-to, sports, cultural, educational and musical programmes.

RCA International Ltd.
RCA House,
50, Curzon Street,
London, W1Y 8EU
England.

(438 S)

µP-control for church organ

A microprocessor register control system has recently been fitted to the organ in the 600 year old St. Lorenz Church in Nuremberg. The system, known as the 'Registronik', was specially developed for the 138-register organ by two engineers of Siemens Gerätewerk, Erlangen. Up to forty register combinations can be stored for instant recall, so that the stops required for different pieces of music can be set before the performance. Whole recitals or the entire music for a church service can be preprogrammed in this way, leaving the organist free to operate the manuals and pedals so that he can give his full attention to the
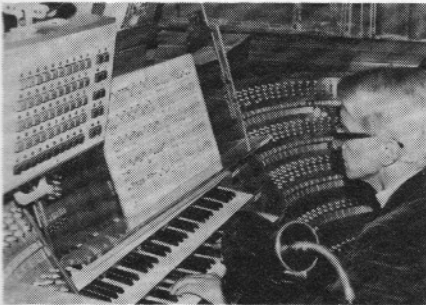
music itself. The control system is a very compact design, the stop keys being grouped together on a panel no larger than a notebook. The associated electronics are accomodated in a small metal cabinet in an adjoining room. The organ was previously equipped with an electromechanical four-combination register control system and, using conventional methods, forty combinations would have required more space than the rest of the organ. The organ which, except for the Passau organ, is the largest in the Federal Republic of Germany will certainly attract many people to Nuremberg.

(441 S)

Little L

A new range of ceramic chip inductors, available from Steatite Insulations Ltd, will not pass through the eye of a needle but the dimensions are sufficiently small for these electronics components to be used in thick film switch circuits. These miniature ceramic chip inductors are an entirely new development designed for hybrid technology with a fixed inductance. With nominal dimensions of only 2.5 mm x 2.5 mm x 1.9 mm, they have inductance ranges from approximately 4 nH to 1 µH, with tolerances of ± 5 and 10%.
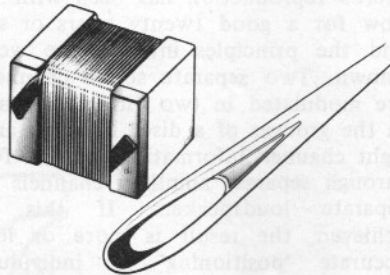
The coil winding is applied as a single layer and a new process has been developed so that the winding ends can be welded to metallised surface terminals on the ceramic body. They can also be soldered together with other components and are claimed to be impervious to attack from all general cleaning fluids.
Higher inductance units are currently under development utilising magnetic bodies together with variable inductance components.
Steatite Insulations Ltd.,
Hagley House,
Hagley Road,
Birmingham,
B16 8QW,
England

(442 S)

The All-Electronics Show
Ars Electronica Ltd
34 - 36 High Street
Saffron Walden
Essex
Telephone:
Saffron Walden 22612/27137
Telex: 81653

What are nasty things like microprocessors doing in a nice publication like this?

A unique gathering of the manufacturers of microprocessors (or 'chips', as they are familiarly known) has been arranged in the West End of London at which, free of charge, visitors may discuss how this new technology will affect them. are Texas Instruments, who invented

Are microprocessors nasty?

Apparently, microprocessors are nasty things — or so one would assume from the amusing title of a recent press release! However, the organisers of the All Electronics Show are also making every effort to bring the manufactures and potential users into (hopefully profitable) contact.
A unique gathering . . . .
A unique gathering of the manufactures of microprocessors (or 'chips', as they are familiarly known) has been arranged in the West End of London at which, free of charge, visitors may discuss how this new technology will affect them. Among those present are Texas Instruments, who invented the integrated circuit, and Fairchild Semiconductor who are now seen as the technology leaders.
The organisers of the event (The All-Electronics Show at Grosvenor House in Park Lane between 27th February and 1st March) claim that there is now virtually no industry in Britain which will not be affected by microprocessors. They add that every director and senior manager of a company manufacturing *anything* should get face-to-face with the manufacturers and distributors of a technology which the Government is supporting to the tune of £ 70 million per annum.
If you would like to ask even the most basic of questions, just send a stamp and addressed envelope to Sam Clarke, Dept. 3, 34-36 High Street, Saffron Walden, Essex and a free admission ticket — together with a special listing of the appropriate exhibitors — will be sent to you.
The All-Electronics Show,
Ars Electronica Ltd.,
34-36 High Street,
Saffron Walden Essex

(443 S)

crosstalk canceller

Separating left from right.

The weakest link in the hi-fi chain as far as crosstalk is concerned is the pickup. A Japanese firm, however, has recently introduced a special unit which, it is claimed, can dramatically improve the performance of cartridges in this respect. The following article takes a look at this interesting development.

Stereo reproduction has been with us now for a good twenty years or so, and the principles involved are well-known. Two separate sound channels are modulated in two different planes in the grooves of a disc. This 'left and right channel' information must be fed through separate amplifier channels to separate loudspeakers. If this is achieved, the result is more or less accurate 'positioning' of individual instruments within an overall sound image or stereo 'picture' as it is called (see figure 1). The position of a particular instrument, or of vocals, within the stereo image is determined by the proportion (and phase) of the corresponding electrical signal present in each channel. The greater the difference in signal strength, the more the resulting

sound will appear to be shifted towards the loudspeaker of the channel where it is strongest.

Talking about crosstalk

In the ideal situation the left and right channel information is only combined as the output sound waves of the two loudspeakers encounter one another in the listening room. In practice, however, it is unfortunately the case that neither channel is completely free of some small part of the other channel. The effect of this is to reduce the differences between the two channels so that they tend to sound more similar. As figure 2 illustrates, the process is analogous to mixing a touch of black with a white paint and vice versa. The result is a light and dark grey, which provide much
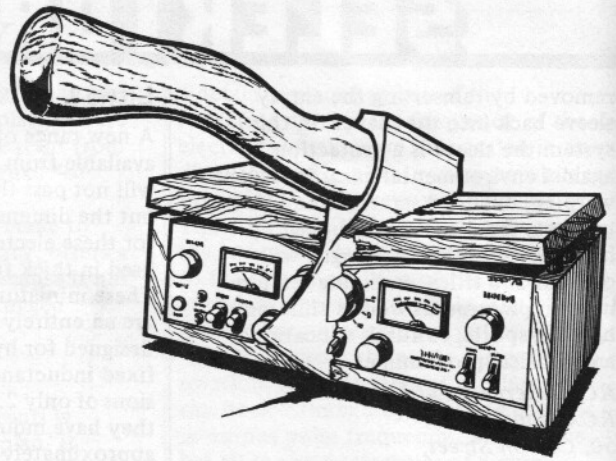
1a   stereo 'picture'
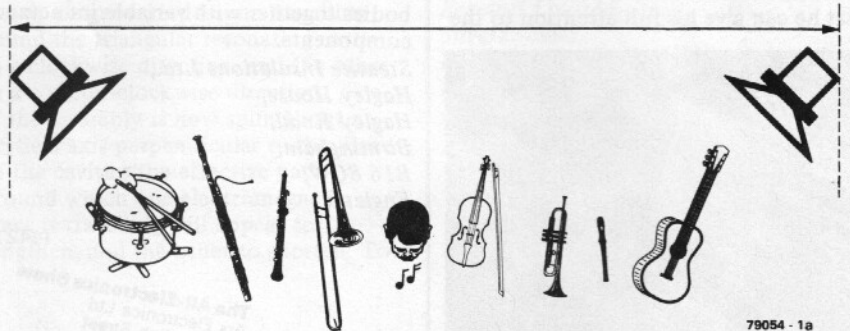
79054 - 1a

1b   stereo 'picture'

79054 - 1b

2

79054 - 2

3

79054 3

less of a contrast than pure black or white. In audio terminology this is known as crosstalk. The greater the crosstalk, the greater the similarity between the two channels. This results in a smaller stereo picture (figure 1b), giving the sound a greater approximation to mono reproduction.

Crosstalk can be caused in amplifiers by capacitive and/or inductive coupling between the wiring and layout of the two channels, or via a common supply line. Poorly designed balance controls are another common cause of crosstalk. In general, however, crosstalk produced in the amplifier is of secondary importance, since there is another point in the hi-fi chain which is much more critical. Furthermore it is possible to eliminate amplifier-induced crosstalk virtually completely provided one is willing to go to the expense of employing a separate supply for both channels (both in the pre-amp and power amp), separate pcbs etc., in short, with the exception of the case and mains plug, using completely separate mono amplifiers for each channel.

As mentioned, the weak link in the chain for crosstalk is not the amplifier, but the cartridge. In the particularly crucial range of frequencies between several hundred and several thousand Hz, channel separation is typically not much better than 25 dB. At higher frequencies this figure is even lower,

however it is also less important. The reasons for the comparatively poor channel separation of pickup cartridges are fairly complex and would require a considerable explanation. Suffice to say that the cartridge is by far the worst culprit when it comes to producing crosstalk.

'Phasing out' crosstalk

Ideally one would like to increase the channel separation of cartridges to around 40 dB (a figure of roughly 40 to 50 dB is the best that can be obtained in the actual cutting process of a disc and in the tracking performance of the stylus). However, improvements of this order now seem possible with a new approach by the Japanese Company, Denon (see figure 3). The circuit which, according to Denon, virtually eliminates pickup crosstalk is called the Phono Crosstalk Canceller (PCC). The unit, which is incorporated into a number of Denon amplifiers (there are plans to market the unit separately), is provided with four potentiometer controls, two of which are employed to (audibly) eliminate crosstalk from the left-hand channel to the right-hand channel, whilst the other two are set for minimum crosstalk from the right-hand to the left-hand channel. The adjustment procedure is performed with the aid of a test record.

The operation of the crosstalk canceller

can best be illustrated with reference to the series of phasor diagrams in figure 4. If a voltage is summed with a second voltage which is of equal magnitude but in antiphase to the first, the result is of course zero voltage. The vectors representing two such voltages are shown in figure 4a, and the sum of these two vectors would be a third vector of zero length, i.e. no vector at all.

Assume now that two voltages A and B have a phase difference φ, the corresponding vectors will also form an angle φ (4b); the sum of these two voltages will be represented by the vector C, and the difference (A-B) by the vector D.

If, in figure 4c, A represents the signal voltage of one stereo channel, whilst B represents the crosstalk voltage from the other channel, then it is possible to resolve B into a crosstalk component C, which will be in phase with the signal voltage, and a crosstalk component D, which will be $90°$ out of phase with the signal voltage. It is thus further possible to eliminate the crosstalk signal by introducing voltages C' and D' (which produce B') and summing these with the single channel information + crosstalk signal.

The same is equally true for figure 4d, where the crosstalk signal B is $180°$ out of phase with that of figure 4c.

Were the value of φ and the magnitude of the crosstalk vector constant, i.e.
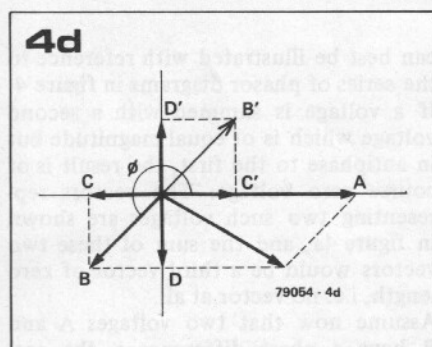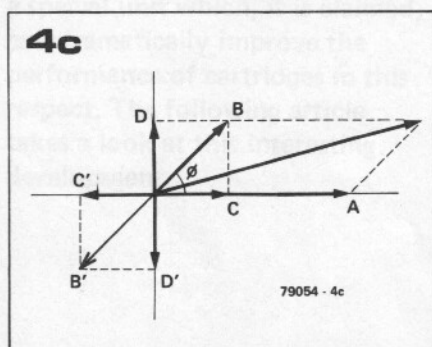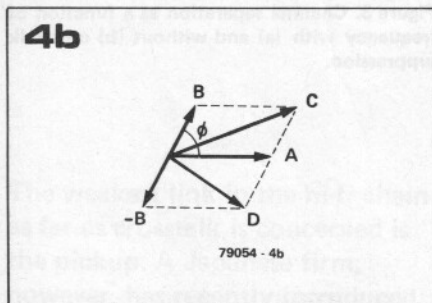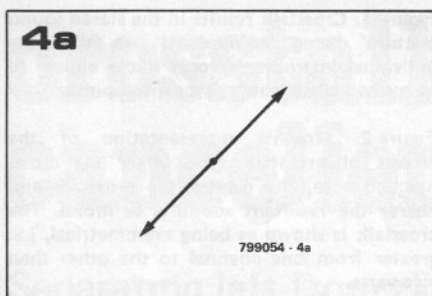
Figure 4. Phasor diagrams illustrating how the crosstalk signal can be eliminated by summing it with a signal of equal amplitude but opposite phase.

Figure 5. Block diagram of the Denon Phono Crosstalk Canceller.

Figure 6. Circuit diagram of the PCC-1000.
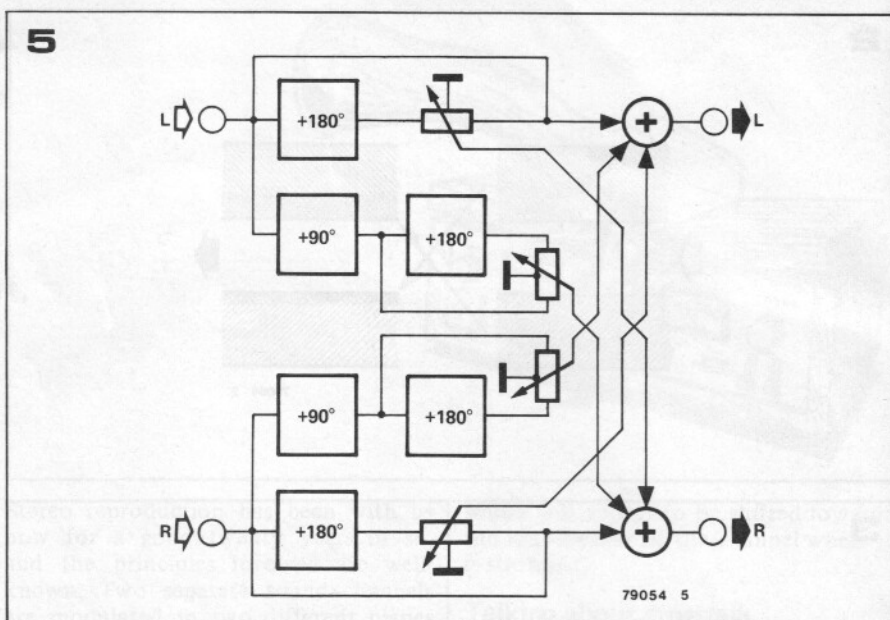
independent of frequency, the suppression of crosstalk would be complete. Unfortunately, however, as a glance at figure 3 makes clear, that is not the case. Nonetheless, it is a fact that suppression of crosstalk is most important in the mid-range of frequencies, where both φ and the length of the crosstalk vector (channel separation in dB) are more or less constant. Thus the principle remains valid.

In practice there are pickup elements with a crosstalk voltage as shown in both figure 4c and figure 4d, which means that the C' and D' voltages not only must be independently variable, but must be available in both phase versions. For independent control of the C' and D' voltages, two potentiometers per channel are required, and since the crosstalk from one channel to another is not necessarily the same as that going the other way (in fact it generally is not), four potentiometers in all are needed.

Block diagram of the PCC-1000

Figure 5 shows the block diagram of the Denon Phono Crosstalk Canceller PCC-1000. Each channel comprises two 180° phase-shifters, one 90° phase-shifter, two single-ganged potentiometers with fixed, earthed centre taps, and a summing circuit. The wiper voltages of the potentiometers in each channel are fed to the summing circuit of the other channel. The fixed, earthed centre taps ensure that the compensation voltages are available in both polarities depending upon the type of pickup being used.

Circuit

The circuit diagram of the PCC-1000 is shown in figure 6. The unit is connected between the tape output and tape input (monitor input) of the preamp. Since the preamp tape sockets are no longer available for their original application, the PCC-1000 itself provides the necessary connections. Switch S2 is the new tape monitor switch.

Switch S3 selects (1) 'left channel only', (3) 'right channel only', and (2) 'normal', (i.e. stereo). The bypass switch for the unit is S1.

Working our way back from the outputs, transistors TR5, 7 and 9 (6,8 and 10) plus accompanying passive components form the summing amplifier to which the three input signals (see figure 5) are fed via R29, R31 and R33 (R30, R32, R34). The junction of these resistors is at virtual earth.

The voltage at the collector of TR1 (TR2) is in antiphase with the input voltage. The wiper voltage of VR1 (VR2) determines the amplitude and phase (polarity) of the compensation voltage C' (see figures 4c and 4d). The RC network C7/R15 (C8/R16) introduces a phase shift of 90°, whilst TR3 again causes a 180° phase shift between in- and output voltage. The level and polarity of the D' compensation voltage is determined by the setting of VR3 (VR4).

That basically is all that there is to the circuit. The remaining components are part of the power supply stage.

In conclusion

The PCC-1000 crosstalk suppressor from Denon, is certainly an interesting and potentially valuable idea. However the question is whether the improvement in channel separation is matched by an equal improvement in the quality of the resultant sound. The problem of evaluating hi-fi equipment is fraught with the dangers of subjectivity, and it has not been unknown for a reviewer to remark upon the better stereo imaging of a particular pickup for example, when that pickup in fact had a poorer channel separation than others which were under review. This is a subject which we hope to come back to in the future. At least one can say that for anyone interested in 'state-of-the-art' hi-fi the crosstalk canceller is definitely well worth a listen.

6

CROSSTALK CANCELLER PCC-1000

TR1,2,3,4,5,6,7,8 : 2SC1775 (F)
2730158013

TR9,10 : 2SA872 (E)
2710070001

TR11 : 2SC1235 (D)
2730163011

TR12 : 2SC1213A (C or D)
2730111050

TR13 : 2SC1775 (E)
2730163011

TR14 : 2SA673 (C or D)
2710040057
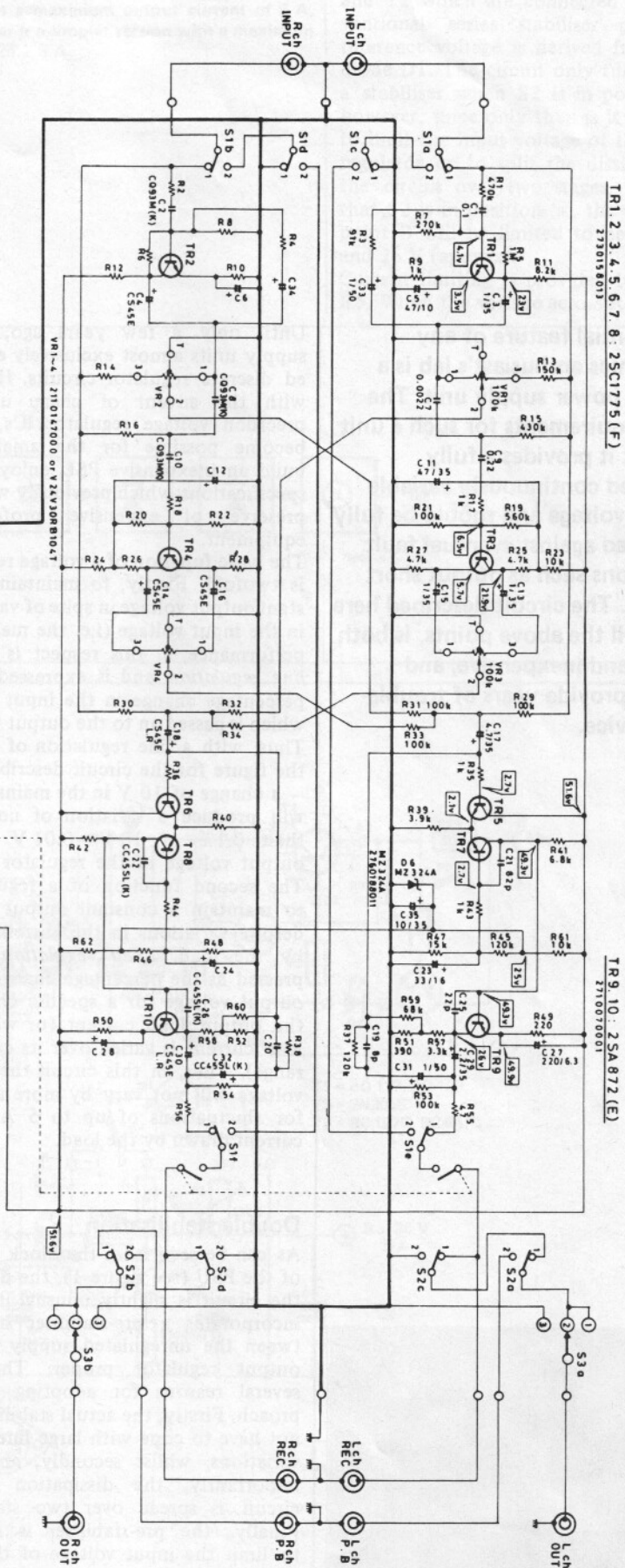
TRANSISTOR

TR1~8	2SC1775(F)	2730158013
TR9, 10	2SA872(E)	2710070001
TR11	2SC1235(D)	2730163011
TR12	2SC1213A(C)	2730111050
TR13	2SC1775E	2730158026
TR14	2SA673A(C)	2710040057

DIODE

D1~4	2760191008
D5	2760049011
D6	2760188011

S1a~f : P.C.C. (1. ON, 2. OFF)
(212085006)

S2a~d : TAPE MONITOR (1. OFF, 2. ON)
(212240007)

S3a~b : OUTPUT (1. Lch ONLY
2. NORMAL, 3. Rch ONLY)
(212407001)
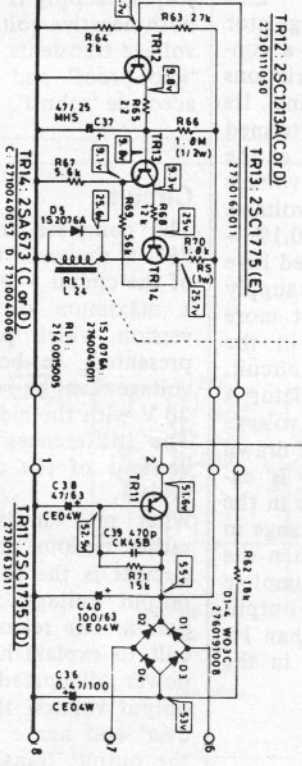
NOTES

ALL RESISTANCE VALUES IN OHM K=1,000 OHM M=1,000,000 OHM
ALL CAPACITANCE VALUES IN MICRO FARAD P=MICROMICRO FARAD
ALL VOLTAGES AND CURRENTS IS MEASURED AT NO SIGNAL INPUT CONDITION.
EVERY VOLTAGES AND CURRENTS IS MEASURED AT NO SIGNAL INPUT CONDITION.
CIRCUIT AND PARTS ARE SUBJECT TO CHANGE WITHOUT PRIOR NOTICE.

FOR EUROPE

POWER TRANSFORMER

FOR USA

POWER TRANSFORMER

79054 6
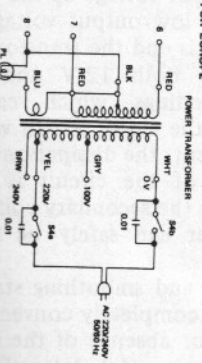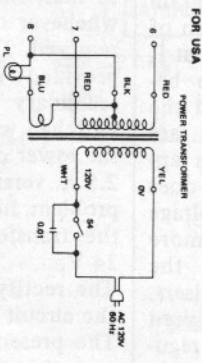
robust lab power supply

An essential feature of any electronics enthusiast's lab is a reliable power supply unit. The basic requirements for such a unit are that it provides a fully stabilised continuously variable output voltage and should be fully protected against eventual fault conditions such as output short circuits. The circuit described here meets all the above points, is both simple and inexpensive, and should provide years of trouble-free service.

Until only a few years ago, power supply units almost exclusively employed discrete regulator circuits. However with the advent of cheap universal precision voltage regulator ICs, it has become possible for the amateur to build an inexpensive PSU enjoying the specifications which previously were the preserve of expensive professional equipment.

The basic function of a voltage regulator is twofold. Firstly, to maintain a constant output voltage in spite of variations in the input voltage (i.e. the mains). Its performance in this respect is termed *line regulation* and is expressed as the percentage change in the input voltage which is passed on to the output voltage. Thus, with a line regulation of 0.1% — the figure for the circuit described here — a change of 10 V in the mains supply will produce a variation of not more than 0.1% of 10 V = 0.01 V in the output voltage of the regulator circuit. The second function of a regulator is to maintain a constant output voltage despite variations in the current drawn by the load. *Load regulation* is expressed as the percentage change in the output voltage for a specific change in the output load current (or when the load current is varied over its complete range). Thus, in this circuit the output voltage will not vary by more than 1% for fluctuations of up to 5 A in the current drawn by the load.

Double stabilisation

As can be seen from the block diagram of the PSU (see figure 1), the design of the circuit is slightly unusual in that it incorporates a pre-stabiliser stage between the unregulated supply and the output regulator proper. There are several reasons for adopting this approach. Firstly, the actual stabiliser does not have to cope with large line voltage variations, whilst secondly, and more importantly, the dissipation of the circuit is spread over two stabilisers. Finally, the pre-stabiliser is required to limit the input voltage of the regulator IC used in the circuit.

Apart from the preliminary stage, the design of the PSU is fairly conventional:

mains step-down transformer plus rectifier, smoothing capacitor, the two series-connected regulator stages and finally, a meter circuit to measure the output voltage/current. The first stabiliser circuit is provided with current limiting, whilst the second is protected against short-circuits and thermal overload. In view of the fact that, as we shall see, the supply is also protected against both negative voltages and large positive voltage transients, the circuit is virtually 'idiot-proof' and definitely merits the accolade 'robust'.

Circuit

The complete circuit diagram of the PSU is shown in figure 2. Two versions of the circuit — one designed to supply a maximum of 5 A, and a simpler version which provides 2.5 A — are presented. In both cases the output voltage can be varied between 5 and 20 V with the aid of potentiometer P1. The differences between the two versions of the circuit are detailed in table 1.

What may initially appear to be a rather curious problem with regulator circuits is the fact that the lower the output voltage, the greater the dissipation. The reason for this is not difficult to explain however, since the less power 'dissipated' in the form of an output voltage, the more power is 'left over' and hence must be dissipated in the output transistors of the regulator circuit itself. Thus it only makes sense to limit the input voltage of the circuit whenever only low output voltages are required. To this end the transformer is provided with both 12 V and 24 V secondary windings which can be switched with the aid of S2. In view of the lower current, the dissipation of the 2.5 A version of the circuit is not a problem, hence the secondary voltage of the transformer can safely be left at 24 V.

