

ELEKTOR ELECTRONICS

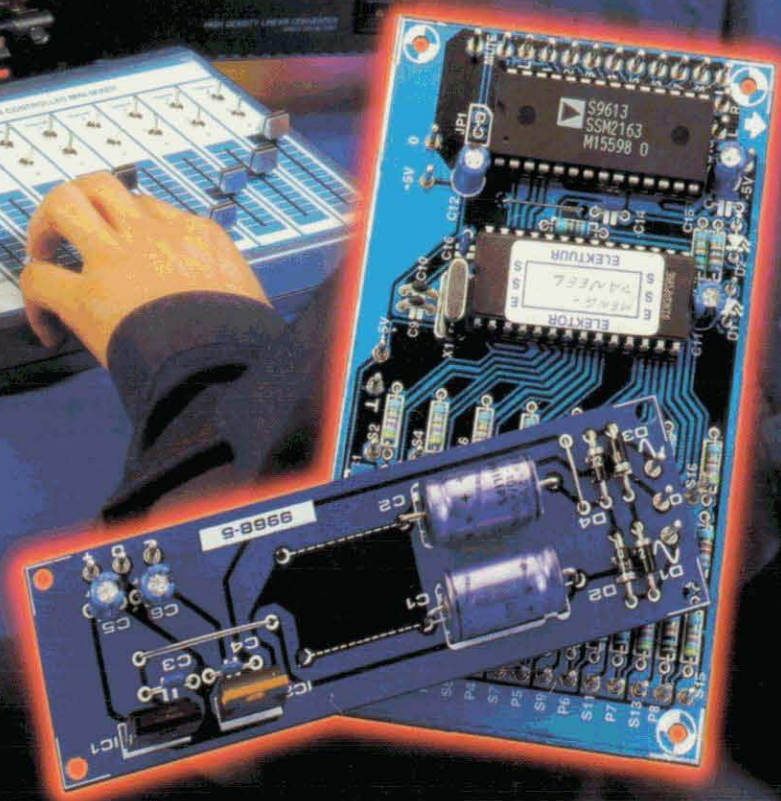
**Focus on
MOBILE TELEPHONES**



UP-CONTROLLED MIXER BOARD

BATTERY-OPERATED SINE-WAVE GENERATOR

EPROM PROGRAMMER



March 1997 Volume 23

Number 253 ISSN 0268/4519

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A B C
AUDIT BUREAU OF CIRCULATIONS
CONSUMER PRESS

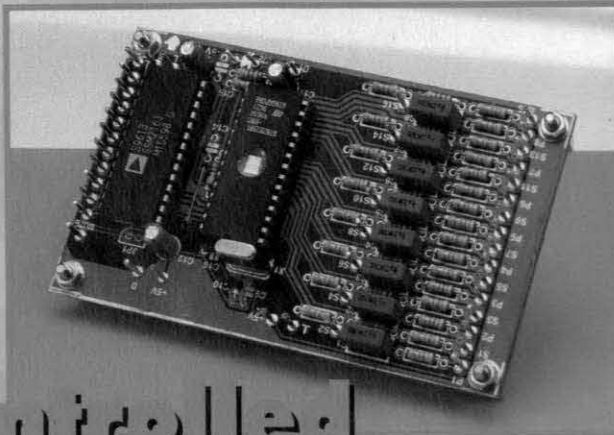
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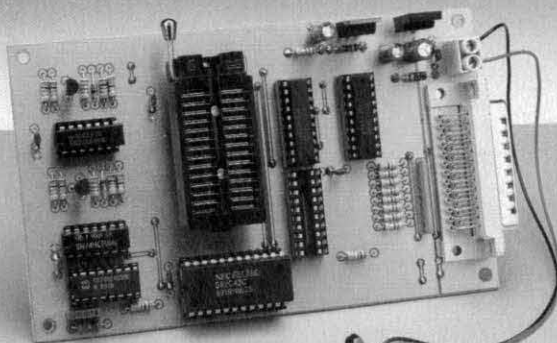
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μ P-controlled mixer board



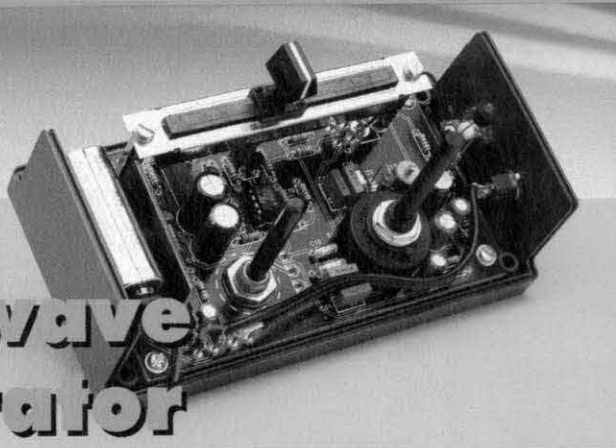
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EPROM programmer