The rectifying and smoothing stages of the circuit are completely conventional. The presence or absence of the second smoothing capacitor, C2, determines the size of the ripple voltage at the output. For the 2.5 A version of the circuit C2
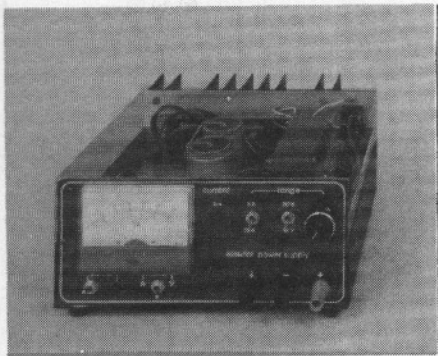
specifications:

output voltage: 5 . . . 20 V continuously
adjustable
output current: depending upon the
model; 2.5 or 5 A
current limiting: at a single fixed value,
plus short-circuit protection at 5 A
LED current limit indicator
meter: single switched meter for both
voltage and current
load regulation: ≤ 1%
line regulation: < 0.1% (referenced to
line voltage variations)
noise voltage: < 75 μV
ripple voltage: (100 Hz): < 500 μV

Figure 1. Block diagram of the 'robust' lab
PSU.

Figure 2. Complete circuit diagram. Two
versions of the circuit are possible: one
provides a maximum output current of 5 A,
the other is a simpler version with a maximum
output of 2.5 A.

can be omitted; but it must be included
in the 5 A version for the specifications
listed above to apply.

The pre-stabiliser stage is formed by T1
and T2 which are connected as a con-
ventional series stabiliser pair. The
reference voltage is derived from zener
diode D1. The circuit only functions as
a stabiliser when S2 is in position 'a',
however, since only then is it necessary
to limit the input voltage of the output
regulator or to split the dissipation of
the circuit over two stages. Assuming
that S2 is in position 'a', the voltage at
point B will be limited to between 25
and 26 V (approx).

Current limiting is provided by T3 and
R5. When the voltage across R5 exceeds

1

2
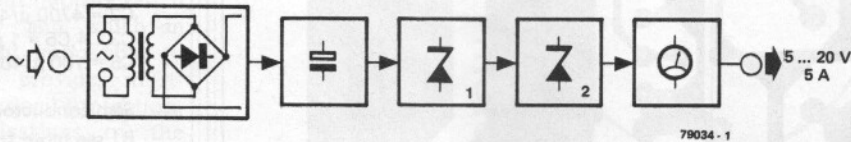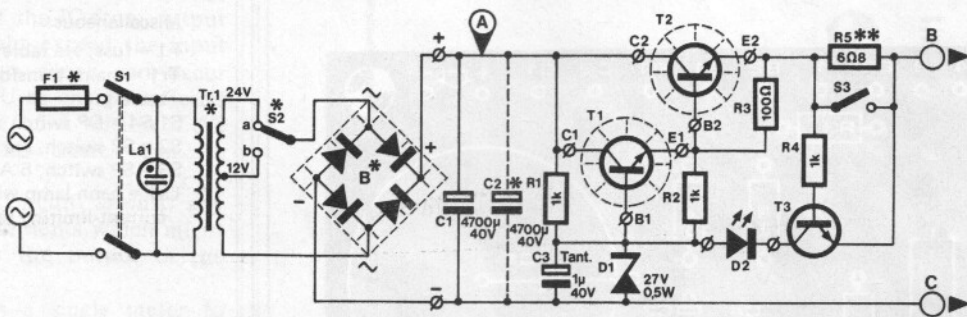
** see text

*see table

T1 = BD 137, BD 139
T2 = 2N3055
T3 = BC 107C, BC 547C
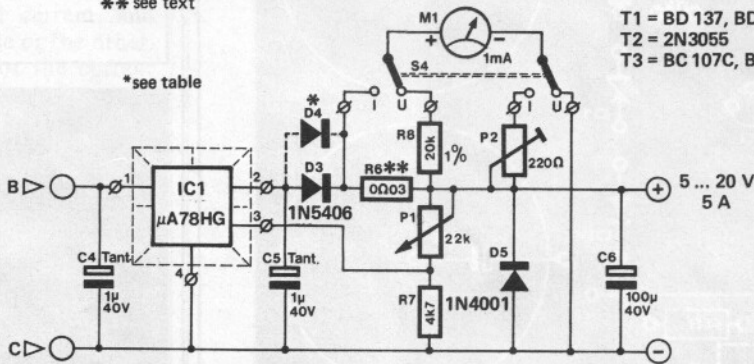
μA 78HG

bottom view

79034 - 2

3

79034

| 3 | 4 | 2 | E2 | 1 | B2 | E1 | B1 | C2 | C1 | + | ◇ | − |

R3
R2
R1
C1
R5
R4
C4 C3
C5
T3
D1
D5
C2
D3 D4
R8
R6
C2
R7
P2
C6
S4u
P1 S4x S3 D2 S4x P1 + − S4u
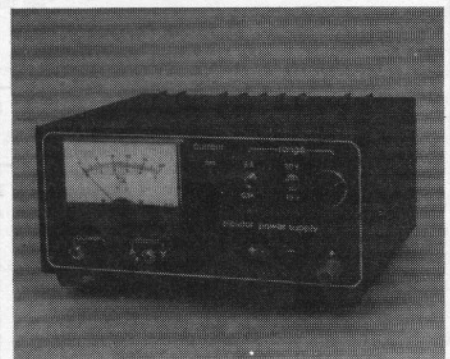
Figure 3. The printed circuit board and component layout (EPS 79034). Since a relatively large number of components must be cooled, not all of the circuit can be accommodated on the board.

Figure 4. Front panel design for the PSU (EPS 79034-F).

approx. 0.7 V, T3 turns on, turning off T1 and T2, and lighting LED D2. With the component values shown, the current limit comes into operation at approx. 100 mA, although this can be varied by altering the value of the current sense resistor R5. One should bear in mind that the dissipation of this resistor will be a maximum of 0.7 times the current limit in amps. The maximum current should not be allowed to exceed 2 A, since at that stage, should a short-circuit occur at the output, something like 60 W is already going to be dissipated in T2.

The current limit facility can be disabled by closing S3, when the circuit will simply be short-circuit proof, the current being limited in such an eventuality to the maximum current of 5 A. The output voltage regulator is formed by the IC type μA 78HG from Fairchild. This device provides a stabilised output voltage which can be continuously varied between 5 and 24 V and which in normal use is virtually impossible to damage. The IC also provides short-circuit and thermal overload protection. The principal specifications of the μA 78HG are listed in table 2, while pin-out details for the four-lead TO-3 package are shown in figure 2.

The output voltage is set by means of potentiometer P1, which together with R7 forms a variable voltage divider. The IC controls the output voltage such that the voltage at the 'control' input (pin 3), which is derived from the voltage divider, is always 5 V. D3 and D4 are included to protect the IC from output voltages which might exceed the input voltage, a situation which can occur when using the PSU to charge batteries for example. In the 2.5 A version of the circuit one of the diodes can be omitted.

D5 protects the circuit against any negative voltage transients which might find their way to the output of the circuit.

The PSU employs a single meter to display both voltage and current, and switch S4 selects one mode or the other. R6 is a shunt resistor for the current measurement and the meter scale can be calibrated by means of P2. Calibration for voltage measurements is not required. Instead of a moving coil meter it is possible to use the universal digital meter published in the January issue (Elektor 45), in which case some component values need to be changed. Resistors R7 and R8 of the digital meter should be changed for a wire link and a 1 k 1% resistor respectively, while in the PSU circuit R8 should be altered to 19 k (18 k and 1 k in series, both 1%). The above meter can be powered directly from point A of the PSU circuit.
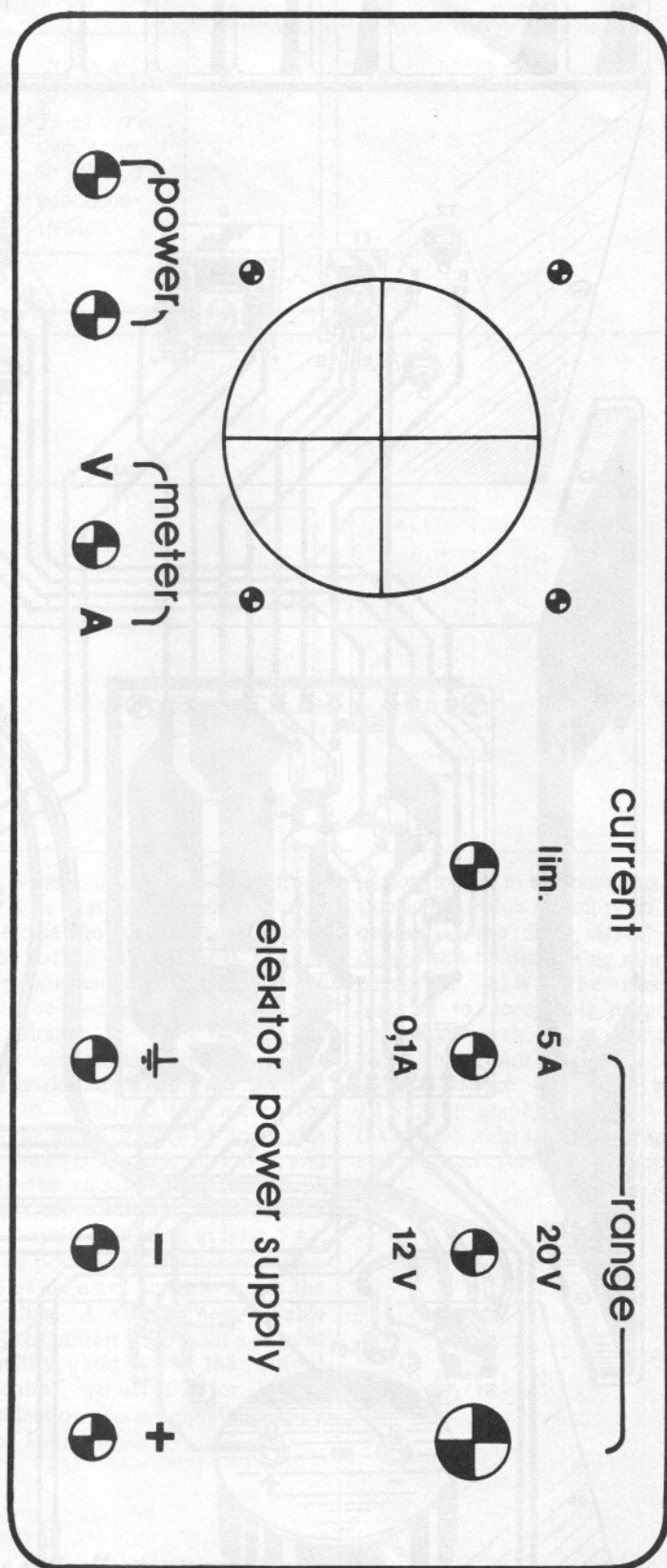
Construction

To ensure a long and trouble-free operating life it is worthwhile spending

5

79034-5
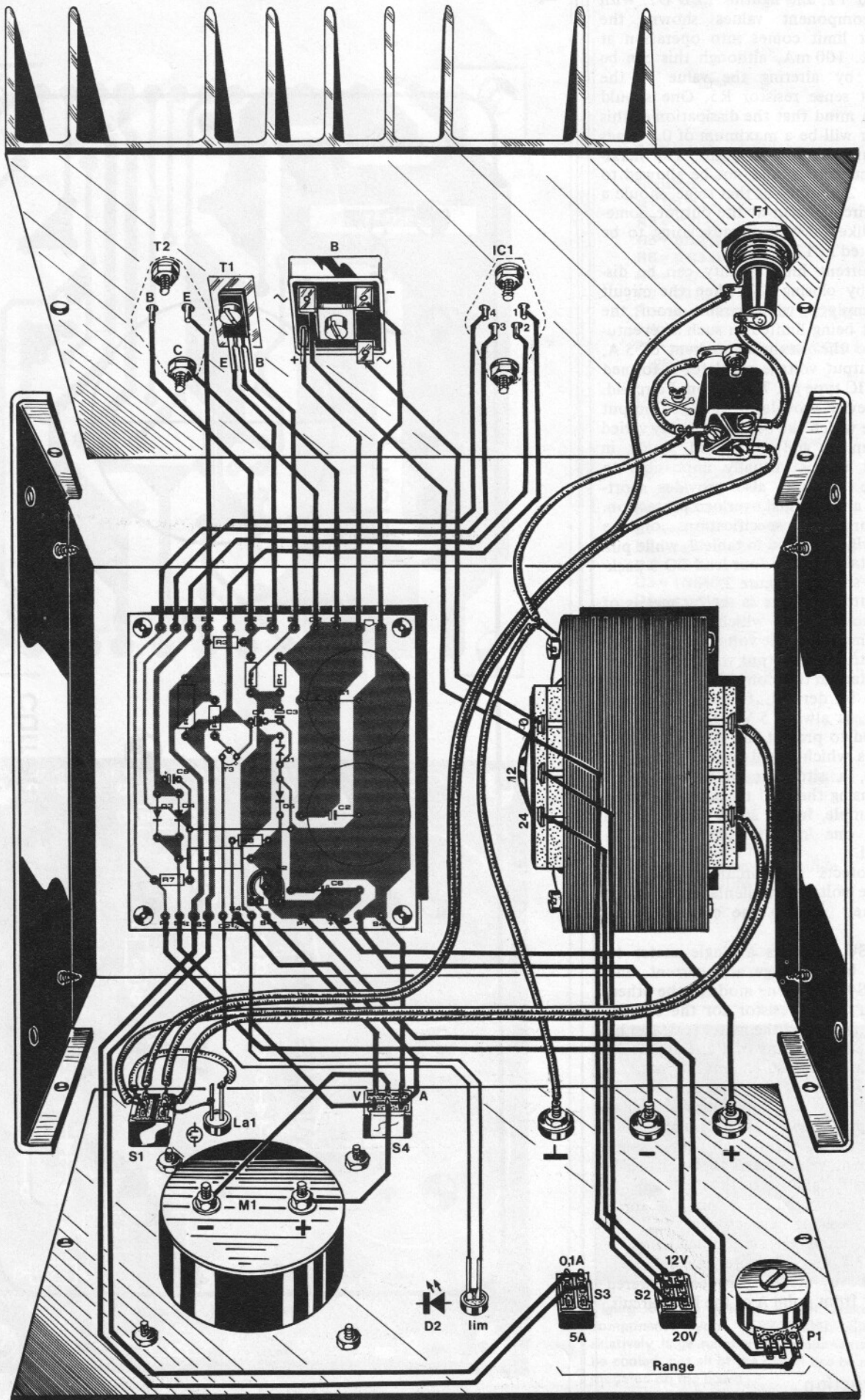
Table 1.

Differences between 2.5 and 5 A versions of the PSU

	2.5 A	5 A
F1	250 mA fuse	500 mA fuse
Tr1	2 x 12 V/3.5 A transformer	2 x 12 V/7 A transformer
S2	omitted	SP switch, 7 A
B1	B40C2500	B40C5000
D4	omitted	1N5406

Table 2.

Specifications of µA 78HG

max. dissipation: 50 W (at 25°C)
max. input voltage: 40 V
max. voltage difference between in- and output: 25 V
max. current: 7 A
control voltage: 4.8 V . . . 5.2 V
load regulation: ⩽ 1%
line regulation: ⩽ 1%
quiescent current: ⩽ 10 mA
ripple suppression: ⩾ 60 dB
noise voltage: 75 µV

a certain amount of attention on the constructional details of the PSU.

The printed circuit board for the project is shown in figure 3. However, since a comparatively large number of components must be cooled, most of these are mounted off-board. Particular attention must be given to the cooling arrangements for the bridge rectifier, B1, transistors T1 and T2, and the voltage regulator, IC1. In the case of the IC, one must reckon with a dissipation of something like 50 W, hence a beefy heat sink is a must.

Similarly, adequate precautions should be taken with T2, since it will dissipate anything up to 60 W. The bridge rectifier and T1 are not quite such a problem and could be cooled by, for example, mounting them on the case. However, do not forget to electrically insulate the components being cooled — with mica washers and silicon grease) — with the possible exception of IC1 wich may be mounted without insulation.

The shunt resistor, R6, will have to be self-wound. The simplest method of doing this is to wind 36 cm of 0.6 mm (24 s.w.g.) diameter enamelled copper wire on a 1 W resistor (e.g. 10 k). The inductance of such a home-made resistor can be neglected in this type of application. Care should be taken to ensure that the connecting wire is rated to carry the full 5 A the circuit can

supply. Wiring details are shown in figure 5. Note that in contrast to normal usage the case should not be connected to circuit earth, but rather is earthed via a seperate socket. In this way the circuit can be used for both positive and negative voltages.

The only component in the circuit requiring initial adjustment is P2, which is used to calibrate the meter for current. The simplest way of doing this is to set the PSU for, say, 10 V out, and then load the circuit with 45 Watt car headlamp bulb, with an ammeter in series (full scale deflection at least 4 A). With S4 in position 'I' the meter deflection can be adjusted until it shows the same reading. A slightly less reliable method is to inhibit the circuit's current limit facility, and with the output short-circuited, adjust P2 for a full-scale deflection (corresponding to a current of 5 A).

Operation

Using the PSU is quite straightforward, the only problem which might present itself is switch S2 (which, of course, is only present in the 5 A version of the circuit). As was already mentioned, this switch should be set to position 'b' for high-output-current low-output-voltage applications. Should the switch be left

in position 'a' in such circumstances, the thermal shutdown facility of the IC will quickly come into effect, since the device will be dissipating more than the permitted 50 W. The dissipation is reduced to acceptable proportions by changing over the position of the switch, with the result that the maximum output voltage is limited to approx. 12 V. The graph in figure 6 illustrates the relationship between output voltage and current for the two positions of S2.

ring modulator

and envelope follower

A ring modulator is a circuit which was originally employed in telecommunications systems for the modulation and detection of transmission signals. More recently however, the ring modulator has found an interesting application in the field of electronic music and is in fact now a common feature in many synthesisers.

A ring modulator is basically a four quadrant multiplier, that is to say, a circuit which will multiply two input voltages, regardless of whether they are positive or negative and ensure that the product voltage is of the correct polarity. Thus a positive voltage multiplied by a negative voltage will yield a negative voltage, a negative voltage times a negative voltage will give a positive voltage, and so on.

The question is: why is such a circuit of interest to the electronic music enthusiast? The answer can be found by considering the following mathematical expression for the product of two sinewaves:

$$\sin \alpha \cdot \sin \beta = \tfrac{1}{2} \cos (\alpha - \beta) - \tfrac{1}{2} \cos (\alpha + \beta).$$

Since a cosine is simply a sinewave with a $90°$ phase shift, it can be seen that multiplying two sinewaves results in two new sinewave signals whose frequencies are the sum and difference respectively of the two original signals. Note that this is only true for sinewave signals and not for other types of waveform. However the same effect will be produced by combinations of sinewaves. Thus, for example, if a combination of two sinewaves is multiplied with a third sinewave, each of the constituent sinewaves in the original signal will produce its 'own' sum and difference products. The multiplication of two sinewave input signals is illustrated in the oscilloscope photo of figure 1. The sinewave of the upper trace is multiplied with a second sinewave of higher frequency to produce the product waveform shown on the lower trace.

'Klangs'

The most significant feature of the ring modulator is its ability to exploit the harmonic relationship of different notes. This can best be explained with the aid of a further example. Assume that we feed two sinewave signals with frequencies of 2.5 and 4.5 kHz respectively to one of the ring modulator inputs.

The ratio of these two frequencies is 5:9, which means that, in musical terms, the resultant note is roughly equivalent to a lower seventh (the actual frequencies are somewhat on the high side, however they are only chosen to illustrate an example). If now a third sinewave with a frequency of 500 Hz is fed to the other input of the ring modulator, what will appear at the output? The 2.5 kHz signal multiplied with the 500 Hz tone produces two new signals of 2 and 3 kHz respectively. Similarly, the 4.5 kHz and 500 Hz signals will produce two new signals of 4 and 5 kHz. Thus at the output of the ring modulator will be four signals with frequencies of 2, 3, 4 and 5 kHz, i.e. a major chord. The musical relationship of the lower seventh has therefore been transformed into a different musical relationship, that of a major chord.

However, the above example is not typical, since it will be the exception rather than the rule that musically related frequencies at the input of the ring modulator will also produce a musically coherent chord at the output. In the vast majority of cases the harmonic relationship of the sum and difference signals produced at the output of the ring modulator will be uncorrelated, resulting in a dissonant, unmusical sound.

This is particularly true if, instead of sinewaves, other types of waveform are used as input signals. Figure 2 illustrates what happens when a sinewave is multiplied with a squarewave input. It is well known that non-sinusoidal periodic waveforms can be considered as consisting of a sinusoidal fundamental with the frequency of the signal in question, plus a number of harmonics of the fundamental, i.e. sinewaves whose frequency are a multiple of the fundamental frequency. Thus, for example, a sawtooth waveform of 1 kHz consists of sinewaves of 1 kHz, 2 kHz, 3 kHz . . . etc. The character of the resultant note depends upon the relative strength of the constituent harmonics.

If a sawtooth is fed to one input of a

3

79040 - 3
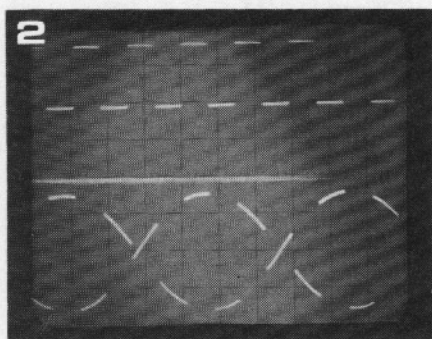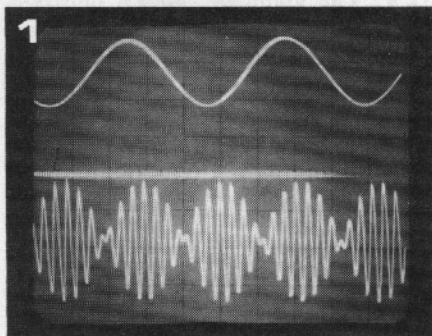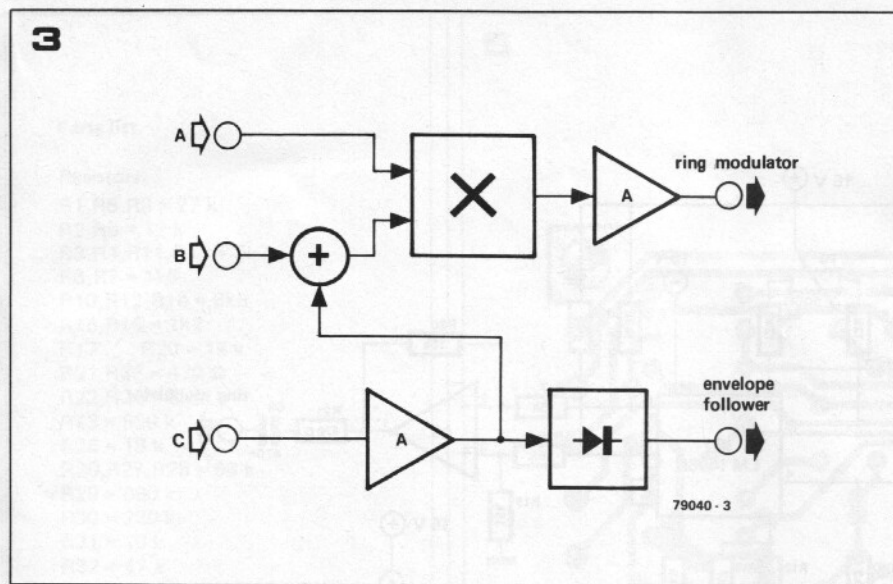
ring modulator and a pure sinewave of, e.g. 300 Hz, is fed to the other input, then each harmonic of the sawtooth will be multiplied by the 300 Hz sinewave, and a series of signals with frequencies of 0.7 kHz, 1.3 kHz, 1.7 kHz, 2.3 kHz, 2.7 kHz, 3.3 kHz etc. will be produced at the output. Thus the ring modulator has converted the original 1 kHz sawtooth and the 300 Hz sinewave into a complex note composed of musically unrelated harmonics. If now the 300 Hz sinewave is replaced by a second sawtooth signal, the harmonic structure of the resulting output signal is even 'denser' and more complex. At the lower end of the spectrum alone, the output signal will contain the following frequencies: 100, 300, 400, 500, 600, 700, 800, 900, 1100, 1200, 1300, 1400, 1500, 1600 and 1700 Hz. Each of these tones will have a characteristic amplitude, with particular frequencies tending to predominate whilst others are relatively attenuated. Due to its extremely complex harmonic structure, the timbre of the resultant signal resembles that of a large bell or gong, or the sound of metal striking metal (hammer on an anvil etc.). This type of percussive effect is called a *klang*, and is frequently used by composers of electronic music.

The potential of the ring modulator can best be exploited if both input signals are varied in frequency (e.g. modulated by a low frequency signal). The result is sounds which exhibit tremendous variations in both pitch (as far as one can still talk of the 'pitch' of such sounds) and tone colour, and which run the gamut of tonal possibilities between pure harmonies and the shrillest of dissonances. Extremely interesting effects can also be obtained by combining 'normal' sounds with a noise signal, by using the ring modulator in conjunction with various types of filter, and by using a combination of several ring modulators. The well-known modern composer Stockhausen once wrote a work for Hammond organ and four ring modulators!

Frequency doubler

The ring modulator can also be employed in more 'conventional' musical applications as a frequency doubler or octave shifter (doubling the frequency is of course equivalent to shifting the pitch of the signal up an octave). To achieve this effect one simply feeds the same signal to both inputs of the ring modulator. It is clear that the difference frequency of the two input signals will in this case be 0 Hz, i.e. there will be no difference signal at the output, whilst the sum signal will have double the frequency of the original input signal(s).

If the ring modulator is used as a frequency doubler for non-sinusoidal and polyphonic signals considerable intermodulation between the constituent harmonics will produce an interesting range of effects. A further possibility is to process one of the two input signals through a phasing or echo unit.

Finally, it is also possible to use the ring modulator in a somewhat less conventional mode, namely as a voltage controlled amplifier. The control voltage is fed to one input, whilst the signal to be modulated is fed to the other.

The ring modulator as an instrument

The above remarks give only a brief outline of the 'musical' applications of the ring modulator. However it is plain that, as an instrument, it is ideally suited for those interested in the field of experimental music, the persons looking for totally new tonal effects. The ring modulator is a 'difficult' instrument, which, if its capabilities are to be exploited to the full, demands a considerable degree of skill and knowledge on the part of the operator. Nonetheless, the ring modulator is a basic feature of most reasonably-sized synthesisers, as well as being a common accessory in the equipment of guitarists, 'keyboard players' and other instrumentalists.

The ring modulator is not a ring modulator

After the foregoing — of necessity — somewhat lengthy digression, we can now concentrate on the technical aspect of the circuit. First, however, it is worth clearing up a slight confusion which unfortunately exists regarding the true name of the circuit in question.

The term 'ring modulator' in fact describes a particular type of circuit, which happens to function as a four quadrant multiplier (at least as far as AC voltages are concerned), and in the early years of electronic music was used to denote specifically this effect. In the intervening period, however, new and better circuits have been designed to accomplish the same end, and these are now used almost exclusively when it comes to musical applications. The name ring modulator remained, however, since most musicians are interested only in what comes out of the 'black box' and not what it contains.

A more accurate name for the type of multiplier used in the majority of modern ring modulator circuits is 'double-balanced modulator'. This is a somewhat delicate circuit, consisting of a combination of voltage-controlled current sources. Fortunately the complete circuit of a double-balanced modulator is now available in IC form, so that all that is required to construct a 'ring modulator' suitable for musical applications is the addition of a few ancillary components.

Circuit

The block diagram of the Elektor ring modulator is shown in figure 3. It will be seen that the ring modulator (shown marked with an X sign) has three available inputs. Both the A and B inputs accept signal levels of up to approximately 1.5 volts peak to peak and are therefore compatible with the Elektor Formant and other synthesisers.

Input C has a preamplifier with a

4

Figure 4. Complete circuit diagram of the ring modulator. The actual process of 'ring modulation' is carried out in the double-balanced modulator IC1.

Figure 5. Printed circuit board for the circuit of figure 4 (EPS 79040).
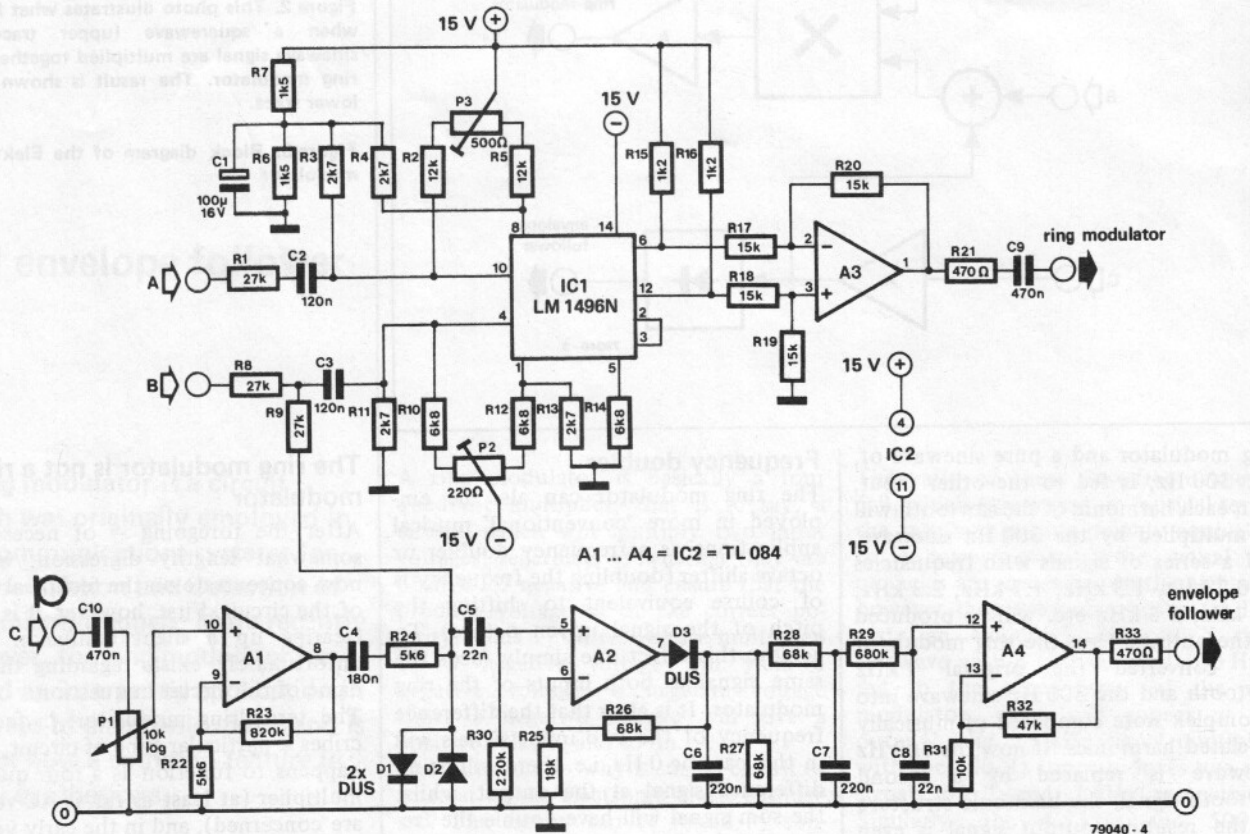
maximum input level of 10 mV and is sufficiently sensitive for the majority of guitar pickups and microphones.

An additional feature of this circuit is that the B and C inputs can be used simultaneously as they are mixed prior to the input of the ring modulator IC.

A further addition to the circuit (although not a functional part of the ring modulator) utilises two op-amps, A2 and A4, to form a peak rectifier and amplifier providing an envelope follower circuit which has an output level of up to 10 volts peak to peak. This gives a waveform output which is relative to the envelope of the low level instrument input (input C) which may be used in conjunction with synthesisers.

The complete circuit diagram of the ring modulator is shown in figure 4. The heart of the circuit is IC1, the double-balanced modulator, which is responsible for multiplying the input signals. The IC used is the LM 1496N from National (or MC 1496P from Motorola). A number of external resistors are required for the IC to function satisfactorily. It is necessary to limit the amplitude of the two output signals, otherwise there is the danger that the input signals will not be sufficiently suppressed and will appear at the output. For this reason the input

signals are held to a reasonable level (max. approx. 150 mV$_{pp}$) with the aid of the divider networks R1/R3 and R8/R11. This has the effect of ensuring that the input signals are approx. 50 dB down at the output. The suppression can be optimised by means of adjusting potentiometers P2 and P3.

R6 and R7 set the correct DC offset voltages at pins 8 and 10 of the IC, whilst the remaining associated resistors round the IC ensure the correct DC bias currents. The output voltage is tailored to match the standard Formant level of 1.5 V$_{pp}$. Op-amp A3 functions simply as an output buffer.

The C input, which uses op-amp A1 as a pre-amplifier stage, has been designed for guitar pickups, microphones etc. The input level to this stage is adjustable by means of P1 while the output is fed to the ring modulator via R9 and also to the envelope follower via C5. Diodes D1 and D2 are included to clamp excessively large voltages at this point. The remaining two op-amps, A2 and A4, are used in the envelope follower. Together D3, C6 and A2 form the peak rectifier. The rectified signal is then fed through a lowpass filter with a turnover frequency of 10 Hz. Finally, op-amp A4 ensures that the output voltage of the envelope

5

Parts list.

Resistors:
R1,R8,R9 = 27 k
R2,R5 = 12 k
R3,R4,R11,R13 = 2k7
R6,R7 = 1k5
R10,R12,R14 = 6k8
R15,R16 = 1k2
R17 ... R20 = 15 k
R21,R33 = 470 Ω
R22,R24 = 5k6
R23 = 820 k
R25 = 18 k
R26,R27,R28 = 68 k
R29 = 680 k
R30 = 220 k
R31 = 10 k
R32 = 47 k
P1 = potentiometer, 10 k log
P2 = preset potentiometer, 220 Ω
     (250 Ω)
P3 = preset potentiometer, 500 Ω

Capacitors:
C1 = 100 μ/16 V
C2,C3 = 120 n
C4 = 180 n
C5 = 22 n
C6,C7 = 220 n
C8 = 22 n
C9,C10 = 470 n

Semiconductors:
IC1 = LM 1496N (National) or
      MC 1496P (Motorola)
IC2 = TL 084
D1 ... D3 = DUS

follower can vary between approximately 0 and 10 volts.

Construction and setting-up

The circuit can be mounted on the p.c.b. shown in figure 5. In addition to the MC 1496P, a further equivalent for the LM 1496N exists, namely the S 5596 from Signetics. Unfortunately, however, this IC has a different pin-out, and hence cannot be used with the p.c.b. of figure 5.

The circuit requires supply voltages of +15 V and −15 V. Current consumption is extremely low, being in the region of a few dozen milliamps.

Setting up the circuit is quite straightforward: an input signal is fed to input A and potentiometer P3 is adjusted such that as little of the input signal as possible can be heard at the output. The same procedure is then carried out for input B and potentiometer P2. Finally, the entire setting-up procedure should be repeated, whereupon the circuit is ready for use, and the experimental musician can embark upon what will hopefully be a fruitful 'voyage' of musical discovery . . .
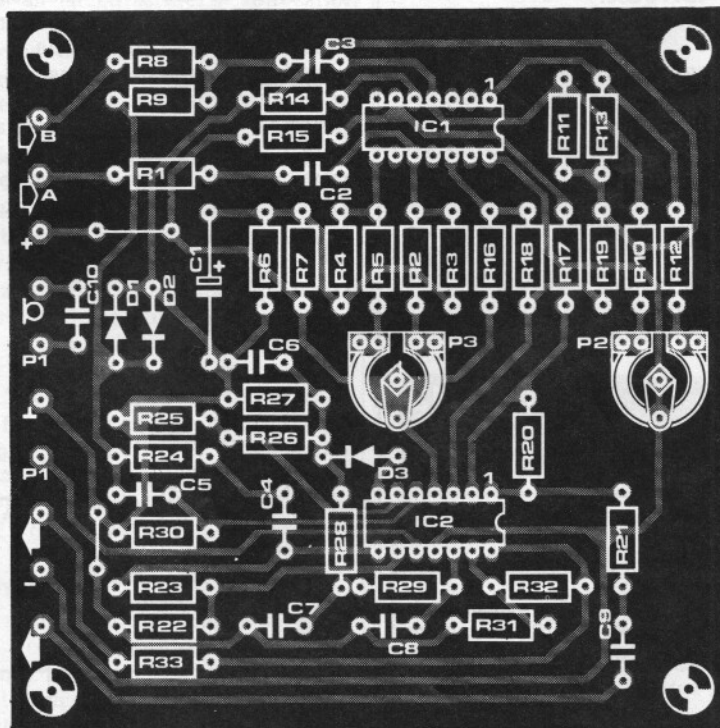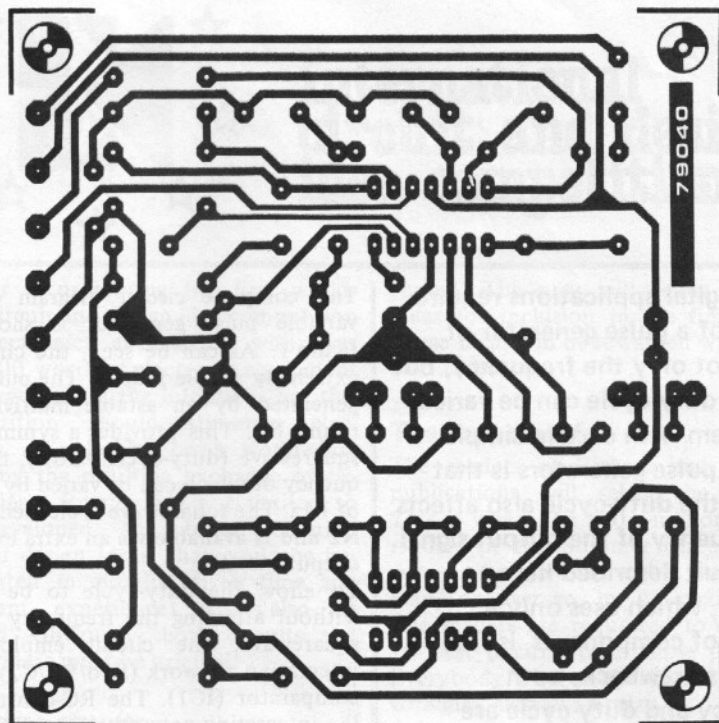
variable pulse generator

Many digital applications require the use of a pulse generator of which not only the frequency, but also the duty-cycle can be varied. A problem with certain simple variable pulse generators is that altering the duty-cycle also affects the frequency of the output signal. The circuit described here, however, which uses only a handful of components, is free from this drawback; both frequency and duty-cycle are independently variable. The frequency range extends from approx. 1 kHz to 20 kHz, whilst the duty-cycle can be varied from almost 0 to 100%.

K. Kraft

The complete circuit diagram of the variable pulse generator is shown in figure 1. As can be seen, the circuit is extremely simple indeed. The pulses are generated by an astable multivibrator round N1. This provides a symmetrical squarewave (duty-cycle = 50%), the frequency of which can be varied by means of P1a. The squarewave is cleaned up by N2 and is available via an extra external output.

To allow the duty-cycle to be varied without affecting the frequency of the squarewave, the circuit employs an integrating network (P1b/R2/C2) and a comparator (IC1). The RC-constant of the integrating network ($C2 = 1/6 \cdot C1$) is chosen such that the voltage across C2 may vary between approx. 20 and 80% of the supply voltage, U_b. Whenever this voltage exceeds the reference voltage on the inverting input of the comparator, the output of the latter changes state. The result is therefore a squarewave signal (U_x) whose duty-cycle is determined by the reference voltage (U_{ref}) of the comparator. This process is clearly illustrated in the timing diagram of figure 2. By varying the voltage at the inverting input of the comparator it is therefore possible to adjust the duty-cycle of the squarewave as desired without affecting the frequency.

There now remains the question of what happens to the duty-cycle if the frequency of the squarewave is varied. Normally the duty-cycle would be influenced by the frequency change, however due to the use of a twin-ganged potentiometer (P1a/P1b), in the circuit shown here, the RC-constant of the integrating network will vary in sympathy with that of the multivibrator. If the frequency, f, of the multivibrator is increased to x·f, the period of the resulting squarewave will be reduced by a factor x. However since the RC-constant of the integrating network is likewise reduced by a factor x, the duty-cycle of the squarewave at the output of the comparator will remain unchanged. It is not difficult to see that altering the RC-constant of the integrating network will not affect the shape of the charge curve of C2, so that the pulse diagram of figure 2 is also valid for any frequency x·f. The ratio T1/T2 and thus the duty-cycle (= T1/T2 x 100%) is therefore constant.

The values of R3, R4 and P2 are chosen
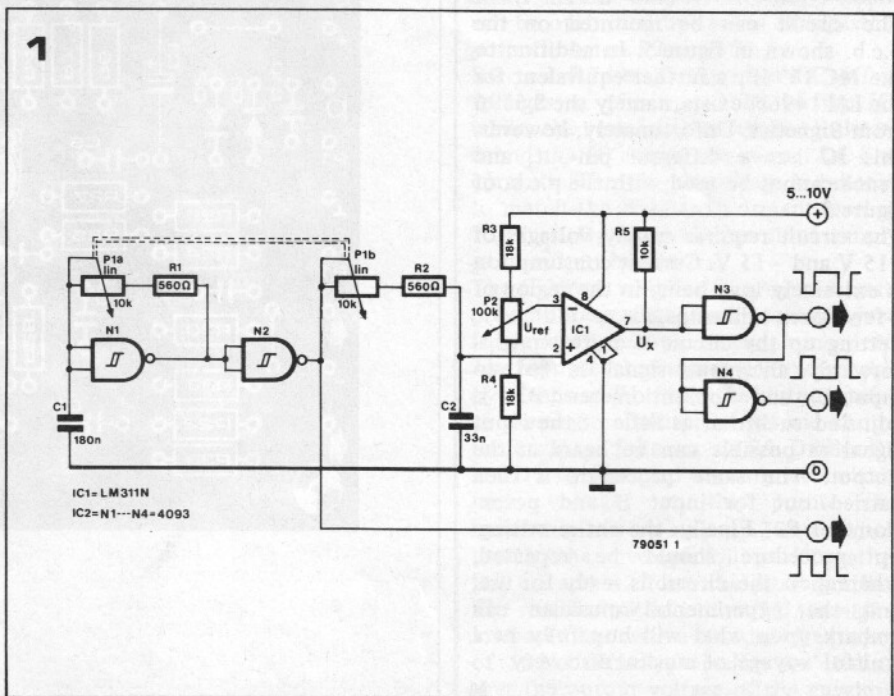
Figure 1. The circuit of the variable pulse generator employs only two ICs, yet both the frequency and duty-cycle are independently variable.

Figure 2. This timing diagram illustrates how the duty-cycle of the output signal is determined by the reference voltage of the comparator (U_{ref}). Furthermore, by varying the RC-constant of the integrating network in sympathy with that of the multivibrator it is possible to make the duty-cycle independent of the frequency.

1

IC1 = LM311N
IC2 = N1 --- N4 = 4093

79051 1

such that the reference voltage at the inverting input of IC1 may vary between 13 and 87% of the supply voltage. As already mentioned, the voltage across C2 can vary between 20 and 80% of supply. Thus it is possible to vary the duty-cycle of the output signal between virtually 0 (i.e. no output signal) and 100% (DC voltage).

The two remaining Schmitt-trigger gates of IC2 are used at the output, N3 to further square up the output signal and N4 to provide an inverted version. Thus if a squarewave with a duty-cycle of 30% is present at the output of N3, the output of N4 will provide a squarewave of identical frequency but with a duty-cycle of 70%.

With the component values as shown in figure 1, the frequency range of the circuit extends from approx. 1 kHz to 20 kHz.

The frequency range can be altered if desired; the essential parameters of the circuit are given by the following equations:

$$C1 = 6 \times C2$$
$$P1a = P1b \text{ and } R1 = R2$$
$$f = \frac{1}{(P1a + R1) \cdot C1 \cdot 0.4}$$

It is also possible to control the amplitude of the output signal by connecting a 22 k potentiometer between the output of N3 or N4 and ground. The output signal can then be taken from the wiper of the potentiometer.

The supply voltage for the circuit need not necessarily be stabilised, however if any sort of demands are to be placed upon the stability of the frequency, amplitude or duty-cycle, it is best to employ a voltage regulator. Since the entire circuit consumes no more than roughly 20 mA, a regulator from the 78L-series is the obvious choice. Depending upon the supply voltage, the 78L05, 78L06, 78L08, 78L09 and 78L010 should prove suitable. ◄
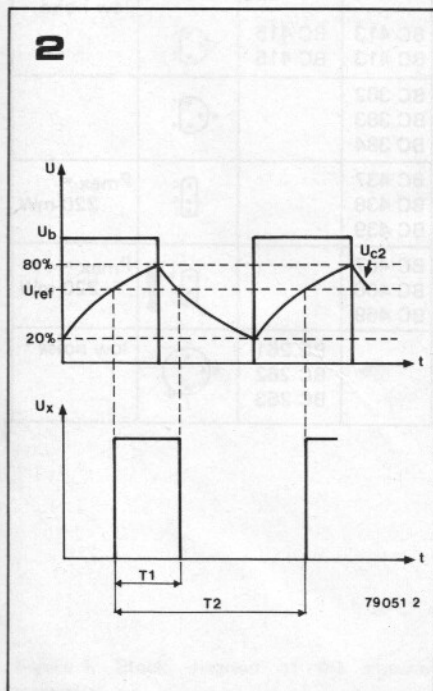
Eurotronics

international circuit and design idea competition

Elektor is promoting the first world-wide circuit and design idea competition for electronics enthusiasts, with over £ 10,000 worth of electronic equipment to be won. It is the intention that this competition should stimulate electronics as a hobby on a world-wide scale, by the resulting exchange of circuit ideas. Entries are not limited to fully-developed and tested circuits: original design ideas, that could be implemented in circuits (given time and sufficient experience), can also be entered. Obviously, both circuits and design ideas must be original.

Complete circuits

Entries should be interesting, original circuits that can be built for less than £ 20.00 — not counting the case and printed circuit board. Circuits used in commercially available equipment, described in manufacturer's application notes, or already published are not considered 'original'.

The complete circuit should be sent in, together with a parts list, a brief explanation of how it works and what it is supposed to do, a list of the most important specifications and a rough estimate of component cost. The latter can be based on retailer's advertisements. A jury, consisting of members of the editorial staffs for the English, German and French issues of Elektor and the Dutch edition, Elektuur, will judge the entries according to the criteria listed above. The best designs will be published in the four Summer Circuits issues, with a combined circulation of over 250,000 copies. All entries included in this final round will be rewarded with an initial 'fee' of £ 60.00.

Design ideas

Readers who cannot submit a complete circuit (for lack of time, know-how or hardware) may enter an interesting and original design idea. However, the same basic rule holds: the idea should be for a feasible circuit that can be built for an estimated component cost of less than £ 20.00. The idea should be described as fully as possible. Perferably, a block diagram and — if at all possible — a basic (untested) circuit should be included. The jury will select the best ideas for inclusion in the final round. These ideas will be rewarded with a 'fee' of £ 20.00.

The final round

The readers of Elektor and its sister publications will select the winners! This is where the half-a-million-or-more readers of the Summer Circuits issues come in (yes, we know that each copy is read, on average, by 2.6 people . . .). The readers are requested to select the 10 best circuits from those published. Everybody who co-operates in this final vote may also win a prize.

The prizes

Over £ 10,000 worth!
The ten entries selected by our readers will receive a total of £ 10,000 worth of prizes. Dream prizes for any enthusiastic electronics hobbyist!

The closing date for the competition is 31st March, 1979.
Entries should be sent to:
Elektor Publishers Ltd.,
Elektor house,
10 Longport,
Canterbury, CT1 1PE,
Kent, U.K.
Both the envelope and the entry should be clearly marked 'Eurotronics circuit' or 'Eurotronics design idea'.

Closing date: 31st March, 1979.

General conditions

- Members of the Elektor/Elektuur staff cannot enter the competition.
- Any number of circuits and/or design ideas may be submitted by any person.
- Entries that are not included in the final round will be returned, provided a stamped, addressed envelope is included.
- The decision of the jury is final.

TUPTUNDUGDUS

Wherever possible in Elektor circuits, transistors and diodes are simply marked 'TUP' (Transistors, Universal PNP), 'TUN' (Transistor, Universel NPN), 'DUG' (Diode, Universal Germanium) or 'DUS' (Diode, Universal Silicon). This indicates that a large group of similar devices can be used, provided they meet the minimum specifications listed in tables 1a and 1b.

	type	U_{ceo} max	I_C max	h_{fe} min.	P_{tot} max	f_T min.
TUN	NPN	20 V	100 mA	100	100 mW	100 MHz
TUP	PNP	20 V	100 mA	100	100 mW	100 MHz

Table 1a. Minimum specifications for TUP and TUN.

Table 1b. Minimum specifications for DUS and DUG.

	type	U_R max	I_F max	I_R max	P_{tot} max	C_D max
DUS	Si	25 V	100 mA	1 μA	250 mW	5 pF
DUG	Ge	20 V	35 mA	100 μA	250 mW	10 pF

Table 2. Various transistor types that meet the TUN specifications.

TUN		
BC 107	BC 208	BC 384
BC 108	BC 209	BC 407
BC 109	BC 237	BC 408
BC 147	BC 238	BC 409
BC 148	BC 239	BC 413
BC 149	BC 317	BC 414
BC 171	BC 318	BC 547
BC 172	BC 319	BC 548
BC 173	BC 347	BC 549
BC 182	BC 348	BC 582
BC 183	BC 349	BC 583
BC 184	BC 382	BC 584
BC 207	BC 383	

Table 4. Various diodes that meet the DUS or DUG specifications.

DUS		DUG
BA 127	BA 318	OA 85
BA 217	BAX 13	OA 91
BA 218	BAY 61	OA 95
BA 221	1N914	AA 116
BA 222	1N4148	
BA 317		

Table 3. Various transistor types that meet the TUP specifications.

TUP		
BC 157	BC 253	BC 352
BC 158	BC 261	BC 415
BC 177	BC 262	BC 416
BC 178	BC 263	BC 417
BC 204	BC 307	BC 418
BC 205	BC 308	BC 419
BC 206	BC 309	BC 512
BC 212	BC 320	BC 513
BC 213	BC 321	BC 514
BC 214	BC 322	BC 557
BC 251	BC 350	BC 558
BC 252	BC 351	BC 559

Table 5. Minimum specifications for the BC107, -108, -109 and BC177, -178, -179 families (according to the Pro-Electron standard). Note that the BC179 does not necessarily meet the TUP specification ($I_{c,max}$ = 50 mA).

	NPN	PNP
	BC 107	BC 177
	BC 108	BC 178
	BC 109	BC 179
U_{ceo} max	45 V	45 V
	20 V	25 V
	20 V	20 V
U_{ebo} max	6 V	5 V
	5 V	5 V
	5 V	5 V
I_C max	100 mA	100 mA
	100 mA	100 mA
	100 mA	50 mA
$P_{tot.}$ max	300 mW	300 mW
	300 mW	300 mW
	300 mW	300 mW
f_T min.	150 MHz	130 MHz
	150 MHz	130 MHz
	150 MHz	130 MHz
F max	10 dB	10 dB
	10 dB	10 dB
	4 dB	4 dB

The letters after the type number denote the current gain:

A: a' (β, h_{fe}) = 125-260
B: a' = 240-500
C: a' = 450-900.

Table 6. Various equivalents for the BC107, -108, . . . families. The data are those given by the Pro-Electron standard; individual manufacturers will sometimes give better specifications for their own products.

NPN	PNP	Case	Remarks
BC 107 BC 108 BC 109	BC 177 BC 178 BC 179		
BC 147 BC 148 BC 149	BC 157 BC 158 BC 159		P_{max} = 250 mW
BC 207 BC 208 BC 209	BC 204 BC 205 BC 206		
BC 237 BC 238 BC 239	BC 307 BC 308 BC 309		
BC 317 BC 318 BC 319	BC 320 BC 321 BC 322		I_{cmax} = 150 mA
BC 347 BC 348 BC 349	BC 350 BC 351 BC 352		
BC 407 BC 408 BC 409	BC 417 BC 418 BC 419		P_{max} = 250 mW
BC 547 BC 548 BC 549	BC 557 BC 558 BC 559		P_{max} = 500 mW
BC 167 BC 168 BC 169	BC 257 BC 258 BC 259		169/259 I_{cmax} = 50 mA
BC 171 BC 172 BC 173	BC 251 BC 252 BC 253		251 . . . 253 low noise
BC 182 BC 183 BC 184	BC 212 BC 213 BC 214		I_{cmax} = 200 mA
BC 582 BC 583 BC 584	BC 512 BC 513 BC 514		I_{cmax} = 200 mA
BC 414 BC 414 BC 414	BC 416 BC 416 BC 416		low noise
BC 413 BC 413	BC 415 BC 415		low noise
BC 382 BC 383 BC 384			
BC 437 BC 438 BC 439			P_{max} = 220 mW
BC 467 BC 468 BC 469			P_{max} = 220 mW
	BC 261 BC 262 BC 263		low noise

sinewave generator

In last month's issue of Elektor we published a design for a spot sinewave generator which offered truly 'top-notch' specifications. For the purposes of many amateurs, however, the accuracy provided by such a circuit (e.g. harmonic distortion of less than 0.0025%) is an expensive luxury. The circuit described here represents the other side of the coin — a simple cost-effective sinewave generator whose frequency can be continuously varied over virtually the entire audio spectrum, while being easy to construct and requiring no calibration. Just for good measure the circuit also offers the choice of a squarewave output.