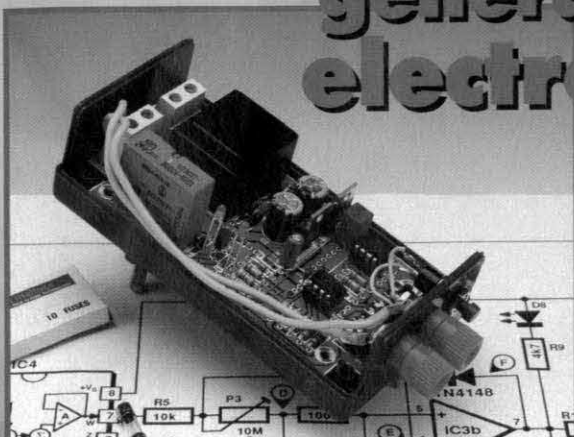
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YOUNG WOMAN ENGINEER OF THE YEAR TELLS *ELEKTOR ELECTRONICS* SHE CHOSE ELECTRONICS BECAUSE OF "THE VARIETY"

Maria Holton, a twenty-nine year old Major Project Engineer with Thorn Lighting Limited at Romford, Essex, was named '1996 Young Woman Engineer of the Year' last January.

Maria, who is responsible for the engineering work on major projects within the southeast region of Thorn Lighting, received a cheque for £750 and a silver rose bowl.

The Award was presented to Maria by Dr Mary Harris, Director General of the Year of Engineering Success (YES) at a special ceremony in London –

the first event marking the beginning of YES, making Maria one of its first successes.

Maria, a mother with a two-year-old son, told *Elektor Electronics* at the ceremony: "I didn't chose engineering for the glamour. It was the variety of the work and the way engineering and electronics in particular give you the opportunity to go off at different tangents."

Currently, Maria is enjoying the challenge of holding down a highly responsible job with Thorn Lighting and the same time raising a lively two-year-

old.

Runner-up for the award and winner of the WISE prize was Kim Hepworth from Kempsey, Worcestershire, who received a cheque for £500. Kim, aged 29, is a Project Group Manager with the Defence Research Agency in Malvern, Worcestershire.

The third prize winner, Hazel McGill, aged 26, from Walsall, West Midlands, was presented with a cheque for £250. Hazel is a Systems Engineer with GPT Limited, Coventry.

The Mary George Memorial Prize, an additional award given to a young entrant showing particular promise as an Incorporated Engineer, was presented to Diane Delaney, aged 22, from Oldham, Lancashire. Diane is a Test Engineer with MEM 250V Limited, Oldham, and a student member of the IEEIE. She was presented with a cheque for £250 and a silver salver.

Other finalists were Eloise MacDonald from GEC Marconi Sensors, Helen Robson, serving on HMS Collingwood, and Jean Suchin, working with British

Maria Holton finished her secondary education at Bishop Stortford's School, Enfield in 1983 and immediately embarked on a National Certificate course in engineering at Southgate Technical College, which coincided with the commencement of her apprenticeship with Thorn Lighting, Enfield. Maria continued her technical education at East Herts College, Turnford, and by 1988 she had successfully completed an HNC course in Engineering.



In 1992, following several promotions, Maria was appointed Deputy to the Chief Lighting Engineer and more recently has moved on to Major Project Engineer, the position she currently holds. Her role requires responsibility for engineering work on major projects within the south-east region, maintaining support for sales personnel through the preparation of lighting schemes and relevant technical reports, site visits, responding quickly to enquiries from customers and visiting their premises when necessary.

Upon completion of her secondary education at Fort Augustus Secondary School, Inverness-shire, **Hazel McGill** enrolled at Blackpool and The Flyde College, completing an HNC in Electronic and Software Engineering in 1991 when she commenced a 3-year training programme with GPT Limited, Coventry. Whilst undertaking her training, Hazel commenced an HND in Electronics and Telecommunications at Coventry Technical College, gaining the award in 1994.



In 1994, Hazel was appointed to her present position of Systems Engineer for the Public Networks Group of GPT where her responsibilities include the commissioning of systems and subsystems for GPT customers on their premises. This involves Hazel in travelling throughout the UK. Hazel enjoyed the challenge of running her own contract, adhering to strict deadlines which ensure effective organization of her time and resources. Customer liaison, quality control, staff management and training are just some of the task which Hazel's job encompasses.

Kim Hepworth left Woodroffe School, Lyme Regis, Dorset, in 1986, having completed an A level in maths and physics, and immediately began a four-year apprenticeship with the Defence Research Agency, Malvern, Worcestershire. During her apprenticeship Kim obtained a National Certificate followed by an HNC in Electronic Engineering at Worcester Technical College.