The idea of incorporating a limiter in the feedback loop of an oscillator circuit as a means of stabilising the amplitude of the output signal was originally employed in the spot sinewave generator published in last month's issue of Elektor. That circuit was designed for extremely low harmonic distortion and high amplitude stability. The circuit described here, although employing a similar principle to its 'big brother' of last month, is intended to meet a different set of criteria. It was felt that many amateurs would appreciate a simple low-cost sinewave generator with continuously variable frequency which would require no complicated calibration procedure.

Block diagram

The block diagram of the simple sinewave generator is shown in figure 1. A selective filter is followed by a limiter circuit which clamps the signal level to + and $-U_b$. The output of the limiter is fed back to the input of the selective filter, thereby providing the conditions for oscillation. The circuit will only continue to oscillate if the loop gain of the system is greater than unity. To ensure that this requirement is always satisfied an amplifier is included in the feedback loop. The circuit is forced to oscillate at the centre frequency of the filter, since only at that frequency will the in- and output signals of the filter be in phase.

The reason why the amplitude of the output voltage of such an oscillator remains constant was described in detail in the above-mentioned article on the spot sinewave generator, to which readers are here referred. A continuously variable oscillator frequency is obtained by making the centre frequency of the selective filter tunable. The Q of the filter will inevitably vary with the centre frequency, thereby affecting the suppression of higher

Figure 1. Block diagram of the sinewave generator.

2

A1 . . . A4 = TL 084 = IC1
D1 . . . D4 = 4x 1N4001

79019 2

Circuit
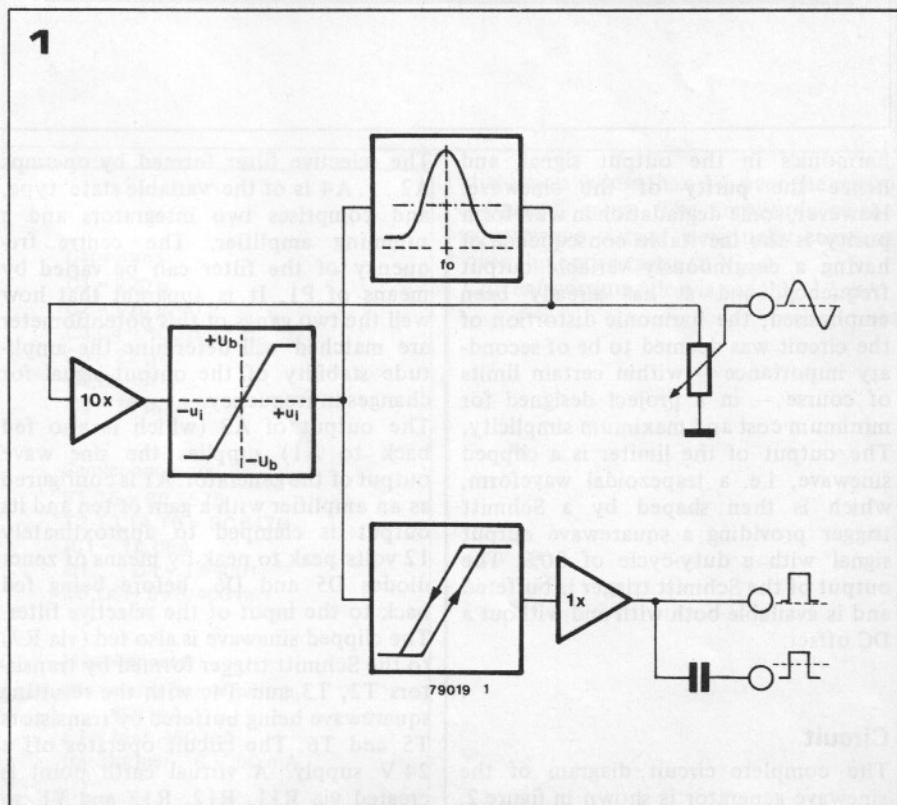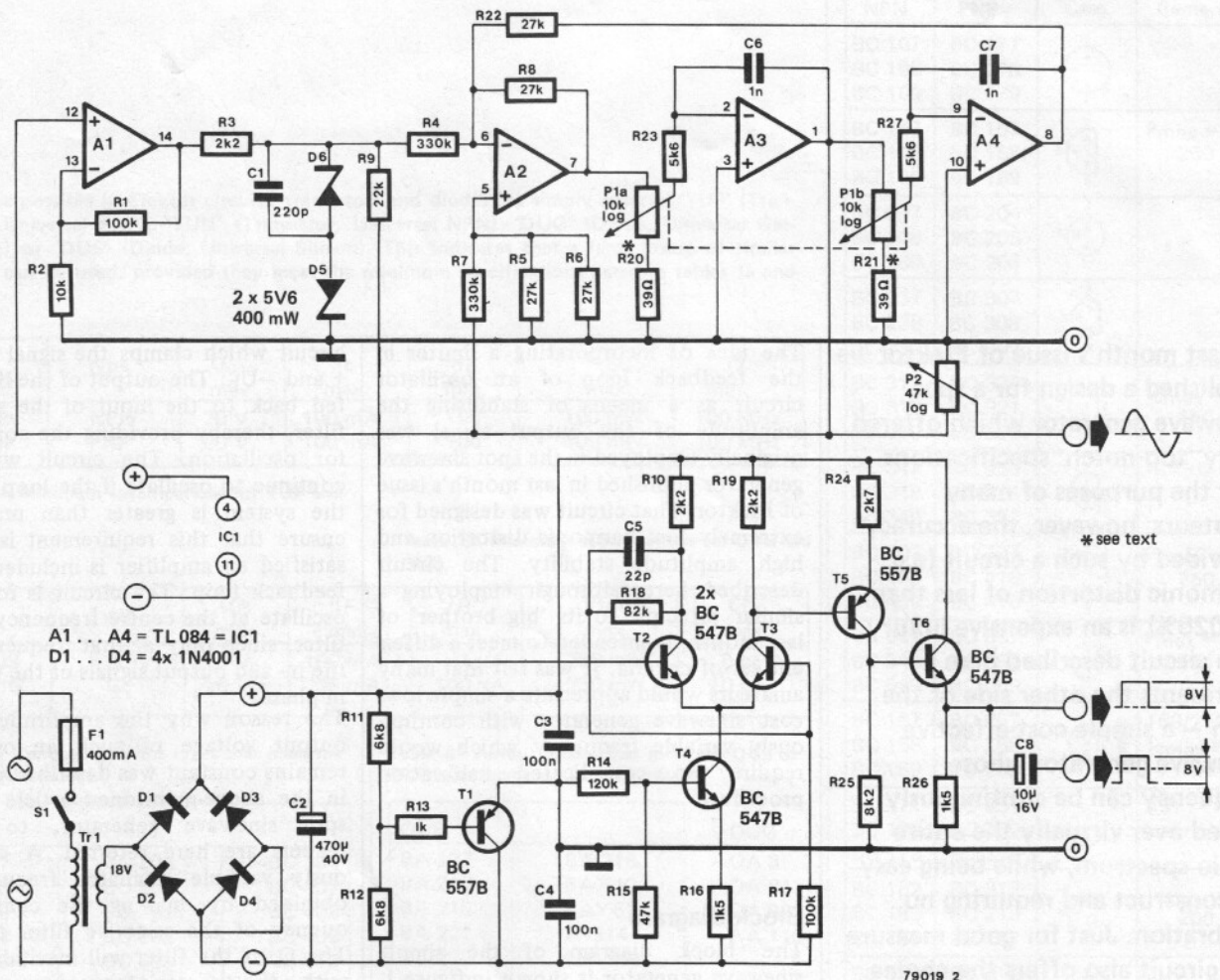
harmonics in the output signal, and hence the purity of the sinewave. However, some degradation in waveform purity is the inevitable consequence of having a continuously variable output frequency, and as has been emphasised, the harmonic distortion of the circuit was deemed to be of secondary importance — within certain limits of course — in a project designed for minimum cost and maximum simplicity. The output of the limiter is a clipped sinewave, i.e. a trapezoidal waveform, which is then shaped by a Schmitt trigger providing a squarewave output signal with a duty-cycle of 50%. The output of the Schmitt trigger is buffered and is available both with and without a DC offset.

Circuit

The complete circuit diagram of the sinewave generator is shown in figure 2.

The selective filter formed by op-amps A2 . . . A4 is of the 'variable state' type, and comprises two integrators and a summing amplifier. The centre frequency of the filter can be varied by means of P1. It is apparent that how well the two gangs of this potentiometer are matched will determine the amplitude stability of the output signal for changes in frequency.

The output of A3 (which is also fed back to A1) supplies the sine wave output of the generator. A1 is configured as an amplifier with a gain of ten and its output is clamped to approximately 12 volts peak to peak by means of zener diodes D5 and D6, before being fed back to the input of the selective filter. The clipped sinewave is also fed (via R9) to the Schmitt trigger formed by transistors T2, T3 and T4, with the resulting squarewave being buffered by transistors T5 and T6. The circuit operates off a 24 V supply. A virtual earth point is created via R11, R12, R13 and T1, so

that a roughly symmetrical supply of ± 12 V is obtained.

Construction

The component layout and track pattern of the p.c.b. for the sinewave generator is shown in figure 3. One can either provide the case with three separate output sockets, or else use a single socket with a three-way waveform selector switch.

The circuit requires no calibration. The only preliminary measure which, in view of component tolerances, may prove necessary is to experiment slightly with the value of R20 and R21. The frequency range of the sinewave generator is approx. 20 Hz to 25 kHz. The amplitude of the sinewave output is constant over the range 150 Hz to 6 kHz. Above this point there is a very slight rise in amplitude, and below 150 Hz the amplitude will tend to fall slightly. Harmonic

Figure 2. Complete circuit diagram. The amplitude of the sinewave output signal can be varied by means of P2.

Figure 3. Track pattern and component layout of the p.c.b. for the sinewave generator (EPS 79019). Only the transformer and potentiometers are mounted off-board.

distortion is less than 1% over the entire frequency range. The amplitude of the squarewave output is virtually constant over the entire range (8 V_{pp}).
Current consumption is roughly 12 mA.
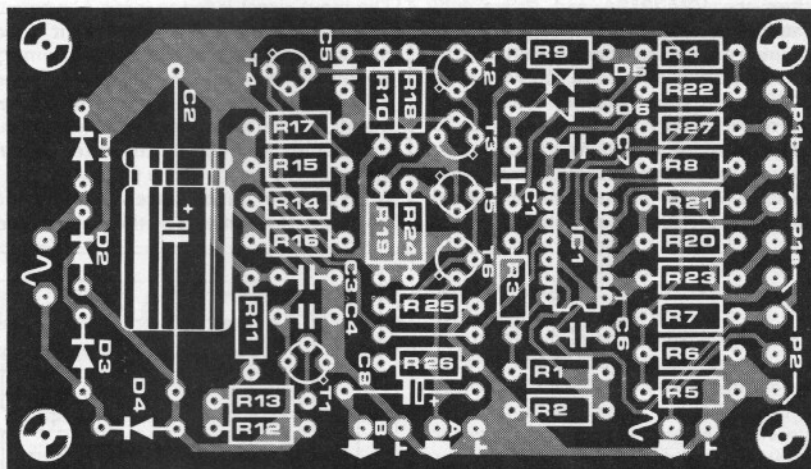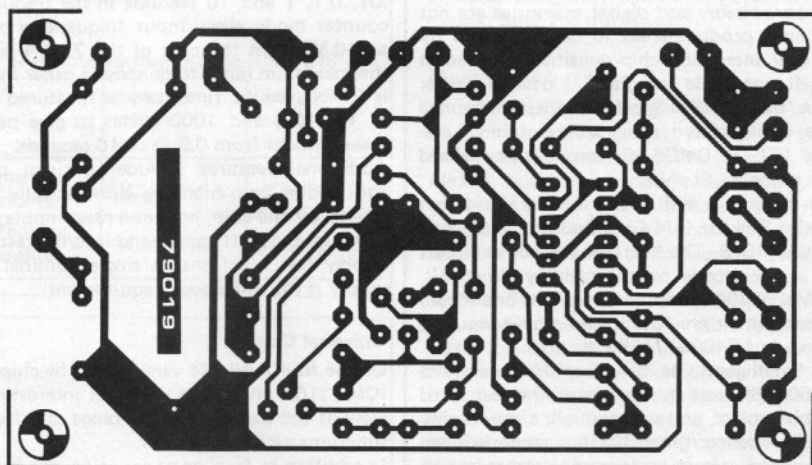
Parts list

Resistors:
R1,R17 = 100 k
R2 = 10 k
R3,R10,R19 = 2k2
R4,R7 = 330 k
R5,R6,R8,R22 = 27 k
R9 = 22 k
R11,R12 = 6k8
R13 = 1 k
R14 = 120 k
R15 = 47 k
R16,R26 = 1k5
R18 = 82 k
R20,R21 = 39 Ω (see text)
R23,R27 = 5k6
R24 = 2k7
R25 = 8k2
P1a/b = stereo potentiometer,
        10 k log.
P2 = potentiometer, 47 k log.

Capacitors:
C1 = 220 p
C2 = 470 μ/40 V
C3,C4 = 100 n
C5 = 22 p
C6,C7 = 1 n
C8 = 10 μ/16 V

Semiconductors:
T1,T5 = BC 557B
T2,T3,T4,T6 = BC 547B
IC1 = TL 084
D1 . . . D4 = 1N4001
D5,D6 = 5V6/400 mW

Miscellaneous:
S1 = mains on/off switch,
    400 mA
F1 = fuse, 400 mA
transformer, 18 V/50 mA

APPLIKATOR

Universal Counter

Microprocessors and digital memories are not the only product areas to be influenced by the ever increasing chip densities achieved in LSI (Large Scale Integration) devices. Other more 'traditional' logic functions, which once were implemented using a mountain of discrete TTL- or CMOS ICs can now be realised with a single LSI chip.

This point was well illustrated by the design for the Elektor '1/4 GHz Counter' published in June 1978. The heart of the above circuit was a six-decade counter/display driver IC, the MK 50398N from Mostek. This one IC did the job which previously would have required a boxful of 7490's, 7475's etc.

As 'intelligent' as it was, however, the MK 50398N was by no means the last word on this subject, and sure enough, a new family of LSI counter/timer ICs has recently been announced, whose performance represents an advance on anything seen so far.

The device in question is the ICM 7216A/B/C/D from Intersil. As the type number suggests, there are four different versions of the chip; the ICM 7216A and B are fully integrated universal counters/display drivers for common-anode and common-cathode displays respectively (see table 1), whilst the ICM 7216C and D are frequency counter only versions of the above.

The chips combine a high frequency crystal oscillator, a decade timebase counter, an eight decade data counter plus latches, and associated elements for decoding, multiplexing and driving 8 large LED displays. Gate times of .01, 0.1, 1 and 10 seconds in the frequency counter mode allow input frequencies of up to 10 MHz. In the case of the 7216A and B the maximum input frequency in other modes is 2 MHz, whilst times can be measured over 1, 10, 100, and 1000 cycles to give period measurement from 0.5 μs to 10 seconds.

Additional features include: decimal point and leading zero blanking automatically controlled by the chip, hold and reset inputs, low power/display off mode, and internal test and display test functions. A single nominal 5 V supply is the sole power requirement.

Universal Counter

Of the four available versions of the chip, the ICM 7216A and B are the most interesting in view of the truly impressive range of different functions which they offer.

In addition to frequency counting, the devices can operate as a period counter, frequency ratio counter, time interval counter, and unit counter. The internal organisation of the chip is illustrated by the block diagram of figure 1. The input signal is fed to input A, whereupon control logic determines whether it is fed to the clock input of the main counter, or whether (when measuring period, for instance) it is used to gate the internal clock signal of the IC to the main counter. The number of clock pulses counted by the latter is then an index for the length of the period.

When a 'store' pulse is received from the control logic, the contents of the main 10^8 counter are transferred to the data latches. The 8 digit count data is converted into 7-segment code and multiplexed to the segment outputs. As already mentioned, the counter can measure more than simply frequency and period. When operated in the 'unit counter' mode, it counts the total number of pulses in the input signal (instead of the number of pulses per second). The chip will also measure the frequency ratio between two input signals, a facility which in certain situations can offer advantages over simple measurement of frequency. If, for example, an extremely stable reference frequency is available, in principle it is possible to measure an unknown input frequency with greater accuracy using this method. Furthermore, there are instances where the ratio of two frequencies is more important than their exact value, or where the frequencies vary but the ratio remains constant (e.g. in certain music applications). When functioning in the frequency ratio mode one input signal is fed to input A, the other to input B. To ensure good accuracy, the frequency of the signal fed to input A should be greater than that at input B. If the frequency ratio is greater than 10^5, all 8 digits of the display can be used.

The fifth type of measurement of which the chip is capable is time interval. The chip counts the number of microseconds which elapse between a 1-0 transition occurring at input A and a 1-0 transition at the B input. To complete the measurement cycle input A must again go negative after B goes negative

1

EXT OSC INPUT / OSC INPUT / OSC OUTPUT / OSC SELECT / DECODER / DIGIT DRIVERS / DIGIT OUTPUTS (8) / ÷10³ / RANGE SELECT LOGIC / RANGE CONTROL LOGIC / RANGE INPUT / 10⁴ OR 10⁵ / 100Hz / RESET INPUT / STORE AND RESET LOGIC / CONTROL LOGIC / CONTROL INPUT / INPUT A / INPUT B / CONTROL LOGIC / ÷10⁸ COUNTER / OVERFLOW / D.P. LOGIC / EN / CL / OUTPUT MUX / DATA LATCHES / STORE / DECODER LOGIC / SEGMENT DRIVER / SEGMENT OUTPUTS (8) / CONTROL LOGIC / D / Q / CL MAIN / FF / FUNCTION INPUT / FN CONTROL LOGIC / HOLD INPUT / 79044 1

APPLIKATOR

Figure 1. Internal block diagram of the ICM 7216A/B.

Figure 2. In the time interval mode the counter measures the time, T, between a negative-going transition at input A and a negative transition at input B. In order to complete the measurement cycle, a second 1-0 transition at input A is required.

Figure 3. Minimum configuration circuit for a universal counter employing the 7216B. The counter offers six different measurement functions with four ranges per function.

Table 1.

The various versions of the ICM 7216

	common anode displays	common cathode displays
universal counter	ICM 7216A	ICM 7216B
frequency counter	ICM 7216C	ICM 7216D

— see figure 2. Input A goes negative at time t_c, completing the measurement cycle and the elapsed time T is displayed.

Multiplexed interface

In the ICM 7216A and B efficient use is made of inputs and outputs by multiplexing. Not only are the segment driver outputs multiplexed, but the function, range, control and external decimal point inputs are time multiplexed also. The input functions which are required are selected by connecting the appropriate digit driver output to the inputs concerned. The functions selected by each digit for these inputs are listed in table 2. As can be seen, the digit driver outputs are numbered from d_0 to d_7. The digit driver for the extreme right-hand (least significant) digit is d_0, whilst d_7 is the driver output for the extreme left-hand digit. Depending upon which of these outputs is connected to the function input, the chip will operate in one of the above-described modes. The connections to the function input may either be hard-wired or selected via a multi-way switch.

Which digit driver output is connected to the range input determines both the gate period of the main counter when used in the frequency mode, and the number of periods sampled in a period measurement. Both sets of values are listed in table 2. The greater the gate period or number of periods, the more accurate the measurement — although the latter will then take longer and there is a greater risk of an overflow occurring.

The control input provides a number of additional facilities. By connecting d_3 to the control input and simultaneously taking the hold input to V^+, the displays can be blanked, the chip remaining in the display-off mode until hold is returned low (V^-). With the displays blanked the current consumption of the chip is reduced to around 2 mA. In the 'display test' mode all segments are enabled continuously, whilst in the general test mode the main counter is split into groups of two digits which are clocked in parallel. The control input is also responsible for determining the clock frequency. As can be seen from the table, in addition to the 'standard' 10 MHz crystal, there is the possibility of using a 1 MHz crystal or employing an external clock oscillator. The latter facility can prove useful when using the IC in larger systems.

In addition to the multiplexed control inputs, the IC has two 'conventional' inputs in the form of a hold input, which, as has already been mentioned, is normally held low, and a reset input. When the former is taken high the count is stopped and the contents of the main counter are latched, whilst the counter itself is reset. Taking 'hold' low again initiates a new measurement. The reset input is the same as the hold input, with the exception that the latches for the main counter are enabled, resulting in an output of all zeros.

In addition to the five measurement functions already mentioned (frequency, period, frequency ratio, time interval and unit count) the ICM 7216A and B offer the possibility of measuring the internal clock frequency. This facility is a little unusual and appears to be somewhat superfluous, since the gate time of the main counter is also determined by the internal clock oscillator and hence the count displayed cannot be used to determine if the

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Under the heading Applikator, recently introduced components and novel applications are described. The data and circuits given are based on information received from the manufacturer and/or distributors concerned. Normally, they will not have been checked, built or tested by Elektor.
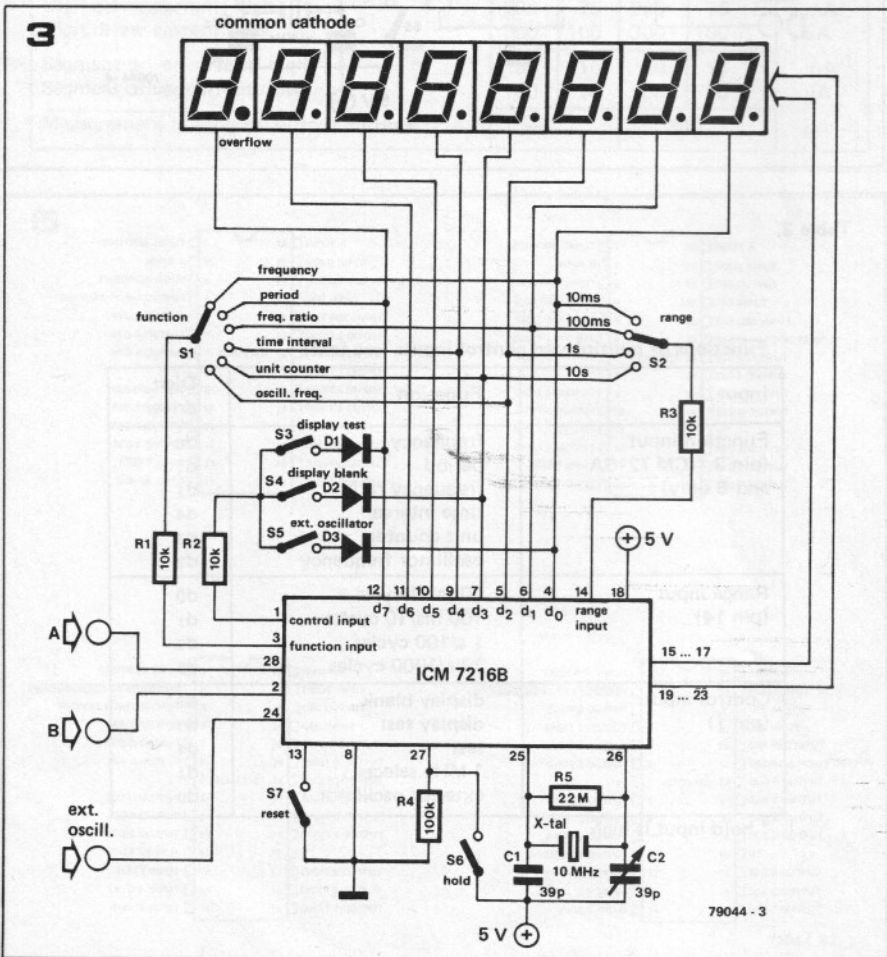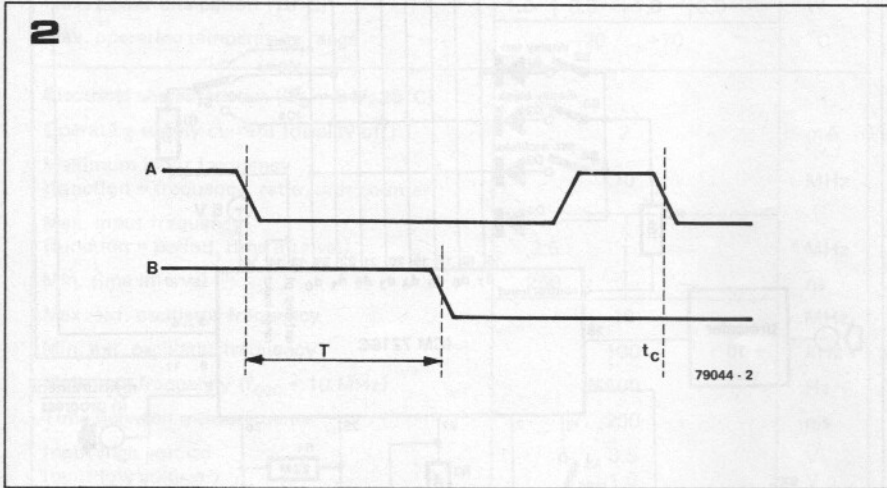
APPLIKATOR

clock frequency is inaccurate. The most that can be ascertained is whether the chip itself is functioning satisfactorily.

Circuit Applications

An idea of the applications to which the ICM 7216 can be put is given by the circuit of figure 3. This circuit, which employs the B version of the chip, represents a 'minimum-component' complete universal counter.

The connections between the multiplex control inputs and the digit driver outputs are made via suitable multi-way switches. The 10 k resistors in series with the multiplex inputs are to improve the noise immunity of these lines. Diodes D1 . . . D3 prevent crosstalk between the digit driver outputs.

When switch S5 is open the circuit is clocked by the on-chip clock oscillator; with S5 closed, however, the external oscillator input (pin 24) is used, in which case the oscillator components (R5, C1, C2 and the crystal) can be omitted.

Positioning of the decimal point is automatically determined by the setting of the 'range' switch. The decimal point in the most significant digit, however, deserves explanation, since it also functions as an overflow indicator. In many cases it can be expected that a separate LED will be used in place of the conventional decimal point segment. The displays shown in figure 3 are of the common cathode type.

The above circuit of course represents only a very basic design which can be extended in numerous different ways for a variety of applications. An obvious example is the use of prescalers to enable frequencies greater than 10 MHz to be measured. Furthermore, since input A and input B are both digital inputs, additional circuitry will often be required for input buffering, amplification and level shifting in order to obtain a good digital signal. The cost and complexity of additional circuitry will of course vary depending upon the sensitivity and maximum frequency required.

Frequency-only applications: the C- and D-versions

The above description has concentrated on the features of the 'universal counter' versions of the chip. However there are also frequency counter only versions of the ICM 7216 for use with both common anode and common cathode LED displays. These have only one measurement input, which corresponds to input A of the universal counter, whilst there is obviously no need for a function input. On the other hand, the 7216C and D do have two facilities absent on the A/B versions: a 'measurement in progress' output and an external decimal point enable input (see figure 4).

The measurement in progress output goes low whenever — as one might have guessed from its name — a measurement cycle is in progress. In addition to being used as an indicator output, this pin can be employed to control external circuitry if so desired.

The external decimal point enable input can be used to control the position of the decimal point directly by using the range switch, a facility which can prove useful with prescalers etc. If the external decimal point is selected, the internal decimal point control should be

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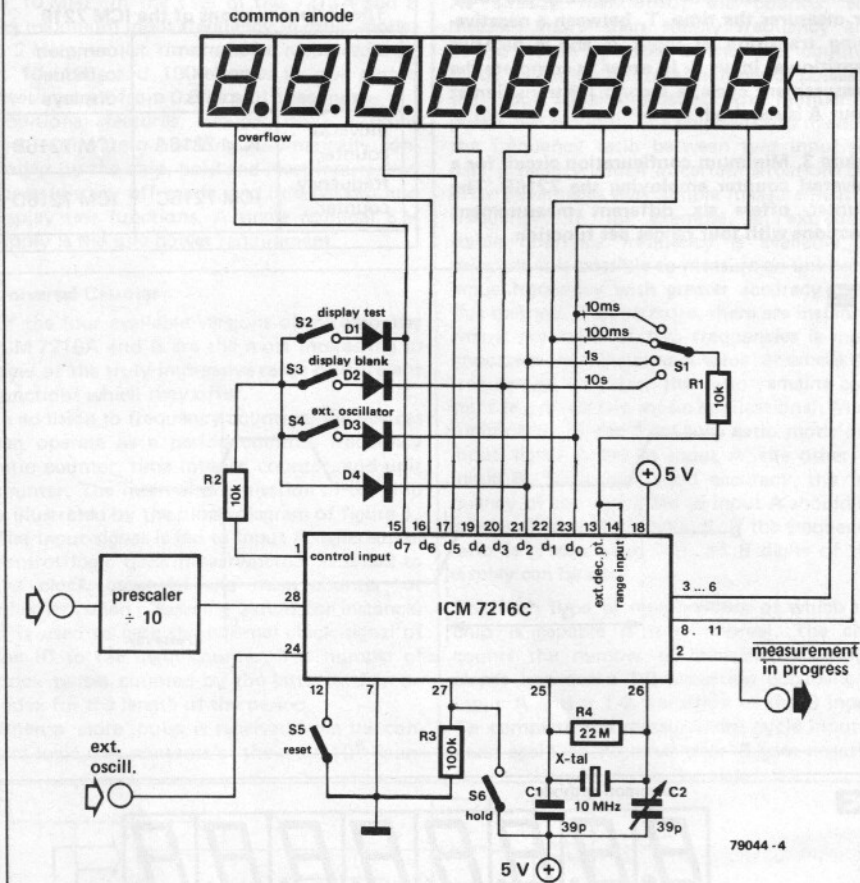
Table 2.

Functions of multiplexed control inputs (see text)

Input	Function	Digit driver
Function input (pin 3 - ICM 7216A and B only)	frequency	d0
	period	d7
	frequency ratio	d1
	time interval	d4
	unit counter	d3
	oscillator frequency	d2
Range input (pin 14)	10 ms/1 cycle	d0
	100 ms/10 cycles	d1
	1 s/100 cycles	d2
	10 s/1000 cycles	d3
Control input (pin 1)	display blank	d3 *
	display test	d7
	test	d4
	1 MHz select	d1
	external oscillator	d0

* hold input is high

APPLIKATOR

Table 3.

Electrical specifications					
type	ICM 7216 A	ICM 7216 B	ICM 7216 C	ICM 7216 D	
Absolute maximum ratings					
Max. supply voltage U_b		6,5			V
Max. digit output current		400			mA
Max. segment output current		60			mA
Voltage on any input or output terminal		$-0.3 \ldots U_b + 0.3$			V
Max. power dissipation (70°C)	1.0	0.5	1.0	0.5	W
Max. operating temperature range		$-20 \ldots +70$			$^{\circ}$C
Electrical characteristics ($U_b = 5$ V, 25°C)					
Operating supply current (display off)		2			mA
Maximum input frequency (function = frequency, ratio, unit counter)		10			MHz
Max. input frequency (function = period, time interval)	2.5		—		MHz
Min. time interval	250		—		ns
Max. ext. oscillator frequency		10			MHz
Min. ext. oscillator frequency		100			kHz
Multiplex frequency ($f_{osc} = 10$ MHz)		500			Hz
Time between measurements		200			ms
Input high voltage		3.5			V
Input low voltage		1.0			V
Digit driver current: high	200	75	200	75	mA
Digit driver current: low	300	100	300	100	µA
Segment driver current: high	35	10	30	15	mA
Segment driver current: low	100	10	100	10	µA
Measurement in progress output current		340			µA

Figure 5. Pin-out of all four versions of the ICM 7216.

disabled by connecting d2 (via a diode, D4, and a 10 k resistor) to the control input. Whenever an active digit driver output is connected to the external decimal point input (like the other control inputs, the latter is multiplexed) a decimal point will be displayed at the corresponding position. Only d7 of the digits cannot be connected to this point, since it will over-ride the overflow output and leading zeros will remain unblanked after the decimal point.

Figure 4 shows a basic frequency counter configuration for the C version of the chip. To extend the frequency range to 100 MHz a prescaler is used, which divides the input frequency by ten.

In the circuit shown, the external decimal point enable input is connected directly to the range switch, therefore the decimal point will be in the correct position and the frequency will be displayed in kHz.

With the exception of the missing function switch, and common anode displays (the C version), the remainder of the circuit is virtually identical to that of figure 3.

The principal electrical characteristics of all four versions of the chip are summarised in table 3.

Intersil data sheet ICM 7216A/B/C/D
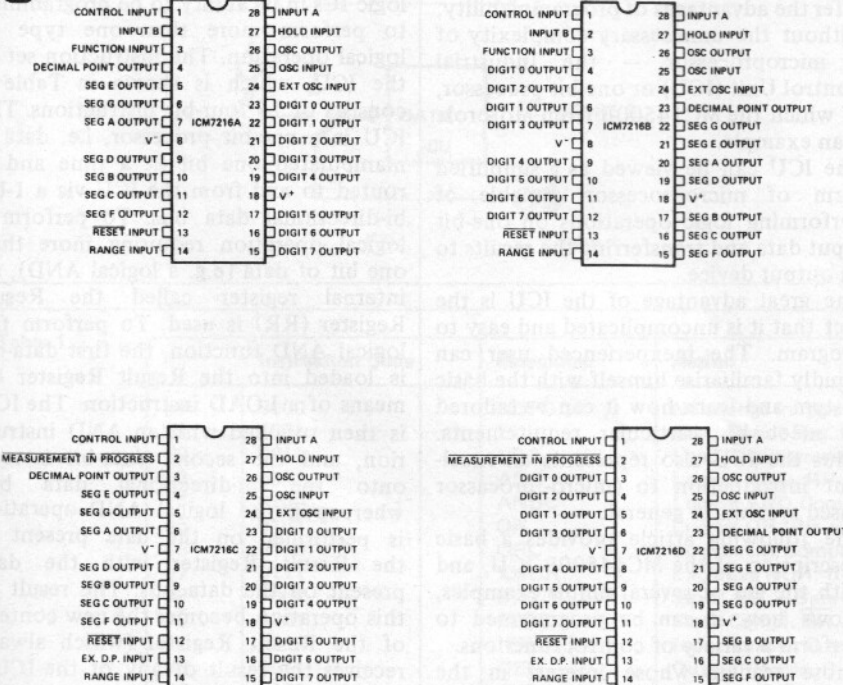
Figure 4. The C- and D-versions of the chip provide frequency measurement only. With the basic circuit shown, the addition of a divide-by-ten prescaler allows frequencies up to 100 MHz to be measured.

79044 5

the ICU -
a 'mini' microprocessor

Who's afraid of the one-bit μP?

One of the problems of microprocessors is that they require a considerable amount of specialised knowledge in order to operate them. An additional problem is that there are many applications for which their inherent sophistication renders them unsuitable.
Recently, Motorola seem to have succeeded in killing two birds with one stone by bringing out a new IC, the Industrial Control Unit, MC14500B. This is a one-bit processor which has been specially designed for simple control applications, and is extremely easy to program.
The following article takes a look at this 'mini'-microprocessor, which should prove of particular interest to those readers who have had problems getting to grips with its 'big brothers'.

Thanks to the inherent flexibility of the stored program concept, which allows system changes to be rapidly implemented simply by altering the program, the microprocessor is being used in an increasing number of control applications. Washing machines, sewing machines, ovens, are only a few of the consumer products which now feature microprocessors, whilst in industry, microprocessors have appeared on the shop-floor in a wide variety of adaptive control processes.
However for certain control applications involving decision oriented tasks, (e.g. intruder alarms, signal controllers for model railways, slide changers, PROM programmers, to name but a few cases which are of interest to the amateur electronics enthusiast) such is the relative simplicity of the system, that the expense and sophistication of a microprocessor would be the equivalent of the sledgehammer used to crack a nut. For this reason, a new type of chip has been developed which is designed to offer the advantages of programmability, without the unnecessary complexity of a microprocessor — the Industrial Control Unit (ICU) or one-bit processor, of which the MC14500B from Motorola is an example.
The ICU can be viewed as a simplified form of microprocessor, capable of performing logic operations on one-bit input data and transferring the results to an output device.
The great advantage of the ICU is the fact that it is uncomplicated and easy to program. The inexperienced user can rapidly familiarise himself with the basic system and learn how it can be tailored to meet his particular requirements. Thus the ICU also represents an excellent introduction to (micro-)processor based systems in general.
The following article provides a basic description of the MC14500B ICU, and with the aid of several simple examples, shows how it can be programmed to perform a variety of control functions.
Those readers whose interest in the MC14500B is aroused by the article, are referred to the Motorola handbook for the device, which contains a more detailed description than we have room for here.

Characteristics

The Motorola MC14500B is a single chip, one-bit static CMOS processor, which is housed in a 16-pin DIL package. The IC executes one instruction per clock period and is timed by a single-phase internal clock oscillator, the frequency of which can be varied up to 1 MHz. Alternatively the clock signal can be controlled by an external oscillator. The electrical characteristics of the ICU conform to JEDEC B-Series specifications for CMOS B-Series devices. The IC has an operating supply voltage range of 3 to 18 V (in practice, assuming the device is not being operated in an electrically noisy environment, a supply voltage of 5 V can often be chosen, allowing the IC to be used in conjunction with TTL), and is capable of driving at least one Low Power TTL IC (the Data- and Write outputs can drive two normal TTL ICs).
The ICU differs from conventional logic ICs in its ability to be programmed to perform more than one type of logical operation. The instruction set of the ICU, which is shown in Table 1, consists of 16 four-bit instructions. The ICU is a one-bit processor, i.e. data is manipulated one bit at a time and is routed to and from the ICU via a 1-bit bi-directional data bus. To perform a logical operation requiring more than one bit of data (e.g. a logical AND), an internal register called the Result Register (RR) is used. To perform the logical AND function, the first data-bit is loaded into the Result Register by means of a LOAD instruction. The ICU is then supplied with an AND instruction, and the second data-bit is read onto the bi-directional data bus whereupon the logical AND operation is performed on the data present in the Result Register with the data present on the data bus. The result of this operation becomes the new content of the Result Register (which always receives the result of any of the ICU's logical operations, hence its name). Since a third instruction (STORE) would be required to transfer the result of the above logic function to an output device, it can be seen that three separate

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Main characteristics of the ICU:

- can perform 16 logic functions
- 1-bit bi-directional databus
- 1-bit memory
- four flag outputs
- meets Jedec-B specifications for CMOS ICs
- supply voltage range 3 . . . 18 V
- clock frequency DC . . . 1 MHz
- intended primarily for use in industrial control systems

operations are needed to simulate a two-input AND gate (see figure 1).

Like a microprocessor, the ICU operates on the stored program principle. The instructions to be executed by the ICU are normally stored sequentially in the system memory. However, in addition to the ICU's op-codes, the memory must also contain the address of the data to be loaded into the Result Register, or the address of the latch onto which the content of the Result Register is to be stored. The addresses are decoded by input and output selectors — as shown in the block diagram of figure 2.

Once again, let us take the example of a logical AND function being performed on two input signals A and B, which are present at inputs 1 and 5 respectively of the input selector, and assume that the result of this operation is to be stored on output 9 of the output latch. When an address is presented to the input or output selector the corresponding input or output is connected to the data line of the ICU. Thus the AND operation is performed as follows:

1) The system memory provides the ICU with the LOAD (LD) instruction and supplies the input selector with the input address. The logic level of this input is then transferred via the ICU's one-bit data bus to the one-bit Result Register.

2) The ICU fetches the next instruction from system memory — the AND instruction — whilst the input selector is supplied with the address of input 5. The addressed input data is demultiplexed onto the ICU's data line and then is logically 'ANDED' with the data in the Result Register. The original contents of the Result Register are lost.

3) Finally, the ICU is provided with the STORE (STO) instruction, whilst the output selector is presented with the address of output latch 9. The data in the Result Register is then transferred to this output latch via the bi-directional data line.
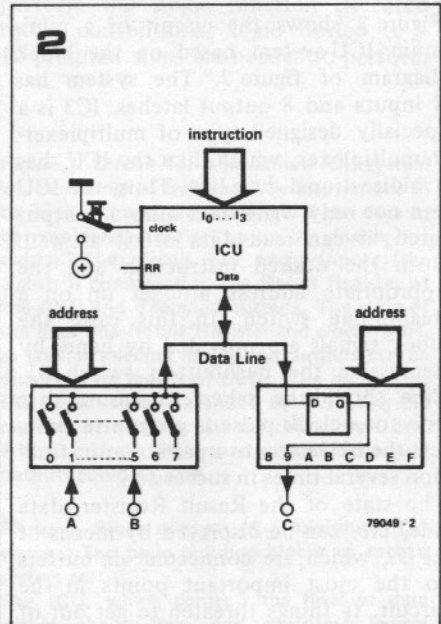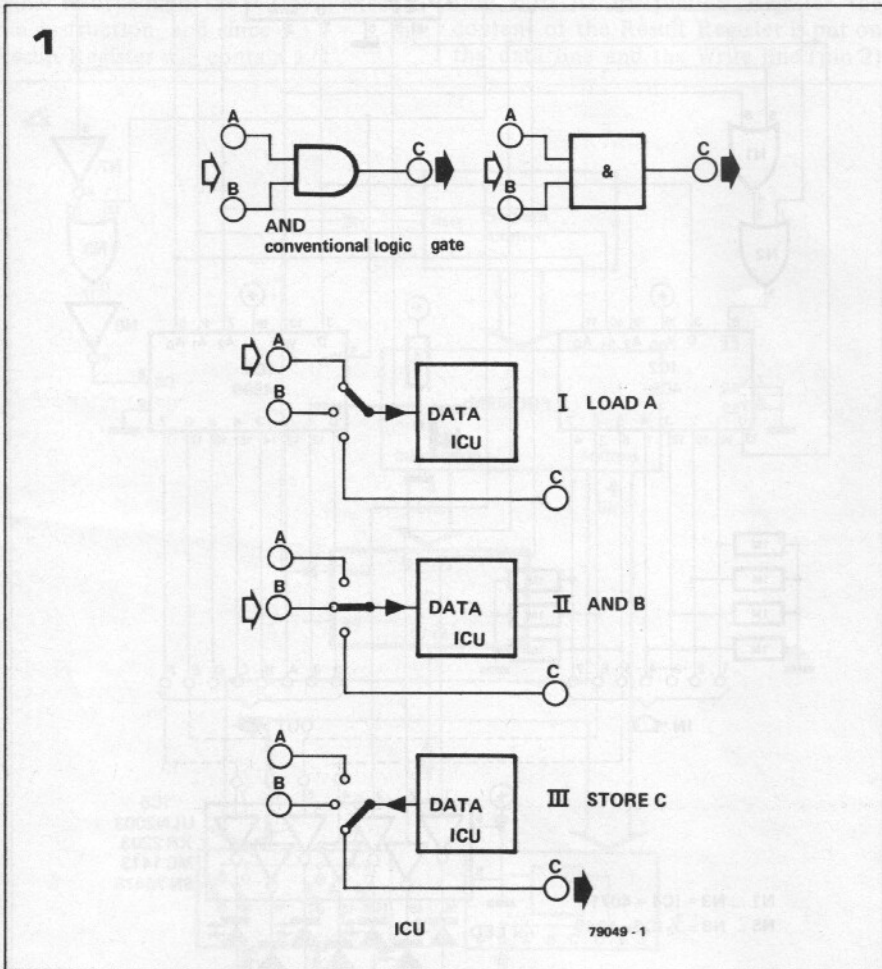
Figure 1. This figure illustrates the difference between dedicated logic devices and the (programmable) ICU. The conventional logic gate requires only a single operation to execute the function. The ICU on the other hand requires three separate operations to perform the same task.

Figure 2. Block diagram of a basic ICU system that is clocked by hand.

Table 1. Instruction set of the ICU.

Table 1	Instruction Code	Mnemonic	Action
#0	0000	NOPO	No change in registers. R → R, FLGO ← ⎍
#1	0001	LD	Load Result Reg. Data → RR
#2	0010	LDC	Load Complement $\overline{Data}$ → RR
#3	0011	AND	Logical AND. RR · D → RR
#4	0100	ANDC	Logical AND Compl. RR · $\overline{D}$ → RR
#5	0101	OR	Logical OR. RR + D → RR
#6	0110	ORC	Logical OR Compl. RR + $\overline{D}$ → RR
#7	0111	XNOR	Exclusive NOR. If RR = D, RR ← 1
#8	1000	STO	Store. RR → $\overline{Data Pin}$, Write ← 1
#9	1001	STOC	Store Compl. $\overline{RR}$ → Data Pin, Write ← 1
#A	1010	IEN	Input Enable. D → IEN Reg.
#B	1011	OEN	Output Enable. D → OEN Reg.
#C	1100	JMP	Jump. JMP Flag ← ⎍
#D	1101	RTN	Return. RTN Flag ← ⎍ , Skip next inst.
#E	1110	SKZ	Skip next instruction if RR = 0
#F	1111	NOPF	No change in Registers RR → RR, FLGF ← ⎍

Program Memory and Program Counter

One of the advantages of an ICU-based system is that the number of inputs and outputs can be expanded virtually ad infinitum, providing the memory is sufficiently wide to address the I/O ports. The Program Counter (PC) supplies the system memory with the address of the instruction to be executed. The PC will normally count up to its highest value and then 'wrap-around' to zero and start counting up again. Thus the sequence of instructions in memory can be repeated, providing a 'looping' program.

Minimum system

Figure 3 shows the circuit of a minimum ICU-system based on the block diagram of figure 2. The system has 8 inputs and 8 output latches. IC3 is a specially designed type of multiplexer-demultiplexer, which, like the ICU, has a bidirectional data line. Thus, the ICU can not only write data onto an output latch, it can read data off it as well. Both the desired instruction and the appropriate address are set up on a dual-in-line switch. In this case, the clock signals are provided by hand, by depressing the pushbutton switch S1. Care should be taken to ensure that only one clock pulse is given at a time, lest the ICU execute a particular instruction several times in succession.

The state of the Result Register, data line, etc. can be displayed by means of LEDs, which are connected via buffers to the most important points in the circuit. If things threaten to get out of hand, S2 takes the reset pin of the ICU high, clearing all registers and resetting the FLAG outputs.

With a four-bit address word, up to 16 locations can be selected; in this case 8 inputs and 8 outputs. The highest address bit, A3, is used to control the Chip-Enable (CE) inputs of IC2 and IC3, and hence switch between input and output lines. In conjunction with the Write signal of the ICU, A3 ensures that only one device, be it IC2, IC3 or the ICU, has access to the data line at any given time.

The basic design of the system shown in figure 3 bears a close resemblance to that of larger microprocessor-based systems, which also contain a data bus and address bus shared by a large number of ICs.

With the practical circuit of figure 3, let us see how one would actually execute the above example of a logical AND function. As we have seen, the program for an AND operation is:

    1. LOAD A
    2. AND B
    3. STORE C

The op-code for these instructions can be found by looking up the instruction set of the ICU in Table 1.

First, however, we must ensure that A is present at input 1, B at input 5 and that
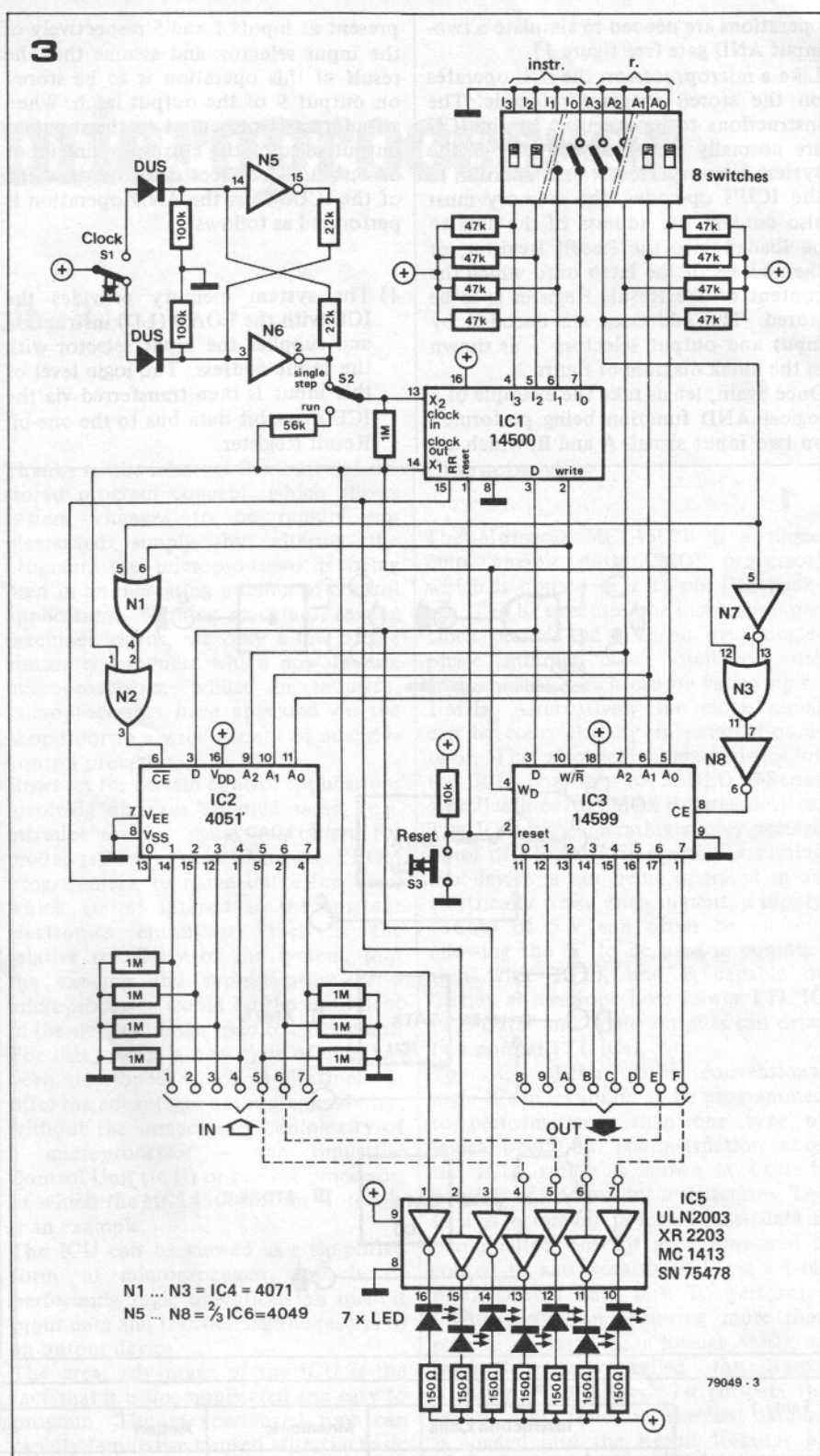
C is stored on output 9. In this case the addresses of these locations are simply the binary equivalent of 1, 5 and 9, i.e. 0001, 0101 and 1001 respectively. Thus the DIL switch should be set as follows:

1) 0001 0001 — whereupon a clock pulse is applied (A is transferred to RR)
2) 0011 0101 — another clock pulse (A · B = C)
3) 1000 1001 — another clock pulse (C is transferred to output 9)

Step by step, therefore, the procedure is as follows:

The four right-hand DIL switches are set to address (in binary) 0001, with the result that on the next clock pulse, input 1 of IC2 is connected to the data line of the ICU. By means of e.g. a wire link, this input should be connected to logic 1. Once the four left-hand switches have been set to the instruction code 0001 (= LOAD), S1 should be pressed, taking the clock signal at pin 14 of the ICU low and extinguishing the clock signal indicator LED. On the negative going edge of the clock signal (the clock signal was previously high) the ICU latches the LOAD instruction

into the Instruction register, and upon S1 being released and the clock signal being returned high, the data on the data line is read into the Result Register. Since the data line is high, a '1' is read into the Result Register, causing the corresponding LED to light.

The second instruction (0011 = AND) and second address can now be programmed on the DIL switch. Since the second instruction is an AND operation, input 5 should also be taken high. As soon as the clock signal is taken low, input 5 will be connected to the data line and the ICU will read the AND instruction into its Instruction Register. The data line LED should light at this stage. When S1 is released and the clock signal returns high, the ICU will execute the instruction, and since 1 · 1 = 1, the Result Register will contain a '1'.

The third instruction differs from the first two slightly. Once the op-code of the instruction (1000 = STO) and the correct address have been programmed on the DIL switch and S1 pressed, the ICU executes the instruction immediately. The only instructions which the ICU will execute on the negative going edge of the clock pulse are STORE and Flag instructions. The Flag instructions (JMP, RTN, FLGO, FLGF) are used to provide external control signals by setting pins 9 through 12 of the ICU. These output flags remain active for a full clock period after the negative-going edge of the clock signal.

In the case of the STORE instruction, the moment the ICU reads the instruction into its Instruction Register the content of the Result Register is put on the data line and the Write line (pin 2)

is enabled (taken high), with the result that the logic state of the data line is latched onto the appropriate output (FF9). On the positive-going edge of the clock pulse the Write line goes high again.

The state of the various indicator LEDs at each stage in the above program are shown in Table 2.

The above program is a simple example of how the ICU can be programmed to simulate a conventional logic gate. Further examples of programs designed to imitate the function of logic ICs (4-input AND, NAND, OR, EXOR etc.) are shown in figure 8.