Having completed her apprenticeship, Kim was appointed Scientific Officer. Rapid promotion followed: first to Project Manager and then to her present position of Project Group Manager. She is currently responsible for five projects, with a total value in the region of £3 million, and her duties include reporting to higher management on the progress of the projects, customer liaison and locating new business. Staff management is a top priority for Kim who leads a workforce of 26 and builds new teams for each fresh project.

In 1992, upon completion of her secondary education at Saddleworth Secondary School, Oldham, **Diane Delaney** commenced a National Certificate course in Electronic and Electrical Engineering followed by an HNC in Power Engineering at Oldham Technical College. Whilst following these courses, Diane completed her Technical Apprenticeship with MEM 250v Limited, Oldham. By 1996, Diane had obtained both a National Certificate and an HNC and is currently completing an HND.



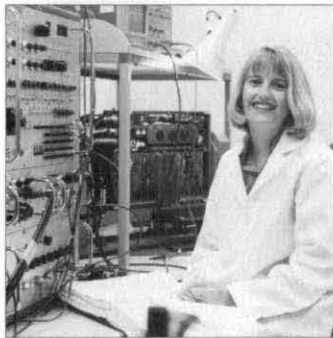
In 1995, Diane was appointed by MEM 250v as a Test Engineer, the position she currently holds. Her responsibilities include the type testing of new and existing products; selective and development testing; calibration of equipment and instrumentation; performing quality audits to ISO9002; and working as part of a product development team. As the Standards Librarian, Diane also has the added responsibility for maintaining the library and ensuring that all standards are controlled.



Eloise MacDonald



Helen Robson



Jean Suchin

Aerospace's Military Aircraft Division.

At the ceremony, Dr Harris exploded the 'five myths' about engineering: poor pay (salaries now compare well with medicine and law); poor prospects (engineers are seven times more likely to become CEOs); poor employment prospects (average unemployment rates among all graduates is eight per cent but only 2.5 per cent among engineering graduates); difficult to get into (of 8,000 companies surveyed, only 30 per cent have filled their vacancies); and, finally, that engineering is boring (when most modern developments incorporate engineering).

The Young Woman Engineer of the Year Award is jointly sponsored by the Institution of Electronics and Electrical Incorporated Engineers (IEEIE) and the Caroline Haslett Memorial Trust (CHMT). It was inaugurated in 1978 to highlight the re-

warding career opportunities available to women in electronic and electrical engineering at Incorporated Engineer level. It is now one of the most coveted awards within the engineering industry and attracts contenders of an extremely high calibre from all areas of electronic and electrical engineering. Previous winners, who all hold key engineering jobs, are ideal role models for others contemplating a career in this fast moving field.

Companies and individuals who would like information on the nomination requirements for the 1997 Young Woman Engineer of the Year Award should contact The Secretary, IEEIE, Savoy Hill House, Savoy Hill, London WC2R 0BS (telephone: 0171 836 3357).

Intel remains No. 1

According to the latest information from Dataquest, Intel has

retained its number one spot as the world's leading semiconductor manufacturer and supplier. The only European company to make it into the top 10 is SGS Thomson sharing 9th and 10th place with Mitsubishi (Philips remained at No. 11, but Siemens dropped to 15th). Interestingly, only Intel and SGS Thomson saw their 1996 revenues go up (by 29% and 24% respectively), all others saw their market share cut.

Intel also remains the largest supplier of semiconductors in Europe, where Siemens took second place even though its market share fell. In Europe also, Intel and SGS Thomson were the only companies to increase their revenue (by 33% and 20% respectively).

World:

- 1 Intel
- 2 NEC
- 3 Motorola
- 4 Hitachi
- 5 Toshiba

Europe:

- Intel
- Siemens
- STM
- Motorola
- Philips

- | | |
|--------------|------------|
| 6 Texas Inst | Texas Inst |
| 7 Samsung | NEC |
| 8 Fujitsu | Samsung |
| 9 Mitsubishi | Hitachi |
| 10 STM | Toshiba |

US suppliers took more than 44% of the world market, Japanese suppliers, almost 36%, European/African/Middle East suppliers together just over 9%, and Asian/Pacific suppliers also just over 9%.

Mobile phones via satellite

Too late to be included in our 'Focus on' article this month comes the news that Motorola, the international electronics giant, with support from the US Lockheed Martin Corporation and the Russian Khrunichev State Research Space Centre in Moscow, has developed a system that will soon allow mobile phone users to make calls from anywhere in the world to any-

The decline in home electronics construction.

From the letters, telephone calls and faxes we have received in response to our query in the January and February 1997 issues, it would appear (reassuringly) that readers' feelings on the subject are broadly in line with our own. Some letters and faxes are reproduced in the Letters section on page 72.