As was pointed out earlier, the ICU requires a number of operations to perform the single function executed by a conventional logic device (e.g. 10 program steps are needed to perform

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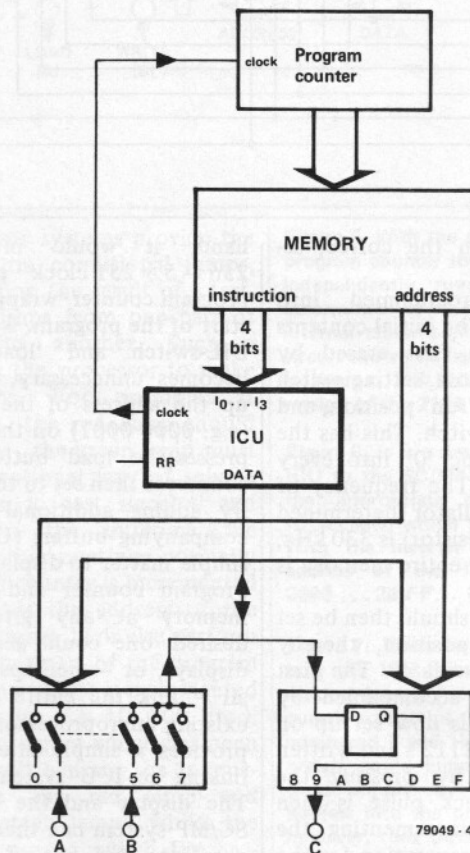
Figure 3. Circuit for a minimum ICU system which is clocked by hand. The instructions to be executed and the addresses of the data to be manipulated are set up on the dual-in-line switch. The circuit has seven inputs (the eighth is connected to the Result Register of the ICU) and 8 latched outputs. The state of the data line Result Register and clock signal, as well as selected inputs and outputs can be displayed by means of LEDs. The number of I/O ports can be extended by increasing the number of address bits on the address bus. With 8 address bits a total of 256 inputs and outputs could be used.

Figure 4. Block diagram of a minimum ICU system. The basic building blocks of such a system are:
The ICU, which controls the flow of data within the system and performs logical operations on the data in its Result Register and data appearing on its 1-bit bidirectional data line.
Program memory, which stores the instructions to be executed by the ICU.
The Program Counter, which ensures that the instructions are presented to the ICU in the correct sequence.
Input and Output Selectors, which decode the operand addresses stored in memory and determine which input or output is connected to the ICU's data line.

Table 2. This table shows the state of the system indicator LEDs at each stage of the AND program. The negative going and positive going edges of the clock signal (1-0-1) are differentiated to further clarify the sequence of events.

Table 2.

INSTRUCTION	CODE	DIL	Clock (X 1)	DATALINE	RR	input 1	input 5	output 9	
LD A	0001	0001	1	X	X	X	X	X	
			0	1	X	1	X	X	load A
			1	X	1	X	X	X	
AND B	0011	0101	1	X	X	X	X	X	
			0	1	1	X	1	X	AND with B
			1	X	1	X	X	X	
STO C	1000	1001	1	X	1	X	X	X	
			0	1	1	X	X	1	store result in C
			1	1	X	X	X	1	

X = 1 or 0, after reset 0
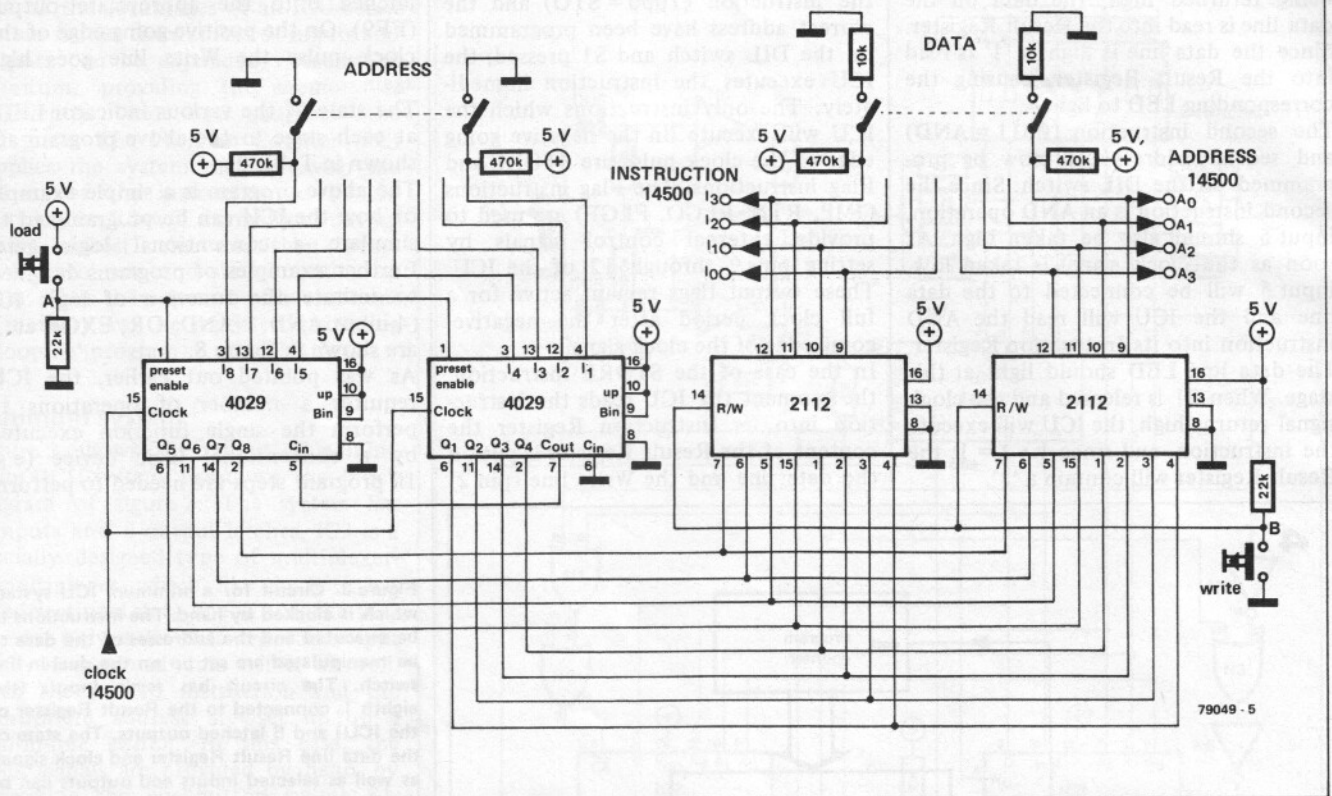
the function of a D-flip-flop). Thus the ICU will inevitably take longer to execute a given logic operation than its dedicated counterpart. For example, with a clock frequency of 330 kHz, the above program for a 2- input AND will take approx. 10 μs. However this trade-off in terms of speed is the consequence of the simplicity and, more importantly, the flexibility of the ICU, which allows it to be programmed for a wide variety of different functions.

The ability to step through a program one instruction at a time is particularly convenient for the beginner who is attempting to familiarise himself with microprocessor programming. However such a procedure is naturally time consuming. Particularly for longer programs, the obvious solution (as is shown in the block diagram of figure 4) is to store the program instructions in memory and employ a program counter to ensure that they are presented to the ICU in the correct sequence. The clock pulses can then be provided by the ICU's internal clock oscillator, the frequency of which can be set to up to 1 MHz (i.e. 1 instruction every 1 μs).

The circuit of a suitable instruction and address memory is shown in figure 5. The instructions and operand addresses are entered by hand into two 256 x 4-bit RAMs (type 2112). The program counter, which consists of two 4029's (presettable binary/decade counters) counts from 000 up to 256 and then starts from 000 again. The counter increments by one after each clock pulse and ensures that the contents of the next memory location are presented to the ICU. Thus the program instruc-

tions are executed in the correct sequence.

Instructions are programmed into memory as follows: The initial contents of the memory are first erased by closing the DATA switch, setting switch S2 in figure 3 to the 'run' position, and pressing the 'write' switch. This has the effect of writing logic '0' into every location in memory. The frequency of the internal clock oscillator (determined by the 56 k external resistor) is 330 kHz, which means that the entire memory is erased in approx. 1 ms .

Switch S2 of figure 3 should then be set to the 'single-step' position, thereby stopping the clock oscillator. The first program instruction accompanied by the operand address is now set up on the data lines of the 2112's and written into the memories by pressing the 'write' switch. A clock pulse is then provided by hand, incrementing the program counter in preparation for the next instruction to be entered.

Once all the instructions have been stored in memory the program can be run simply by switching S2 to the 'run' position. Of course it is also possible to continue to provide the clock pulses by hand, stepping through the program one instruction at a time, and checking the state of the program by means of the LEDs. To this end the second DIL switch and the 'load' button have been included.

When entering a program the program counter is incremented at each instruction, thus a program containing e.g. 5 instructions would leave the program counter at 005. If one then wants to step through the program by

hand, it would involve supplying $256 - 5 = 251$ clock pulses until the program counter 'wrapped round' to the start of the program. With the aid of the DIL-switch and 'load' button, this becomes unnecessary. One simply sets up the address of the first instruction (e.g. $0000\ 0001$) on the DIL-switch and presses the 'load' button. The program counter is then set to that address.

By adding additional LEDs with accompanying buffers (ULN 2003) it is a simple matter to display the state of the program counter and contents of the memory at any given moment. If desired, one could also use 7-segment displays, or — perhaps the best idea of all — link the entire system up to an existing microprocessor system; figure 6 provides a simple interface circuit for linking an ICU system to the SC/MP. The display and the keyboard of the SC/MP system can then be used to read data into and out of the ICU system memory. A further advantage of this arrangement is that the cassette dump routine of the SC/MP can be used to store programs for the ICU system. The ICU represents a useful extension to the SC/MP system, since it can be used to assume a number of simple control tasks, freeing the microprocessor for more complex operations.

Enabling Instructions — IEN OEN

Before proceeding to examine an example of a program which can be run on the above-described system, it is first necessary to take a look at two ICU instructions which are of prime importance: IEN and OEN.

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LD	A	load A
STOC	TEMP	store A̅ in scratch-pad memory
OEN	RR	disable outputs if A = 0
STO	LAMP R	turn on red lamp
STOC	LAMP G	extinguish green lamp
OEN	TEMP	disable outputs if A = 1
STOC	LAMP R	extinguish red lamp
STO	LAMP G	turn on green lamp

79047- 7

All microprocessor systems provide the facility to perform conditional jumps, i.e. depending upon the result of a test, the processor jumps from one part of the program to another. Such a provision allows the processor to make logical decisions. For example: If signal A is high, the red lamp should light; if A is low, the green lamp must light. The conventional way of solving this problem is to test signal A and depending upon the outcome the processor will either continue normally (i.e. the program counter is incremented by one and loads the address of the previous instruction + 1) or else perform a jump to another part of the program (i.e. the program counter is incremented not by one, but by, e.g. 10, 100, etc.). The section of program which has been 'jumped over' will contain the instruction 'turn on the red lamp and extinguish the green lamp', whilst the section of program to which the processor jumps will contain the instruction 'extinguish the red lamp and turn on the green lamp'.

To implement such a jump, however, requires a more complicated chip structure than is present on the ICU, thus an alternative approach is necessary. The solution chosen is to have the ICU execute the program in the correct sequence, however, depending upon the result of the test, prevent the ICU from actually carrying out a block of instructions. This is the function of the IEN and OEN instructions which respectively inhibit input data from effecting the system's output and latch the system's outputs into their current state by inhibiting the Write signal.

Figure 5. With the addition of memory and a program counter the ICU system can perform independently, running programs at a speed determined by the frequency of the ICU's internal clock oscillator. In the case of the circuit shown in figure 3, the clock frequency is approx. 300 kHz, which means that any version of the 2112 may be used.

Figure 6. It is a simple matter to interface the ICU to the SC/MP system. With a little skill the appropriate connections can be via IC sockets, which replace the DIL switches. With the inverter in address line 13, the address of the ICU system memory is 2000 . . . 20 FF.

Figure 7. These two flow diagrams illustrate how the ICU is capable of performing conditional jumps. Assuming that the program in question contains two blocks of instructions, numbered I and II, a normal microprocessor system could jump over a block of instructions simply by forcing the appropriate address into the program counter. The ICU, however, runs through all the instructions in the program, but simply fails to execute the block of instructions to be 'jumped'.

IEN

This instruction causes the ICU to latch the data on the data line into its 'input enabling register'. If the input enabling register is loaded with a logic '0', *all* further input data is interpreted by the ICU as logic '0', until the IEN register is loaded with logic '1' (by a subsequent IEN instruction). (Note that an LDC or ORC instruction will cause the Result Register to be loaded with a logic '1', regardless of the state of the inputs. A certain amount of care is required when using the IEN instruction).

OEN

The operation of the OEN instruction is similar to that of the IEN instruction. The ICU latches the data on the data line into its output enabling register. If that data is logic '0', the Write signal from the ICU is inhibited, thereby disabling the output latches.

Once the OEN register has been loaded with a logic '0' the system outputs will remain in their current state until the OEN register is loaded with a logic '1' (by a subsequent OEN instruction). Thus the ICU will effectively jump over whole blocks of instructions, since they will have no effect upon the system outputs.

An example of a conditional program jump using the OEN instruction is shown in figure 7a. A is first loaded into the Result Register, and the complement of A is stored in a temporary scratch-pad memory. The OEN instruction performs the test 'A = 0'. If A does in fact equal logic '0', the OEN instruction results in the outputs being

Table 3.

Line no.	instr.		hex	binary		
01	ORC	RR	60	0110	0000	force RR to '1'
02	IEN	RR	A0	1010	0000	enable inputs
03	OEN	RR	B0	1011	0000	enable outputs
04	LD	C1	11	0001	0001	load '1'
05	XNOR	B1	7E	0111	1110	EXNOR with first bit of counter
06	STOC	B1	9E	1001	1110	store result in first bit of counter
07	AND	C1	31	0011	0001	generate carry
08	STO	C2	8F	1000	1111	store carry in scratch-pad
09	XNOR	B2	7D	0111	1101	EXNOR previous carry with second bit of counter
10	STOC	B2	9D	1001	1101	store result in 2nd bit of counter
11	AND	C1	3F	0011	1111	generate new carry
12	STO	C2	8F	1000	1111	store new carry in scratch-pad
13	XNOR	B3	7C	0111	1100	
14	STOC	B3	9C	1001	1100	
15	AND	C2	3F	0011	1111	
16	STO	C3	8F	1000	1111	
17	XNOR	B4	7B	0111	1011	
18	STOC	B4	9B	1001	1011	
19	AND	C3	3F	0011	1111	
20	STO	C4	8F	1000	1111	
21	XNOR	B5	7A	0111	1010	
22	STOC	B5	9A	1001	1010	
23	AND	C4	3F	0011	1111	
24	STO	C5	8F	1000	1111	
25	XNOR	B6	79	0111	1001	
26	STOC	B6	99	1001	1001	
27	AND	C5	3F	0011	1111	
28	STO	C6	8F	1000	1111	
30	XNOR	B7	78	0111	1000	
31	STOC	B7	98	1001	1000	
32	ANDC	RR	40	0100	0000	force RR to '0'
33	IEN	RR	A0	1010	0000	disable inputs
34	OEN	RR	B0	1011	0000	disable outputs

blocked, so that instructions 4 and 5 have no effect and are effectively jumped over. Since the second OEN instruction is executed with the complement of A (in this case logic '1'), the Write signal is now enabled and instructions 7 and 8 are executed. If A was not logic '0' but logic '1', instructions 4 and 5 would have been executed, whilst instruction 7 and 8 would have been ignored.

When the Master Reset (RST) pin is taken high, all registers, including IEN and OEN are cleared (i.e. reset to '0'). This means that at the start of each program it is necessary to load the IEN and OEN registers with a logic '1'. This may appear to present a problem, since it cannot always be guaranteed that a logic '1' will be available at one of the inputs. However by using the ORC instruction and the Result Register it is possible to force a logic '1' into the result register (since the data which is inverted and 'ORed' with the Result Register is the initial content of the Result Register, then one or other signal must always be logic '1', RR or $\overline{RR}$ = 1). The IEN register can then be loaded with logic '1' by means of an IEN RR instruction.

Thus every program should commence with the following start routine:

ORC RR
IEN RR
OEN RR

(in the minimum system described above the Result Register is connected to input 0, i.e. address 0000).

It is also a useful precaution to terminate each program by loading logic '0' into the IEN and OEN registers. This prevents the ICU executing any other instructions which may be stored subsequently in memory. The appropriate routine is ANDC RR (which forces a logic '0' into the Result Register, followed by OEN RR and IEN RR.

Sample Program

Table 3 lists an example of a program which can be run on the basic ICU system which has been described above. IC3 is used as a counter, and each time the program, which is 34 steps long, is executed the contents of the counter are incremented by one. The counter is 8 bits wide, however one bit is used as a 'scratch-pad' memory to store the carry bit, so that in actual fact the maximum count is $2^7 = 128$. With a clock fre-

quency of roughly 300 kHz and a program counter which counts up to 256 before wrapping around to 000, the program will perform one complete loop and the counter will increment by one approx. every 0.9 ms ($256 \times 3.33\,\mu s$). LED 8, which displays the content of bit 8 of the counter will therefore flicker on and off every 128×0.9 ms = 109 ms, i.e. something just under 10 Hz.

The counter is actually incremented as follows: when adding two bits together there are only four possible outcomes, $0 + 0 = 0$, $1 + 0 = 1$, $0 + 1 = 1$, and $1 + 1 = 1$. Only in the last case ($1 + 1 = 1$) will a carry be generated. The logic function represented by the above truth table can be simulated by means of an XNOR instruction, which outputs a '1' if and only if both inputs are the same, followed by STOC, which inverts the result. The carry is generated using the AND instruction; a condition for generating a carry is that the result of the XNOR function is '1', and that one of the two inputs was also '1'. The addition is carried out with one bit of the counter, which is combined with the carry from the preceding addition. At the start of the count there is no carry from the preceding bit, so that a '1'

1
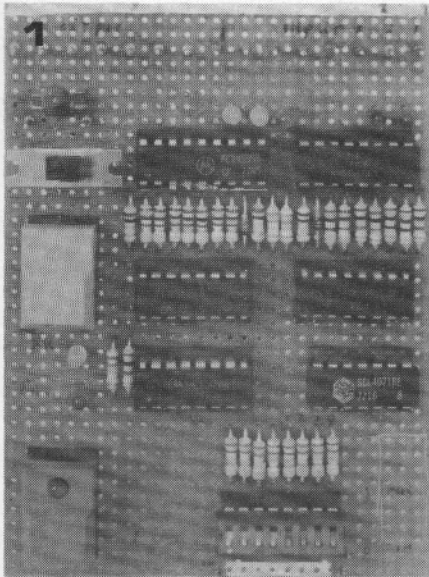
Photo 1. Prototype board for the minimum ICU system.

Table 3. Listing of a sample program which uses IC3 as a counter to make an LED flash off and on.

Figure 8. The ICU is specially designed to execute a wide variety of logic functions. The logic gates shown here can all be simulated by the corresponding set of ICU instructions. As the example of the D flip-flop shows, even quite complicated logic operations can be performed using the ICU.

8

Gate	Instructions
AND	LD A / AND B / STO C
AND	LD A / AND B / AND C / AND D / STO E
NAND	LD A / AND B / STOC C
OR	LD A / OR B / STO C
EXCL. NOR	LD A / XNOR B / STO C
EXCL. OR	LD A / XNOR B / STOC C
Inverter	LD A / STOC B
D Flipflop	ORC RR / OEN RR / LD old clock / STO temp / LD clock / STO old clock / ANDC temp / OEN RR / LD D / ST Q
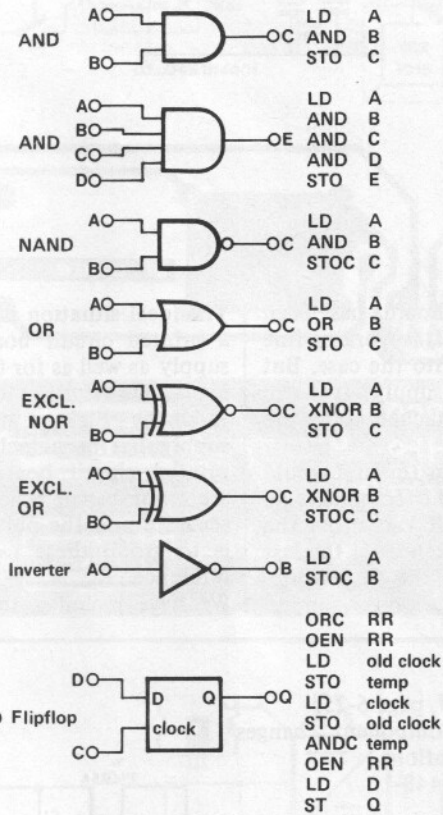
79049 - 8
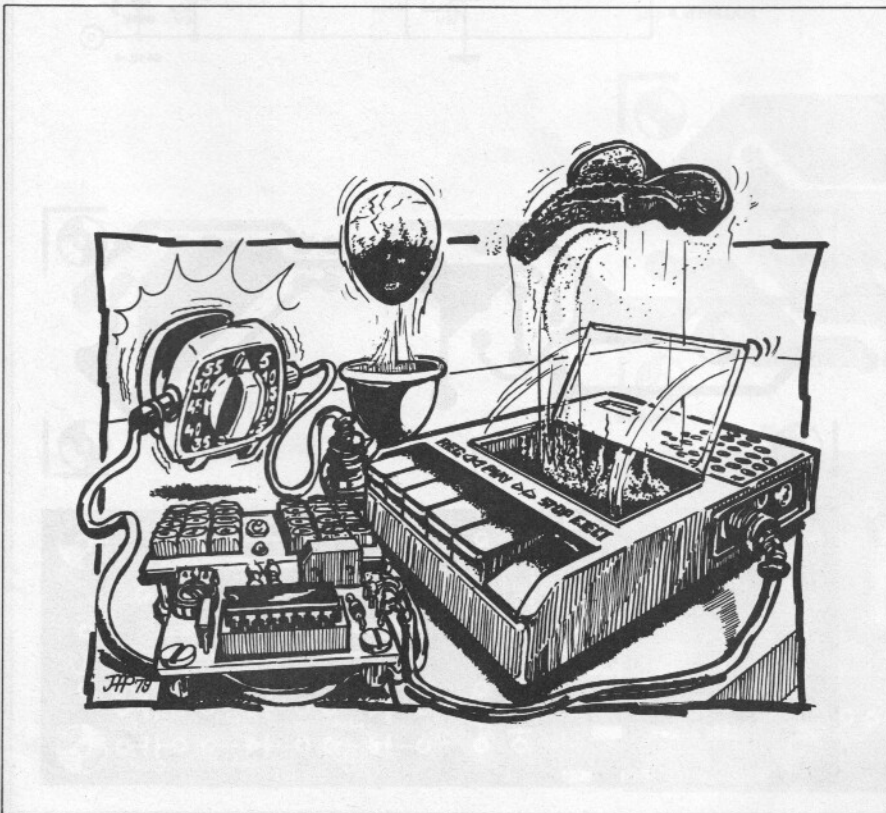
must first be presented to input 1. If a '0' were at this input, the circuit would simply add zeroes and the output of the counter would never change.

The operation performed by the program can be expressed by the following equations:

$S_n = B_n + C_n$ and $C_{n+1} = \overline{S_n} \cdot B_n$

(where S = Sum, B = Bit, C = Carry and n may equal 1 . . . 7)

Thus   Bit 1   '1'
          Carry 1 + '1'
          ———————
          Sum 1   '0'

Carry 2 = $\overline{\text{Sum 1}}$ · Bit 1
         = '0' · '1'
         = '1' · '1'
         = '1'

As a further illustration of the type of programming required, figure 8 lists several short program sections that can be used to simulate standard logic functions.

Lit.:

Motorola Industrial Control Unit Handbook. (Available from Motorola distributors.)

PSUs on PCBs

building power supplies the easy way

The printed circuit board has been completed and tested. It is working fine and now ready to fit into the case. But what about the power supply? Is it still that 'Christmas tree' tacked onto the transformer terminals?

It happens to most of us (or so it would seem) judging from the comments in our reader's letters. All too often the power supply is forgotten until the last moment, especially if the test equipment includes a variable power supply.

The ideal situation is, of course, to have a printed circuit board for the power supply as well as for the project and this is possible via the Elektor Print Service. In many Elektor circuits the power supply has been included on the main printed circuit board. However, there are a number of others that are entirely separate and the purpose of this article is to group these together as a handy reference.

We have included the most useful cir-

cuit diagrams and it will be apparent that many can be modified to suit specific requirements. The 78** regulators are interchangeable provided the transformer can supply 3 volts above the regulated voltage (e.g. the 7815 requires 18 V from the transformer). Remember also that the working voltages of the capacitors must be adequate (otherwise they could become momentary action switches — once!).