As far as the majority of readers (on a statistical basis) is concerned, there appear to be three main reasons for the decline in home electronics construction. There are others, but these apply to small sectors of the readership only and cannot be taken as reasons for reviewing the contents of the magazine. The three main reasons put forward are:

- changes in social life – today, there are many other interests to be pursued (for which there is money, which was definitely not so in the 1960s, 1970s, and early 1980s, the boom years of home electronics construction);
- changes in the market, which mean that there is

nowhere near as much need to build electronic units as even ten years ago since most of such units can be bought at prices that are lower than readers can buy the materials for (and their quality is generally better and guaranteed);

- fewer opportunities for experimenting than in the past since most projects now published in amateur magazines consist (partly or largely) of black boxes which cannot be worked on and which are controlled by software stored in EPROMs or diskettes that cannot be altered (and which, owing to copyright, the reader cannot normally program him/herself).

It is little consolation to readers and staff of amateur electronics magazines that this situation is, of course, not confined to electronics. Anyone who remembers browsing through magazines on a newsstand or at a newsagent's ten, fifteen years ago can evince this.

Assuming that we judge readers' opinions correctly, it appears that we should consider reducing the number of construction projects to, say, 2 or 3 (one simple, one aimed at constructors with some experience, and the other for experienced constructors) per month and endeavour if at all possible, not to use more black boxes in these than are strictly necessary or unavoidable. The remainder of the magazine would then consist of descriptive articles, background information (on electronics and computers), reviews of electronic equipment and computers, hands-on courses, and similar descriptive material.

However, we do not run a magazine for our own fulfilment but to satisfy the interests and requirements of our readers. So, what do you readers feel about these observations? A letter or fax with your views is, as always, very welcome.

Events

March

3—Lecture on Compact Disc Manufacture at the University of West of England, Bristol. Further information from IEEIE at 0171 836 3357

4-6—ICAT '97 at the NEC, Birmingham will show and demonstrate the latest CAD/CAM technology and integrated systems. For a free ticket and further information, phone the ICAT hotline at 0181 984 7711.

16-18—LIBF'97 at the Grand and National Halls, Olympia, London. Now in its 27th year, the London International Book Fair has firmly established itself as Europe's leading Spring publishing event. For further information phone 0181 910 7910.

18-20—Nepcon 1997 Exhibition at the NEC, Birmingham. Do not miss the RS Components stand. RS Components is Europe's leading distributor of electronic, electrical and mechanical components, instruments and associated tools. The company employs 2,000 people, stocks over 80,000 separate items and dispatches over 21,000 parcels every day for UK distribution. The company sells its products through its catalogue, distributed 3 times a year and also available on CD-ROM and through its national network of trade counters. For further information phone 0181 910 7849

20—The new Swanwick Air Traffic Centre. Lecture at Bournemouth University at 7.30 pm. For further information phone 01202 524111
This month the European Real Time Computer Road Show will visit Lannion, Brest, France and Geneva (CERN). For further information phone +31 418 512999

where in the world.

A network, called Iridium, and consisting of 66 small satellites in low orbit (470 miles or 750 kilometres) will come into operation in early 1998. The relatively large number of satellites will ensure that there is one overhead, or nearly so, at any given time anywhere in the world.

The low orbit of the Iridium satellites is dictated by the relatively low power of mobile telephones.

A call from a mobile is transmitted to the nearest Iridium satellite, which relays until a satellite is found above the call's final destination. There, the signal is beamed down to another cellular phone or a traditional line telephone.

Secure chip-cards?

If you thought that all chipcards were secure, think again. Recently, a lecturer at Cambridge University showed that, using TV hacker techniques and easily available components it is possible to crack even the most secure chips, such as Dallas Semiconductor's 5002 microprocessors which is in use world wide.

Comment from Mondex, an electronic cash company: "No one in their right mind would think that chipcards are tamper-proof - they are merely tamper-resistant."

IEEIE & IMechIE to merge?

The councils of the Institution of Electronic and Electrical Incorporated Engineers (IEEIE) and the Institution of Mechanical Incorporated Engineers (IMechIE) have agreed to consult their members about an amalgamation of the two institutions. The proposal is to merge the two institutions into one organization: the Institution of Incorporated Engineers in electronic, electrical and mechanical engineering, resulting in a new institution with a membership of 35,000 catering for Incorporated Engineers and Engineering Technicians across the three disciplines.

HDTV standards approved

As forecast in our February issue, the Federal Communications Commission - FCC - has approved the compromise standards agreed between broadcasters, computer manufacturers and makers of TV receivers. This means that each of these industries will be able to use the format they like best - which is, as feared, bad news for the consumer.

Children invited to say "yes" to engineering

Children between the ages of 5 and 7 years are being given the opportunity to participate in **Today's Engineers look to the Future** - a national drawing competition jointly sponsored by 13 professional organizations.

Brightly coloured posters depicting a visit by two children to an engineering centre who, with the help of virtual reality, look into the future, have been sent to all primary schools in the United Kingdom. The nine pictures featured on the poster show some of the innovations which will be perfected by professional engineers over the next few years and 5 to 7 year olds are invited to express, through a drawing, objects or systems which they think will be engineering achievements in the future.

The three children whose drawings are considered best by the judging panel will receive:

- 1st prize - return air tickets to Amsterdam plus £50.
- 2nd prize - a trip to Paris on Eurostar plus £30.
- 3rd prize - a private tour of London's Science Museum plus £20.

In addition, the winner's school will receive £1,000, the 2nd prizewinner's school, £750, and the 3rd prizewinner's school, £500.

The closing date for entries will be 10 March 1997 and the presentation ceremony will take place in London during May.

Further information from the Press Officer at the IEE, tel. 0171 344 5445, or the Press Officer at the IEEIE, tel. 0171 836 3357.

Now for the wireless modem!

Motorola is this year putting more effort and money into the production of its Personal Messenger range of wireless modem cards.

The Hanover Industry Fair 14-19 April 1997

Specialist Tour operator Pressplan Travel has arranged a large selection of tours to the Hanover Industry Fair which is being staged between Monday 14 and Saturday 19 April. This fair is the largest and most comprehensive trade fair for industry. It brings together all sectors of industry, covering electric automation and technology, power transmission and control, energy and environmental technology, plant engineering, factory equipment and tools, subcontracting and industrial materials, research and technology, and lighting technology.

The tours vary in duration from one to three nights enabling UK visitors to attend this important event with maximum ease and convenience. Prices start at £478 inclusive of return flights.

Further information from Pressplan Travel Limited, 17 Verulam Road, St. Albans, Herts. AL3 4DA. Telephone 01727 833291; fax 01727 867435.

Medal for Web inventor

The Institute of Physics' 1997 Duddell Medal has been awarded to Tim Berners-Lee, inventor of the World Wide Web. Berners-Lee saw the need for a global information exchange that would allow physicists to collaborate on research while he was working at CERN in 1989. Ingeniously, he integrated hypertext and the Internet and so the web browser and the WWW were born.

electronics software

EDWIN NC

all-purpose electronics design software

This month we have look at EDWin NC, the software bundle that integrates programs for schematic drawing, circuit simulation and printed circuit board design, as well as all auxiliary tools you could desire for these functions.

EDWinNC version 1.43 recently landed on our review desk packaged in an attractive box (see photograph). The box contains a diskette (is that all, you say) and, inevitably these days, a CD-ROM. Current releases of the product also have a small Getting Started manual of 50-odd pages, which should help you to quickly become familiar with the software. The first question you may ask yourself is where to find the information necessary to actually make use of this multi-purpose software. Well, the CD-ROM contains a subdirectory with the conspicuous name Manual which holds four hefty files (adding up to about 8Mbyte) for you to run off on your printer if so desired.

EDWinNC is marked by a kind of shell which covers a schematic drawing program, and a design program for circuit board artwork. These two programs make use of a common netlist. Next, you may launch the simulation software.

The first thing that struck us after launching the program by double-clicking the EDWinNC icon was the appearance of a rather uncluttered taskbar. From the taskbar, you launch the big adventure. In most cases, you will want to start modestly by having a look at one of the many examples available in the /EDWIN subdirectory. This subdirectory contains

EDWin [project name] which is a kind of matrix in which a project is being developed

EDWin Schematics Capture (circuit drawing)
EDWin Layout Design (integrated circuit design)

EDWin Postprocessing
EDWin Mixed Mode Simulator (circuit simulation)
EDWin Diagram Generator (graph plotting)
EDWin Edit Device (component properties editor)
EDWin Library Editor and more.

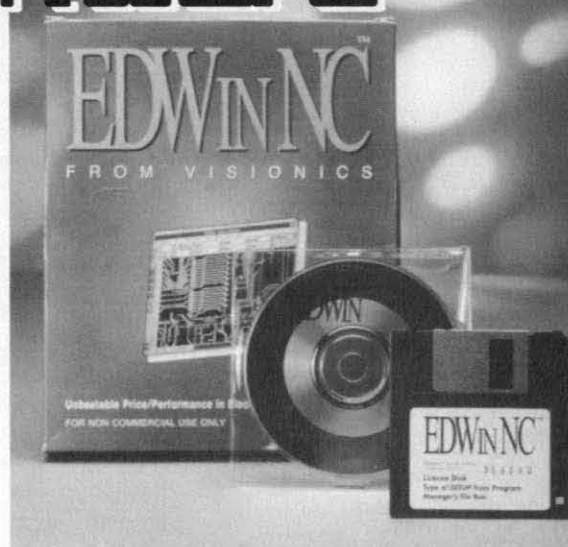
Unfortunately, due to lack of space, it is not possible to mention and discuss all relevant specifications of these sub-programs.