+5 V 500 mA

Issue E26, June 1977, page 6-25.
This circuit with component changes will suit many applications.
Board number EPS 9448-1.
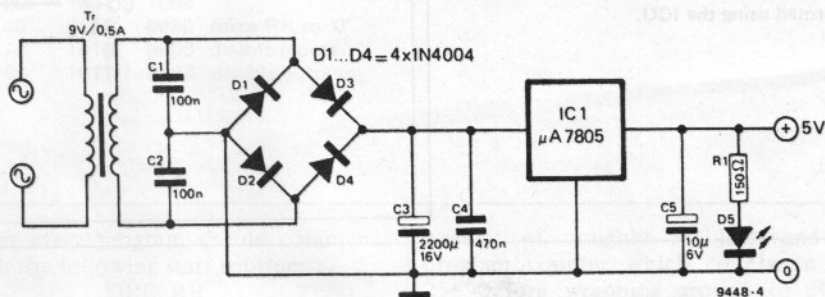
Parts list

Resistors:
R1 = 150 Ω

Capacitors:
C1,C2 = 100 n
C3 = 2200 μ/16 V
C4 = 470 n
C5 = 10 μ/6 V

Semiconductors:
D1,D2,D3,D4 = 1N4004
D5 = LED e.g. TIL 209
IC1 = μA 7805 or LM 129

Miscellaneous:
Tr = mains transformer, 9 V,
0.5 secondary
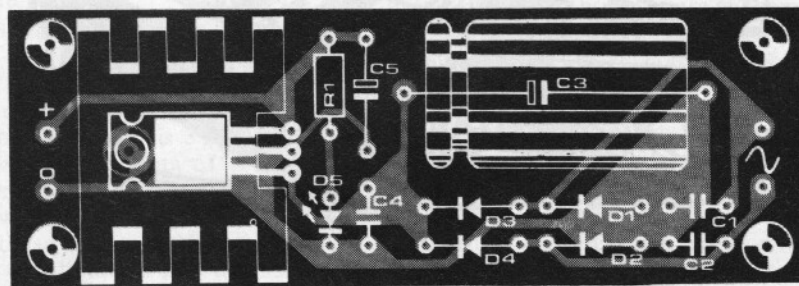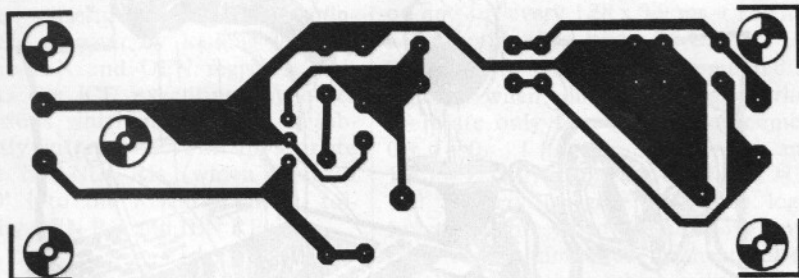
+15 V 250 mA and −15 V 250 mA

Issue E42, October 1978, page 10-38.
Originally designed for the Elektor TV
scope but very useful where op-amps are
used.
Board number EPS 9968-5a.
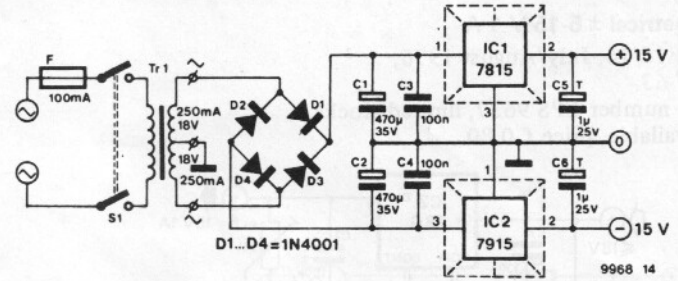
Parts list

Capacitors:
C1,C2 = 470 µ/35 V
C3,C4 = 100 n
C5,C6 = 1 µ/25 V tantalum

Semiconductors:
IC1 = 7815
IC2 = 7915
D1 . . . D4 = 1N4001

Miscellaneous (not on p.c. board
proper, see figure)
Tr1 = mains transformer,
    2 x 18 V/250 mA
S1 = double-pole mains switch
F1 = fuse, 100 mA
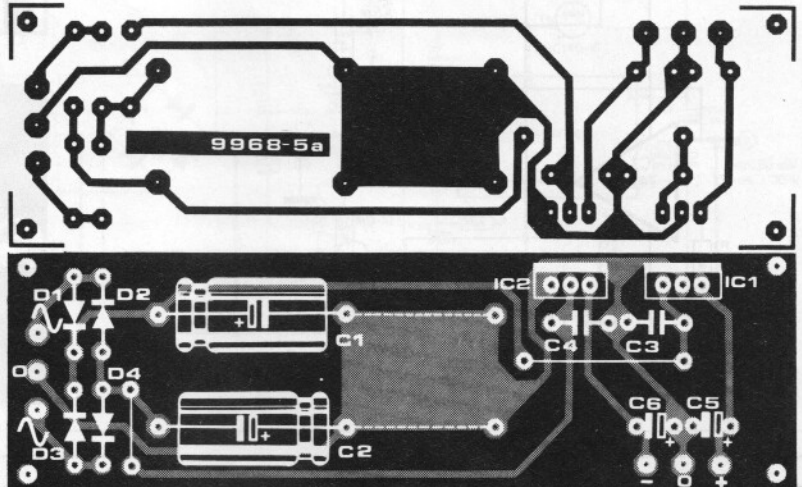
+15 V 1 A

Issue E31, November 1977, page 11-37.
Board number EPS 9218b, limited stocks
still available, price £ 1.05.
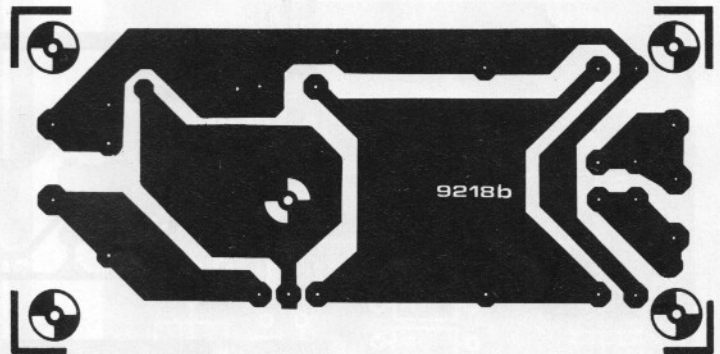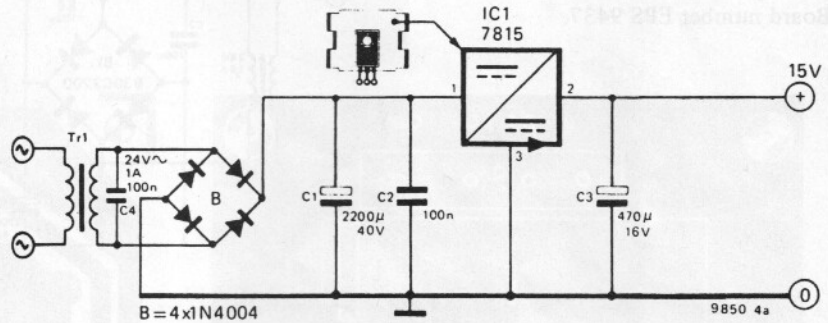
Parts list

Capacitors:
C1 = 2200 µ/40 V
C2,C4 = 100 n
C3 = 470 µ/16 V

Semiconductors:
IC1 = 7815
B = 4 x 1N4004

Miscellaneous:
Transformer with 24 V/1 A
   secondary
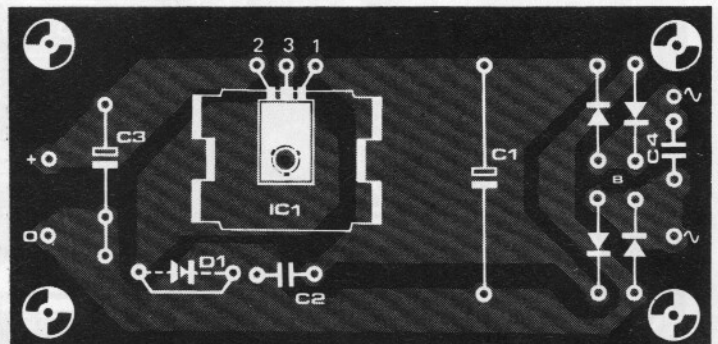
Symmetrical ± 5-15 V 1 A

Issue E15/16, July/August 1976,
page 7-63.
Board number EPS 9637, limited stocks
still available, price £ 0.80.
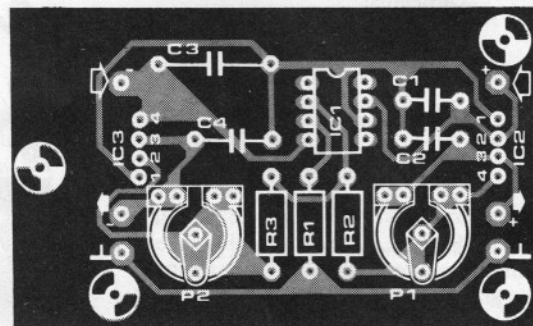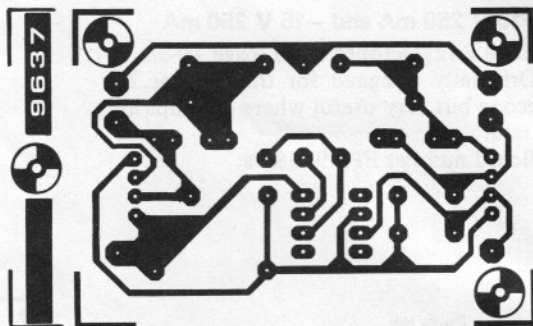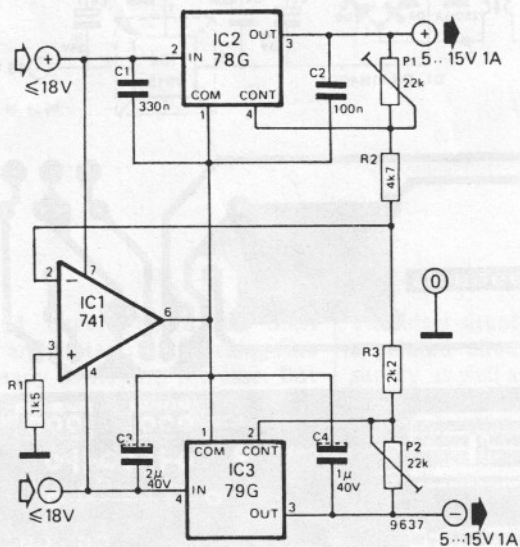
+12 V, +33 V

Issue E19, November 1976, page 11-15.
(Albar).
Board number EPS 9437.
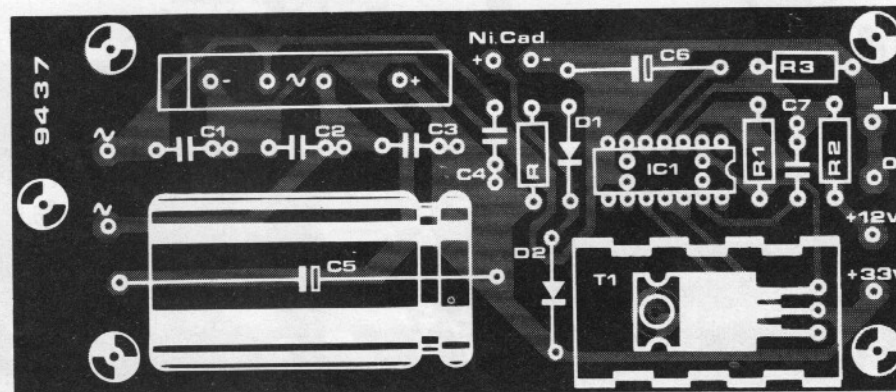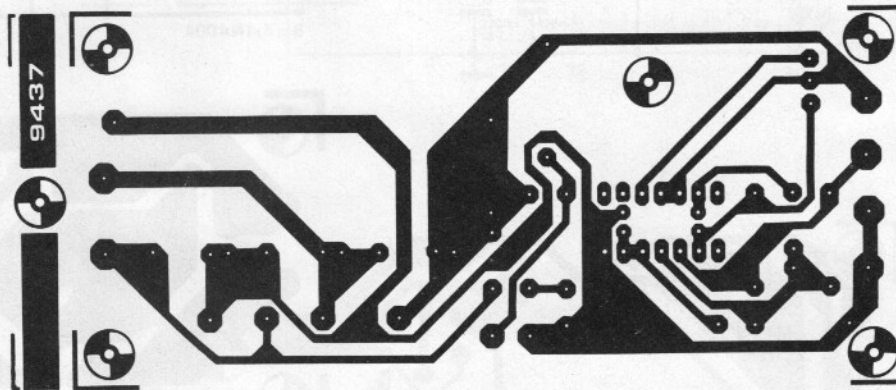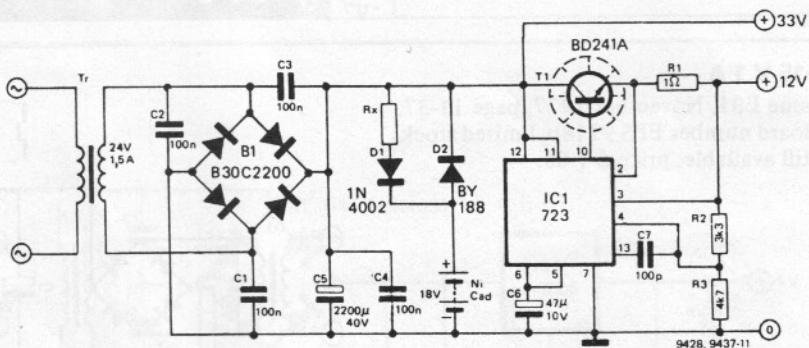
Parts list

Resistors:
R1 = 1 Ω
R2 = 3k3
R3 = 4k7
Rx = see text

Capacitors:
C1 . . . C4 = 100 n
C5 = 2200 μ/40 V
C6 = 47 μ/10 V
C7 = 100 p

Semiconductors:
T1 = BD 241A, MJE 3055
D1,D2 = 1N4002, BY 188
IC1 = 723

Miscellaneous:
Tr = Transformer, 24 V/1.5 A
NiCad Accumulator, 18 V
   (see text)

+30 V 2 A and −30 V 2 A

Issue E18, October 1976, page 10-45.
Outputs independantly variable.
Board number EPS 9004.

Parts list

Resistors:

R1,R2 = 47 Ω
R3,R4 = 0.33 Ω/2 W
R5 = 71k5
R6 = 3k3, 1 W
P1 = 100 k lin.
P2 = 47 k lin.

Capacitors:

C1,C2 = 4700 μ, 35 V
C3,C4 = 1 n
C5,C6 = 100 μ, 35 V

Semiconductors:

IC1 = RC 4194 (Raytheon)
T1 = TIP 2955
T2 = TIP 3055
T3,T4 = BC 140-10, 2N1711
D1 = LED
B1 = B80C5000 (80 V, 5 A)

Various items:

Tr = mains transformer,
2 x 22 V/2 A
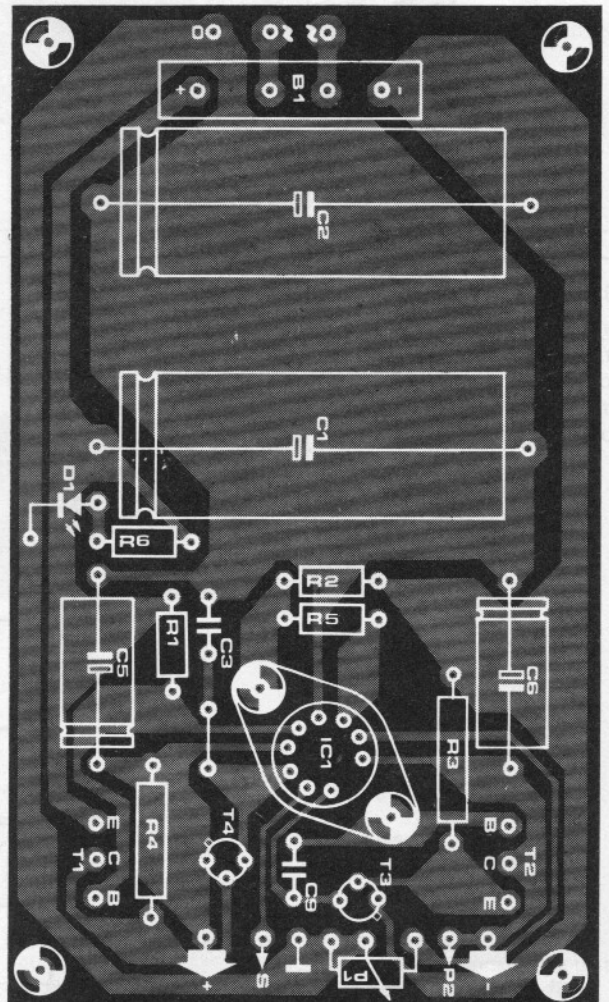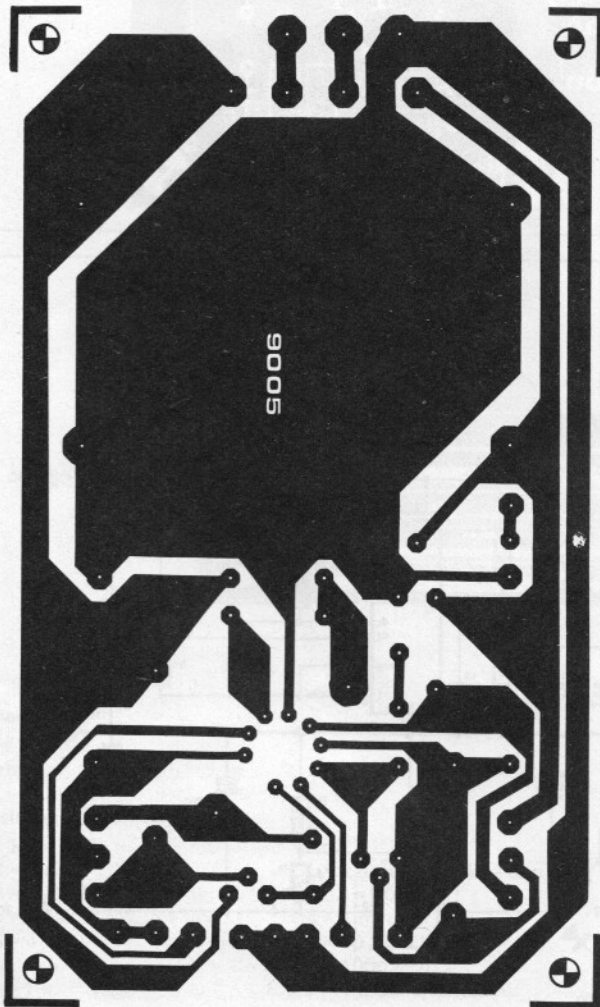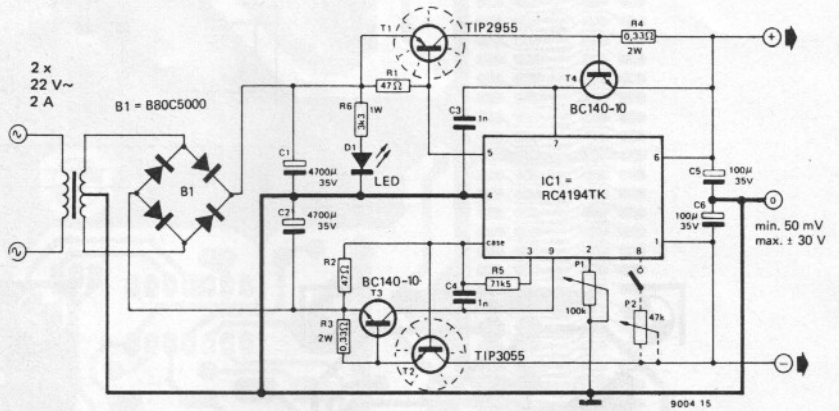
+0 . . . 10 V 300 mA

Issue 27/28, July/August 1977, page 29.
Board number EPS 77059.
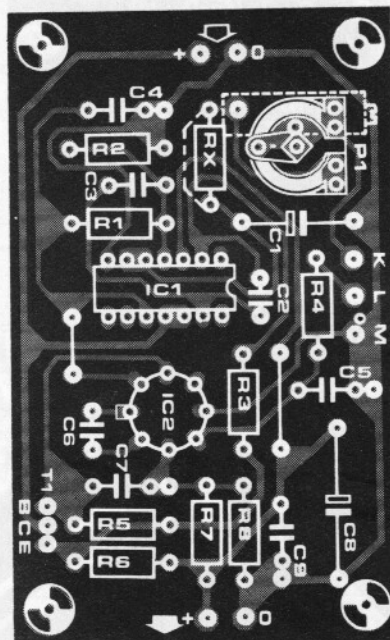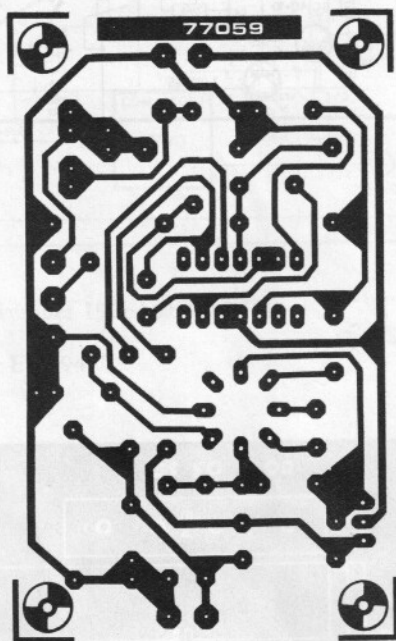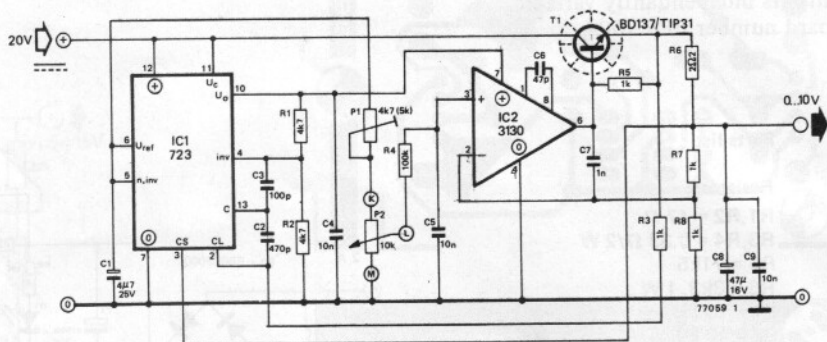
+5 V 3 A and −12 V 500 mA

Issue E35, March 1978, page 3-09.
Originally designed for the SC/MP and
would suit many microprocessor sys-
tems.
Board number EPS 9906.
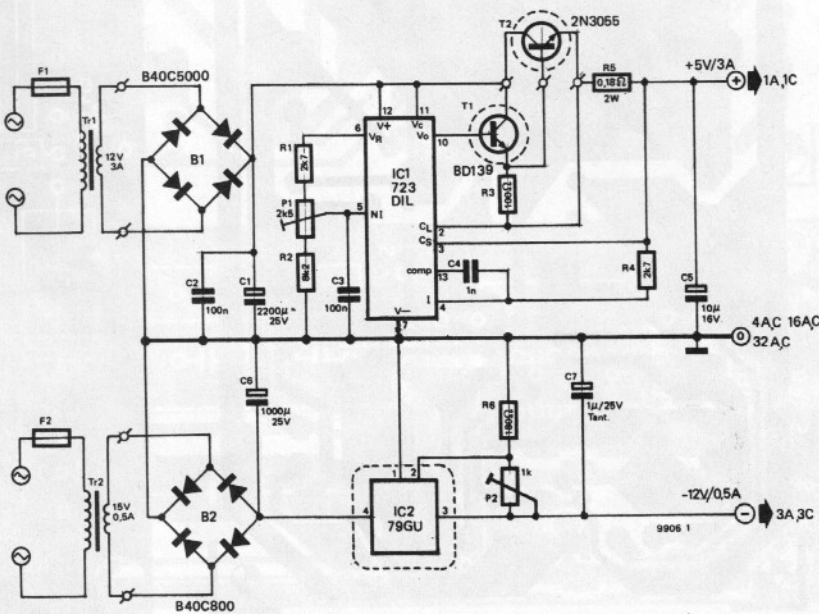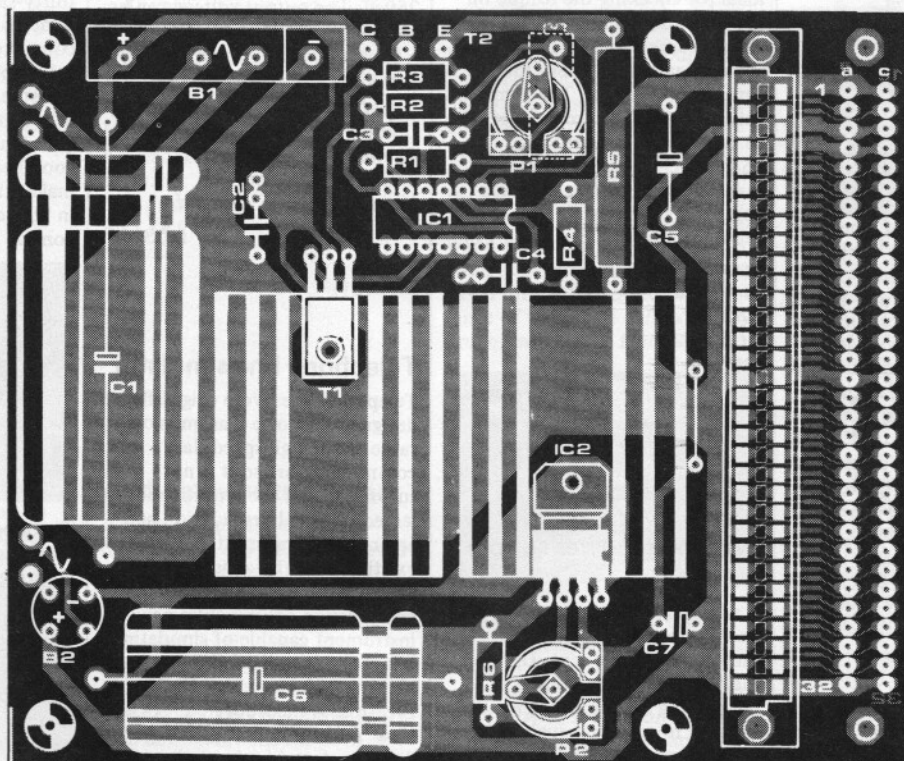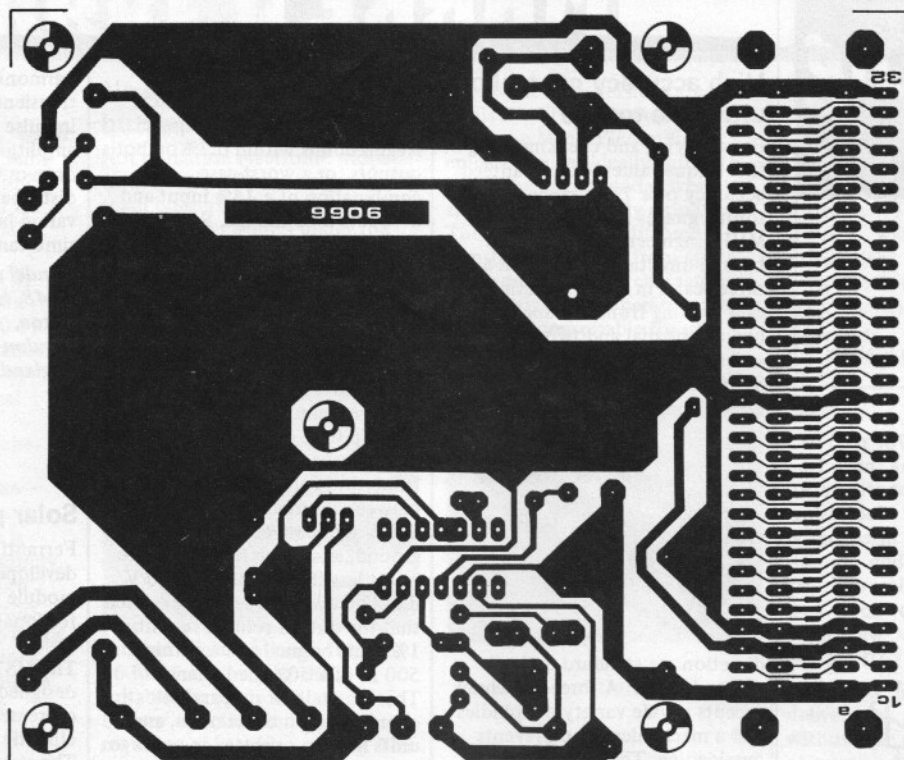
Parts list

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)
C2,C3 = 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
Tr2 = Transformer 15 V,
    0.5 A secondary (see text)
F1,F2 = 300 mA slo blo fuse

MARKET

1/4 Gigahertz counter

Elektor 38, June 1978, p. 6-01.
The sensitivity of the high fre-
quency input amplifier (figure 9)
can be improved by decreasing
R79 to 47 Ω and inserting a
500 Ω (470 Ω) carbon preset
potentiometer in series with it;
R78 is decreased to 15 k and
R84 is replaced by a wire link.
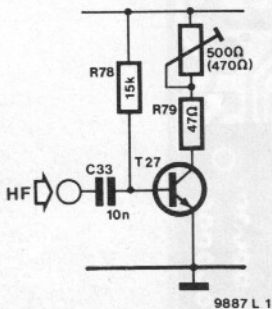
9887 L 1

To reduce clipping of the low
frequency input amplifier
(figure 11) a DUS can be placed
in series with both zener diodes
D32 and D33.
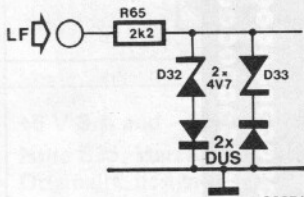
9887 L 2

In the parts list D36 is given as
a 2V7 zener diode; this should in
fact be 4V7 as the circuit diagram
shows.