At the expense of the text, we could easily have filled this page with dozens of other screendumps illustrating other interesting aspects of these seamlessly integrated software modules. Because a picture tells more than a thousand words (Confucius), we chose to print a single screendump at the largest possible size.

The minimum requirements for the program bundle are a 386 processor running Windows3.x, a CD-ROM player and 8Mbytes of RAM. EDWinNC runs equally well under Windows95 or NT, using a Pentium or Cyrix processor ticking at 150 or 200MHz.

In conclusion, a couple of loose impressions:

- ✗ an astonishing number of functions
- ✗ zoom-in options to various depths
- ✗ requirement to do a redraw when you perform too many complex ma-



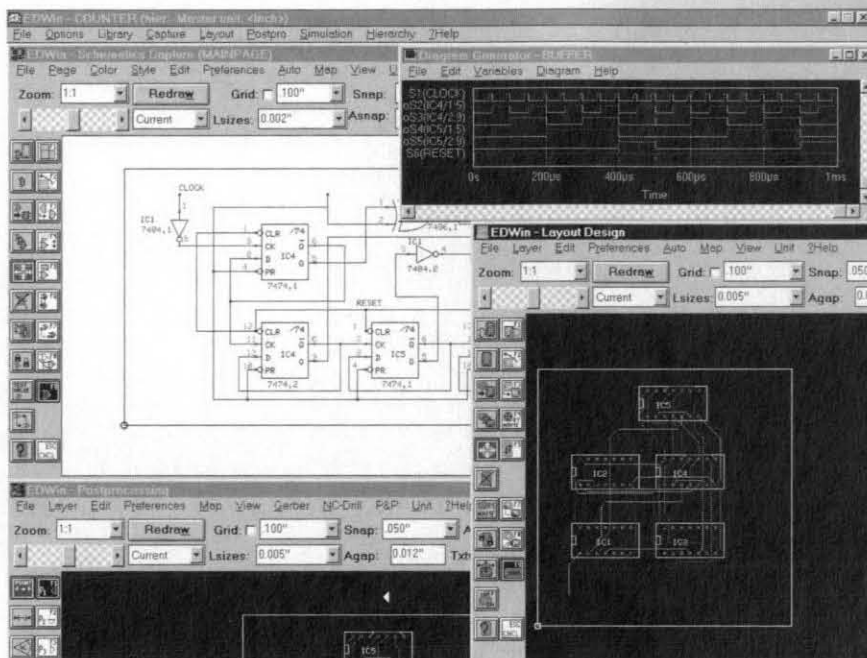
nipulations

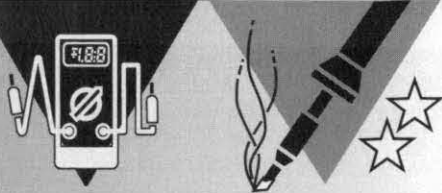
- ✗ an impressive number of libraries
- ✗ extensive library, particularly for microprocessors including those in the Z80xx, 80xxx and 68xx families
- ✗ incredible possibilities for modifications within the editor.

All in all, we were duly impressed by the interesting complexity which goes mainly on account of the plethora of options offered by this software bundle. For further information, see the EDWinNC advertisement on page 5 in this issue, or contact EDWin NC Ltd., P.O. Box 2957, Epping, Essex CM16 7RS. Tel. (01992) 570006, fax (01922) 570220. Email: sales@edwinnc.se

UK distributor: Swift Designs Ltd., Business & Technology Centre, Bessemer Drive, Stevenage SG1 2DX. Tel. (01438) 310133, fax (01438) 722751. Email: designs@swiftdesigns.co.uk. Internet: <http://www.bahnhof.se/~visionics>