Central alarm system

Elektor 42, October 1978
p. 10-20. On the p.c. board for
the master station (figure 9),
pin 3 of IC6 should ideally be
connected to supply common or
positive supply (e.g. pin 1) — we
have often stressed in the past
that unused inputs of CMOS ICs
should not be left floating! In
practice it will not normally make
any difference, but if the IC is
running hot this is almost certainly
the reason.
Similary, on the alarm board
(figure 8): if either of the two
alarm inputs 'X' and 'Y' is not
used, it *must* be connected to
supply common. A floating input
at this point can easily result in
'false alarms'!

High accuracy control of ultra-fine torque

For applying and checking ultra-
fine torque values to a guaranteed
accuracy of ± 2%, a range of
torque guages is available from
MHH Engineering. The guages
have bi-directional operation and
three scales in either direction for
easy reading from any angle —
one on the dial and two (standard
and mirror image) on the sleeve.
Slave pointers operating in either
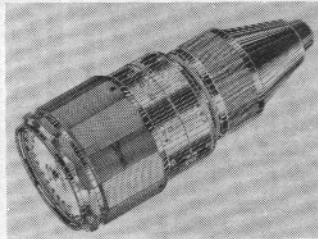
direction are standard on both
dial and sleeve. A three-jaw chuck
accepts a wide variety of spindles
and a mechanical stop prevents
overloading. The instruments are
ideal for checking the torque on
pre-loaded bearings, gear trains,
watch, camera and instrument
spindles and similar very low
torque applications. The torque
values covered are from 10 gf cm
to 15 kgf cm (0.1 ozf in to
15 lbf in). These guages are
manufactured by the Tohnichi
company of Japan.

MHH Engineering Company Ltd.
Bramley,
Guildford,
Surrey,
GU5 OAJ.
England

(1087 M)

Switching power supply with fan

A new dual-output switching
power supply from Gould
Electronic Components Division,
the MGD500, incorporates a
fan-cooling system which enables
the unit to provide a high power
density and also offers the facility
for mounting in any plane.
Designed specifically to power
systems using emitter-coupled
logic, the MGD500 provides two
independently controlled outputs
which track together, and gives a
total power output of 526 W
from a package measuring
5 x 8 x 10.5 in (12.7 x 20.3
x 26.7 cm).
The two d.c. outputs provided by
the Gould MGD500 are 5.2 V
(± 0.2 V), adjustable from 0 to
80 A, and 2.2 V (± 0.1 V),
adjustable from 0 to 50 A, with a
common positive terminal. Input
voltage can be either 230 V or

115 V (± 15%) a.c., at a
frequency of 47 - 63 Hz, and is
selectable from the front panel.
Regulation is within 0.2% on both
outputs for a worst-case
combination of ± 15% input and
0 - 100% load change. Ripple on
both outputs is 10 mV r.m.s.
maximum and 50 mV peak-to-
peak (30 MHz bandwidth), and
temperature coefficient is less
than 0.01% per degC.
The Gould MGD500 is protected
against overcurrent, overvoltage
and overtemperature, and has a
hold-up time of 28 ms at full load
in the event of mains failure.
Insulation voltage is 2.1 kV d.c.
between input and ground and
500 V d.c. between output and
ground, and insulation resistance
is not less than 50 MΩ at 500 V
d.c. The transient response is such
that the output returns to within
1% of its original value within
500 μs of a 50% load change.
There is no limit on parallel
operation with other units, and
units may be operated in series to
a maximum total voltage of
250 V. The output voltage can be
remotely programmed with a
± 5% variation for system margin
checking.

Gould Electronic Components
Division,
Raynham Road,
Bishop's Stortford,
Herts. CM23 5PF England

(1034 M)

Telephone line simulator

Telephone lines were originally
designed for voice transmission
rather than high speed data
communication, so it is not
surprising that the latter is sub-
jected to signal degradation and
errors when transmitted over
existing lines. To assist in the
design of modems and data
transmission equipment a new
instrument capable of simulating
telephone line distortions has
been manufactured by Axel
Electronics Incorporated,
New York.
Switch-selectable simulation of
standard line worst-case characte-
ristics is possible, and in addition
the instrument can superimpose
such steady-state disturbances as
variable random noise, phase
jitter, frequency shifts and
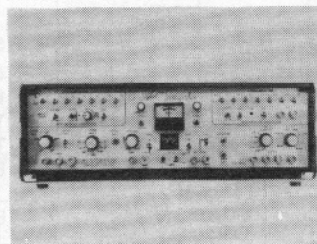
harmonic distortion, as well as
transient phenomena including
impulse noise, phase and
amplitude hits, and amplitude
drop-outs. All simulated
disturbances can be selected and
varied individually or
simultaneously.

Wandel & Golterman (U.K.) Ltd.
40-48, High Street,
Acton,
London W3 6LG,
England.

(1089 M)

Solar power panel

Ferranti Electronics Limited has
developed a new solar power
module for industrial, pro-
fessional and domestic applica-
tions.
The MST300 series have been
designed for long life under
extremes of environmental and
climatic conditions.
The standard module contains
thirty-six silicon cells, each
3 inches in diameter, series
connected to give an output of
1.1 amps at 14.4 volts. It
measures 560 mm x 480 mm and
is only 130 mm deep. Its
aluminium construction offers
good heat sink capability and
makes the module ideal for use
in high ambient temperature
zones.
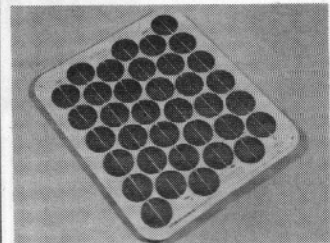
The module is hermetically
sealed to prevent moisture
entering the resin filled space
containing the silicon cells.
Injection of this resin ensures
that all air is removed from
between the cover and base plate,
an important feature of the design
as air pockets have been known to
cause premature module failure.
A cover of fibre reinforced
polyester provides protection
against the environment including
such extremes as sand blasting or
ultra violet degredation.
An additional bonus of the design
concept is the ease with which it
is possible to change the module
dimensions. Where necessary,
additional silicon cells can be
incorporated to meet specific
customer requirements.

Ferranti Electronics Limited
Fields New Road
Chadderton
Oldham
OL9 8NP

(1092 M)

MARKET

Ultra low noise preamplifier

The SL561C from Plessey Semi-conductors, is a high gain, low noise preamplifier designed for use at frequencies up to 6 MHz. Upper and lower cut-off frequencies can be selected by single capacitors and the gain selected between 10 and 60 dB with a single resistor. Operation at low frequencies is eased by the small size of the external capacitors and the low $\frac{1}{F}$ noise.

The noise voltage is less than $1 \ nV/\sqrt{Hz}$ and the current consumption of the circuit is 2 mA from a single 5 volt supply. Applications include use with photo-conductive IR detectors, magnetic tape heads and dynamic microphones. It will also replace an op-amp in many applications where a DC response is not required.

Plessey Semiconductors Limited,
Chenney Manor,
Swindon,
Wiltshire,
SN2 2QW, England

(1088 M)

High profile DIL switch

A special high profile dual in-line switch for front panel and through panel mounting has been announced by Erg Components. The basic version is a 4-pole 2-way DIL switch that can be finger actuated, or switched by using a small probe. All wiping action contacts are gold plated
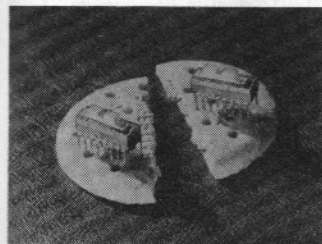
and specifically designed for high reliability $\mu V/\mu A$ switching, with a maximum voltage/current capability of 240 V AC/2 A (non-switching), 30 V/0.25 A (switching). Custom design versions are also available.

Erg Industrial Corporation Ltd.
Luton Road,
Dunstable,
Bedfordshire,
LU5 4LJ,
England.

(1090 M)

New range of miniature buzzers

Not miniature electronic wasps from Scotland but a range of small buzzers being produced by Highland Electronics under the type number GA 100/K. Emitting a 400 Hz signal with an output of 70 — 83 dB (A) at 22 cm., they have no moving contacts and do not cause any electrical or R.F. interference.
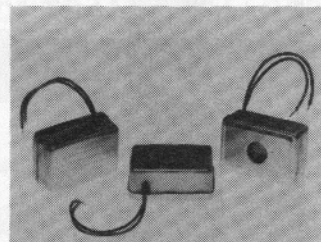
Current consumption is from 16 to 25 mA making them suitable for use in portable or battery operated equipment requiring an audible warning. The case measures 22 x 15 x 10 mm and is made from a high quality plastic, colour-coded according to the four operating voltages of 2.5, 6, 12 and 24 volts.

Highland Electronics Ltd.
Highland House,
8, Old Steine,
Brighton,
East Sussex,
BN1 1EJ.,
England.

(1091 M)

Audio power transistors

A range of epibase and single-diffused TO-220 packaged power transistors now available from Micro Electronics Ltd. are designed for audio output and switching applications, with current ratings of 2 A to 7 A and power ratings of 20 W to 50 W. The devices are available in four chip configurations for both amplification and control circuits.
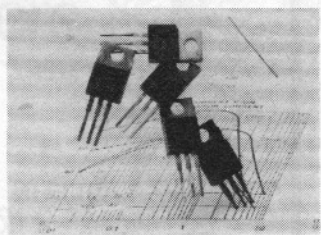
The transistors with epibase chips are designed for good linearity of d.c. current gain, have a higher frequency response (up to 3 MHz), and feature a good safe operating area. Both n-p-n and p-n-p

complementary versions are available. These characteristics make the Micro Electronics epibase devices ideally suited to use in the output and driver stages of high-fidelity amplifiers. The range of single-diffused transistors available from Micro Electronics Ltd. are characterised by a distinct safe operating area, and are more suitable for use in voltage regulators, solenoid drivers, and low-speed switching and control circuits.

Micro Electronics Ltd.,
York House,
Empire Way,
Wembley,
Middlesex.
England

(1093 M)

Digital Gauss/flux meter

RLF Industries has announced a new magnetic-measuring instrument, used for measuring both flux density and total flux. The model 906 Portable Digital Gaussmeter/Fluxmeter is designed for use in the laboratory, in production, or in field locations. When operating in its gaussmeter mode, the instrument uses probes based on the Hall effect. A wide range of transverse and axial probes ia available from RFL.

Built-in axial and transverse reference magnets provide overall accuracy better than 3%. Full-scale ranges of 1000 and 10,000 gauss provide resolution of 1 and 10 gauss, respectively. Capability for 100% overrange provides for measurement up to 20,000 gauss on the instrument's 3-1/2 digit liquid-crystal display.
As an integrating fluxmeter, the Model 906 provides ranges of 10^5 and 10^7 maxwell-turns. Probes required for measurements in the fluxmeter mode are available from RFL, or the user may fabricate his own as the need arises.
The model 906 operates from either 115- or 230-volt, 50-60 Hz power, or from its internal gel-cel (TM, Gould, Inc.) battery which is included for field operation. A charging circuit is included. The

Gaussmeter/Fluxmeter is provided with an impact-resistant plastic case equipped with a carrying handle which serves also as a tilt bail to position the instrument for easy viewing. Size is 8-1/2" wide by 3" high by 9-1/2" deep (21.6 x 7.6 x 24 cm). Weight is 4 lbs, 6 oz. (1.95 kg).

RLF Industries, Inc.
Boonton,
New Jersey 07005, U.S.A.

(1094 M)

Quad bi-fet switch

PMI's new quad Bi-FET switches deliver high-performance but without the problems that plague competing CMOS products.
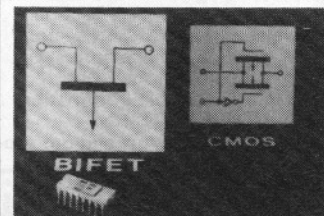
Because these devices employ Bi-FET rather than CMOS processing they are naturally immune to static blow out. No special handling is ever required. Nor is there any danger of SCR-type latch up problems. Available in both normally-open (SSS7510) and normally-closed versions (SSS7511), each is packaged in a 16-pin, hermetic DIP. They are pin-for-pin replacements for the Analog Devices AD7510DI/AD7511DI. 'On' resistance at 75 ohms maximum is low. In addition, high 'off' isolation, low crosstalk and low leakage currents makes these quad switches ideally suited for a variety of applications. The SSS7510/SSS7511 are excellent choices for programmable active filters, programmable-gain amplifiers and position controllers. They are also suitable for chopper, demodulator and general-purpose switching and multiplexing applications. Digital inputs are TTL and CMOS compatible. Break-before-make switching is guaranteed — without the need for external pull-up resistors.

Precision Monolithics, Inc.
1500 Space Park Drive
Santa Clara,
California 95050,
U.S.A.

(1095 M)

TTL ★

Type	Price	Type	Price
7400	10p	74109	25p
7401	10p	74118	75p
7402	10p	74120	80p
7403	10p	74121	25p
7404	12p	74122	35p
7405	12p	74123	40p
7406	25p	74125	35p
7407	25p	74126	35p
7408	12p	74128	60p
7409	12p	74130	120p
7410	12p	74131	90p
7411	15p	74132	45p
7412	25p	74135	90p
7413	25p	74136	90p
7414	45p	74138	100p
7416	25p	74141	55p
7417	25p	74142	180p
7420	12p	74143	270p
7421	20p	74144	270p
7422	15p	74145	55p
7423	20p	74147	100p
7425	20p	74148	90p
7426	22p	74150	65p
7427	22p	74151	45p
7428	25p	74153	45p
7430	12p	74154	70p
7432	20p	74155	45p
7433	28p	74156	45p
7437	25p	74157	45p
7438	12p	74160	55p
7440	12p	74161	55p
7441	40p	74162	55p
7442	40p	74163	55p
7443	60p	74164	60p
7444	60p	74165	60p
7445	65p	74166	75p
7446	50p	74167	160p
7447	50p	74170	100p
7448	50p	74173	80p
7450	12p	74174	60p
7451	12p	74175	60p
7453	12p	74176	60p
7454	12p	74177	60p
7460	12p	74178	75p
7470	25p	74179	120p
7472	20p	74180	130p
7473	20p	74181	130p
7474	20p	74182	60p
7475	40p	74184	120p
7476	30p	74185	100p
7480	40p	74188	320p
7481	85p	74190	70p
7482		74191	70p
7483	70p	74192	55p
7484	70p	74193	55p
7485	60p	74194	55p
7486	20p	74195	50p
7489	130p	74196	50p
7490	25p	74197	50p
7491	40p	74198	100p
7492	30p	74199	90p
7493	30p	74293	90p
7494	70p	74LS10	18p
7495	45p	74S112	80p
7496	45p		
7497	120p	7805	100p
74100	40p	7812	100p
74104	40p	7815	100p
74105	25p	7818	100p
74107	25p	7824	100p
74118	100p		
74166	75p		

CMOS

Type	Price	Type	Price
4000	12p	4040	60p
4001	12p	4043	60p
4002	12p	4046	90p
4006	80p	4047	80p
4007	14p	4048	50p
4009	30p	4049	25p
4011	12p	4050	25p
4012	12p	4054	100p
4013	30p	4055	130p
4015	50p	4056	120p
4016	30p	4060	100p
4017	50p	4066	35p
4018	55p	4069	12p
4019	40p	4070	12p
4020	50p	4071	12p
4022	50p	4072	12p
4023	12p	4081	12p
4024	40p	4093	70p
4025	12p	4510	60p
4026	80p	4511	70p
4027	30p	4516	65p
4028	50p	4518	65p
4029	50p	4520	65p
4030	30p	4528	80p
4032	80p	4583	100p
4033	100p		

CLEARANCE OFFERS

Assorted Japanese IF Transformers
20 for £1.25

Assorted Ceramic Capacitors
(no rubbish)
300 for £1.30

Hook-up Wire in solid black
100 yards for £2.00

Assorted transistors
BC147 BC157 BF194
BC148 BC158 BF195
BC149 BC159 BF196
BF197

100 for £6.00

Reed Inserts 28 mm normally
open gold contacts.
10 for £1.00 — 100 for £7.00

POWER SUPPLY CAPS

2200/16	35p	4700/63	120p
2200 40	50p	4700/100	135p
2200 63	80p	10000/10	150p
2200 100	150p	10000/25	150p
3300 30	50p	10000/25	150p
3300/63	80p	15000/15	150p
4700 40	65p	22000/25	200p
4700 25	50p		

ENQUIRES FOR ANY OTHER TYPES

ELEC CAPACITORS

0.47 25	7p	47 10	8p
1 16	7p	47 16	8p
1 25	7p	47 25	8p
1 50	7p	47 35	8p
2.2 25	7p	47 50	9p
2.2 35	7p	100 10	8p
4.7 10	7p	100 16	8p
4.7 16	7p	100 25	8p
4.7 25	7p	100 63	16p
4.7 50	7p	220 16	12p
6.8 25	7p	220 25	14p
10 10	7p	220 50	22p
10 16	7p	330 25	17p
10 25	7p	330 50	20p
10 50	7p	470 16	14p
22 6v3	7p	470 25	18p
22 10	7p	470 35	20p
22 16	7p	470 50	24p
22 25	7p	1000 16	27p
22 35	7p	1000 25	37p
22 50	8p	1000 35	35p
33 6v3	7p	1000 50	40p
33 16	8p	1000/40	40p
33 25	8p	1000/63	40p
33 40	8p	1200/63	60p
33 50	9p	2200/10	30p

POLY CAPS

1000 PF	5p	0.1 uF	8p
2200	5p	0.22 uF	7p
3300	5p	0.33 uF	9p
4700	5p	0.47 uF	12p
6800	5p	1.0 uF	20p
0.01 uF	5p	2.2 uF	25p
0.022 uF	5p	4.7 uF	36p
0.033 uF	5p	6.8 uF	40p
0.047 uF	5p	10 uF	60p

TANT. BEADS

0.1/35V	14p	3.3/16V	14p
0.15/35V	14p	4.7/16V	14p
0.22/35V	14p	4.7/25V	14p
0.33/35V	14p	6.8/6V3	14p
0.47/10V	14p	6.8/35V	14p
0.47/35V	14p	10/35V	14p
0.68/35V	14p	22/15V	21p
1.00/10V	14p	22/15V	21p
1.00/35V	14p	33/16	20p
1.5/35V	14p	47/3V	20p
2.2/25V	14p	47/16V	20p
2.2/35V	14p	100/3V	20p

LINEAR

AY38500	450p
CA3039	70p
CA3046	50p
CA3060	225p
CA3065	200p
CA3076	250p
CA3080	75p
CA3084	250p
CA3085	85p
CA3086	45p
CA3088	190p
CA3089	190p
CA3090AQ	360p
CA3123E	130p
CA3130	90p
CA3140	60p
LF356	150p
LF357	80p
LM211H	150p
LM3002R5	170p
LM301AN	20p
LM304	
LM307N	85p
LM308TO5	80p
LM308DIL	100p
LM309A	100p
LM310TO5	150p
LM311TO5	100p
LM317K	325p
LM324	100p
LM339	60p
LM348N	90p
LM380	90p
LM381N	90p
LM382	90p
LM391	180p
LM555	25p
LM709C	40p
LM710TO5	40p
LM710DIL	65p
LM723TO5	40p
LM723DIL	40p
LM733	120p
LM741	12p
LM748	40p
LM3130N	100p
LM1458	100p
LM3080	55p
LM3900	55p
LM3909N	60p
MC1310P	140p
MC1312P	190p
MC1314P	190p
MC1315P	60p
MK50398	660p
MM5314	180p
MM5316	150p
NE529K	150p
NE555	25p

NE556	90p
NE562B	400p
SAD1024	1500p
SL917B	680p
SN76003N	150p
SN76013N	110p
SN76013ND	125p
SN76023N	110p
SN76023ND	125p
SN76033N	150p
SN76227N	160p
SN76228N	180p
SN76660N	75p
TAA300	100p
TAA350	190p
TAA550	35p
TAA661B	140p
TAA700	350p
TAA790	350p
TAD100	130p
TAD110	130p
TBA120S	60p
TBA120T	86p
TBA480Q	200p
TBA520Q	200p
TBA530Q	200p
TBA540	200p
TBA550Q	250p
TBA560C	250p
TBA641A12	250p
TBA700	180p
TBA720Q	200p
TBA750Q	200p
TBA800	80p
TBA810	90p
TBA820	100p
TBA920Q	200p
TCA270Q	220p
TCA270S	220p
TCA760	200p
TCA4500A	450p
TDA1008	450p
TDA1034	450p
TDA2002	300p
TDA2020	350p
TL084	120p
XR320	250p
XR2206	450p
XR2207	450p
XR2208	600p
XR2216	650p
XR2567	250p
XR4136	150p
XR4202	150p
XR4212	150p
XR4739	150p
ZN414	100p
95H90	700p

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100 off Green/Yellow Leds	1200p

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SELF TAPPING, SELF CUTTING
SCREWS, NUTS, BOLTS, WASHERS,
EYELETS ETC. ETC.
WEIGHT 1kg 2.2lbs.
Approx 1400 items
ONLY £1.80 (U.K. only)

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AC107	30p	BC178	12p
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AC127	20p	BC182L	12p
AC127-01	25p	BC183	12p
AC128	20p	BC183L	12p
AC151	30p	BC184	12p
AC153	30p	BC184L	12p
AC153K	40p	BC186	20p
AC154	30p	BC204	12p
AC187	20p	BC207	12p
AC188	20p	BC212	12p
ACY19	35p	BC212L	11p
ACY20	35p	BC213	12p
ACY22	40p	BC213L	12p
ACY41	50p	BC214	9p
AD130	150p	BC214L	10p
AD141	150p	BC237B	16p
AD149	80p	BC268	16p
AD161	30p	BC300	20p
AD162	30p	BC301	25p
AD161 2MP	60p	BC303	30p
AF114	25p	BC307	10p
AF115	25p	BC308	12p
AF116	25p	BC309	12p
AF117	25p	BC318	12p
AF118	85p	BC328	12p
AF178	95p	BC337	20p
AF139	35p	BC338	12p
AF239	45p	BC348	20p
AU110	180p	BC461	35p
BA114	12p	BF516	35p
BA121	12p	BF517	35p
BA154	12p	BF547	12p
BA157	15p	BF547B	13p
BA173	15p	BF548	12p
BAX13	5p	BF548C	14p
BAX16	5p	BF549H	14p
BAW21	20p	BF549C	14p
BB105	35p	BF557	13p
BB110	15p	BF557B	15p
BC107	10p	BCY38	20p
BC108	10p	BF595	15p
BC108C	10p	BF597	15p
BC109	10p	BF40	45p
BC109C	10p	BF80	45p
BC113	12p	BFW58	40p
BC114	10p	BFW60	40p
BC116	12p	BFW88	30p
BC117	12p	BCY71	20p
BC118	12p	BCY72	20p
BC125	16p	BD115	35p
BC125B	20p	BD121	85p
BC126	20p	BD132	35p
BC134	20p	BD133	45p
BC136	30p	BD136	40p
BC137	25p	BD139	40p
BC140	30p	BD140	40p
BC141	30p	BD144	160p
BC142	30p	BD182	100p
BC143	30p	BD188	130p
BC147	10p	BD207	70p
BC148	10p	BD270	60p
BC148C	14p	BD222	65p
BC149	10p	BD238	50p
BC153	14p	BD242	60p
BC154	18p	BD252	80p
BC157	10p	BD263	65p
BC158	10p	BD607	80p
BC159	10p	BD608	80p
BC167A	12p	BD609	80p
BC168	14p	BD610	80p
BC169	15p	BD679	75p
BC171	12p	BD680	75p

BDX32	200p
BDX42	50p
BDY10	100p
BF115	15p
BF120	20p
BF121	50p
BF167	45p
BF173	35p
BF180	35p
BF181	30p
BF182	25p
BF183	25p
BF184	20p
BF185	20p
BF194	10p
BF195	10p
BF197	10p
BF198	15p
BF199	15p
BF200	30p
BF224	20p
BF225	20p
BF241	15p
BF244B	35p
BF255	25p
BF257	25p
BF258	25p
BF259	25p
BF271	20p
BF274	25p
BF324	20p
BF336	20p
BF337	20p
BF355	25p
BF394	25p
BF451	25p
BF458	50p
BF594	50p
BF595	15p
BFR40	45p
BFR80	45p
BFW58	40p
BFW60	40p
BFW88	30p
BFW89	30p
BFW91	20p
BFX29	90p
BFX34	20p
BFX38	25p
BFX44	20p
BFX48	45p
BFX81	35p
BFX85	35p
BFX87	22p
BFX88	20p
BFY18	30p
BFY19	20p
BFY50	20p
BFY51	25p
BFY52	25p
BFY53	25p
BFY90	75p
BR101	12p
BRY39	12p
BRY56	12p
BSX20	12p
BSY95	20p
B1100A	80p
BU105	200p
BU133	180p
BU208	220p
BY100	12p
BY126	15p
BY127	15p
BY164	50p
BY164	50p
BYX94	8p
CI120	30p
CI164	20p
F100	42p
E300	47p
E310	50p
E470	180p
E430	125p
MJF340	35p
MPSA05	30p
MPSA06	32p
MPSA56	25p
TIP29	35p
TIP29C	40p
TIP30	35p
TIP30A	40p
TIP30B	40p
TIP30C	40p
TIP31	40p
TIP31A	40p
TIP31B	50p
TIP31C	55p
TIP32	40p
TIP33	60p
TIP34	70p
TIP35	70p
TIP36	225p
TIP41A	75p
TIP41B	80p
TIP42A	80p
TIP42B	80p
TIP42C	90p
TIP2955	70p
TIP3055	70p
TIS90	25p
1N914	5p
1N3754	20p
1N4001	5p
1N4002	5p
1N4003	6p
1N4004	6p
1N4005	6p
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2N3054	50p
2N3055	60p
2N3702	12p
2N3703	12p
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100K LIN		250K LOG	
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