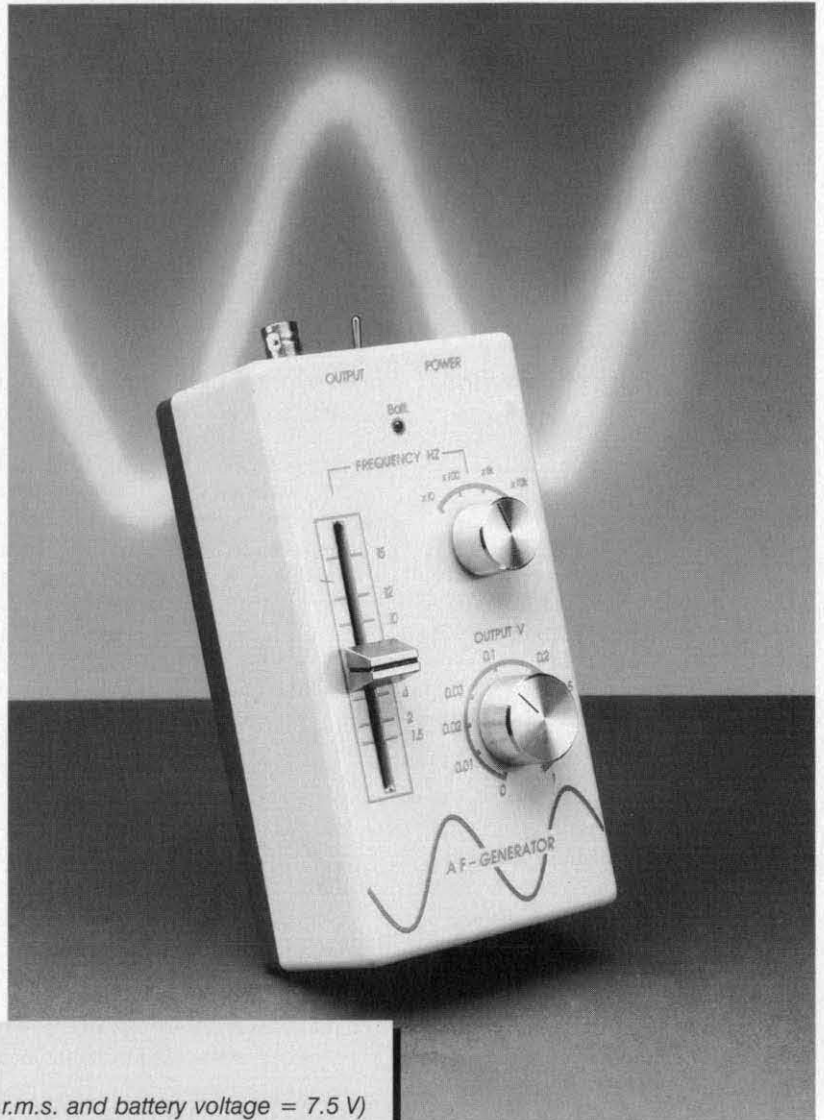
(975021)





battery-operated a.f. signal generator

Testing and faultfinding of audio equipment and low-frequency test instruments is all but impossible without a good signal generator. The function generator used in so many small workshops is, owing to the rather high distortion of the sine-wave output, not really suitable in many cases. This article describes a sine-wave generator whose output signal has very low distortion and in which, moreover, hum and earth loops are obviated thanks to its power being supplied by a battery.



Design by F. Hueber

Parameters

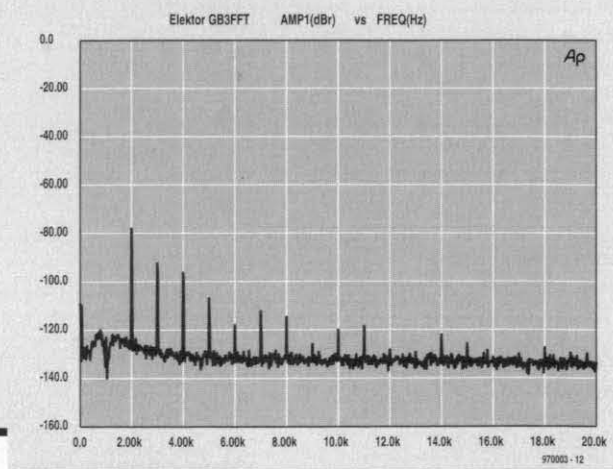
(Measured with an output e.m.f. of 1 V r.m.s. and battery voltage = 7.5 V)

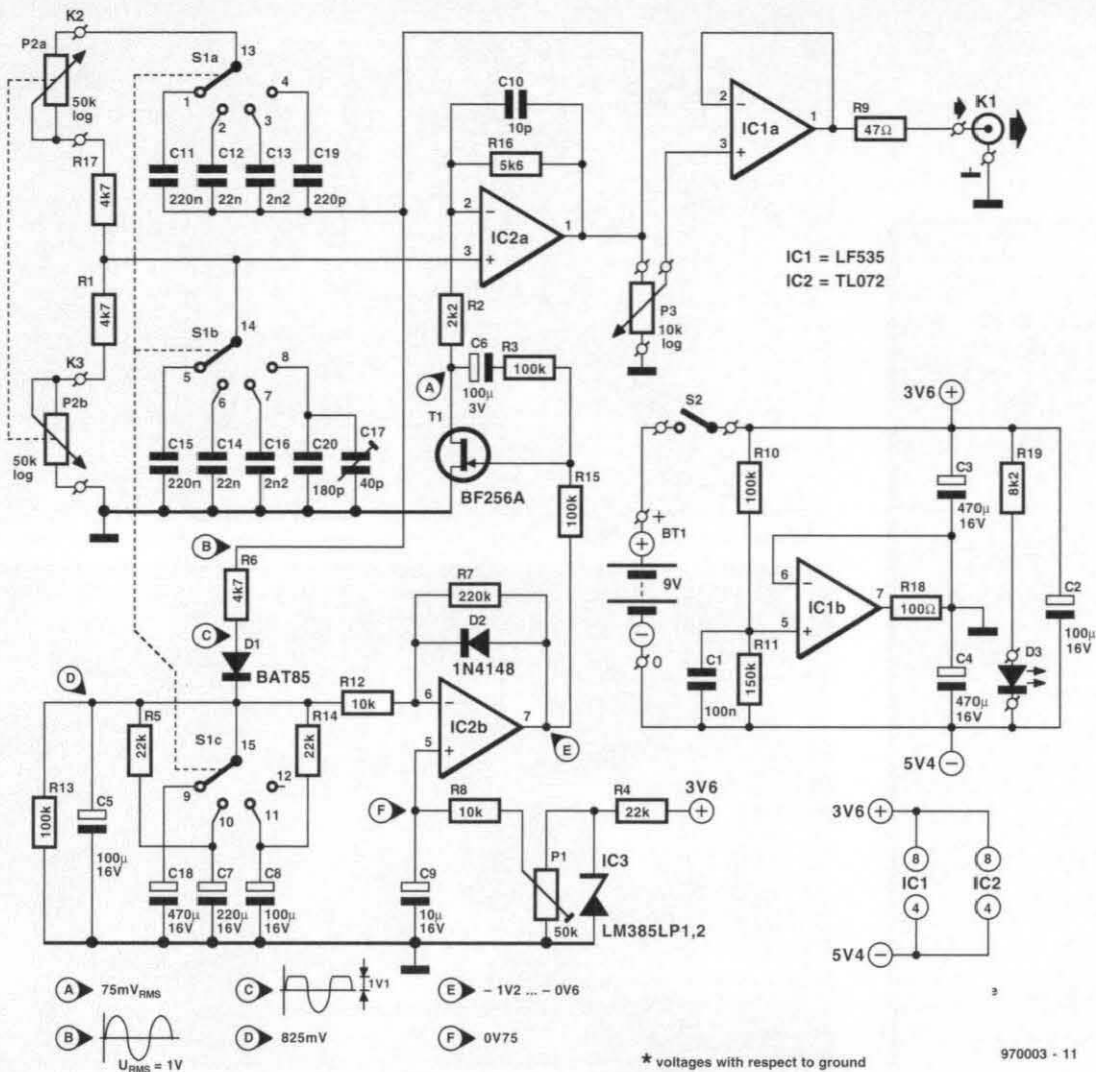
Frequency range	15 Hz – 150 kHz in four bands
Output waveform	sinusoidal
Output voltage	variable between 0.01 V and 1 V r.m.s.
Output voltage error	≤ ±0.2 dB
Output impedance	50 Ω

Distortion (THD+N)

15 Hz – 150 kHz:	≤ 0.25%
30 Hz – 15 kHz:	≤ 0.1%
40 Hz – 10 kHz:	≤ 0.05%
60 Hz – 1.5 kHz:	≤ 0.03%
100 Hz:	≤ 0.045%
1 kHz:	≤ 0.015%
10 kHz:	≤ 0.035%
100 kHz:	≤ 0.158%

Power supply	9 V battery
Current drain	about 7.5 mA





The unit described is a small, lightweight sine-wave generator whose power is supplied by a 9-V battery. Owing to the low current drain, battery life is surprisingly good. The distortion of its 1 V r.m.s. output signal is low (worst case $\leq 0.25\%$).

CIRCUIT DESCRIPTION

As the circuit diagram in **Figure 1** shows, the design is based on a classical Wien bridge oscillator. The frequency is continuously variable in each of four 1:10 ranges and is set with double-gang potentiometer P₂. The frequency ranges are determined by capacitors C₁₁–C₁₇, C₁₉, and C₂₀, and selected with switch S₁.

In the upper frequency range of 15–150 kHz, parasitic capacitances of ICs, board tracks, and so on, cause the distortion to be rather higher than in the other ranges.

The oscillator is based on op amp IC_{2a}. Like all RC oscillators, the Wien bridge needs to be controlled to ensure smooth onset of oscillations and at the same time to guard against the oscillator being overdriven. Generally, this can be arranged in several ways. It is, for instance, possible to include a resistor with positive temperature coefficient (PTC) or a small light bulb in the feedback loop of IC_{2a}, which is, however, not feasible in this design owing to the ensuing high current drain. Another method is the use of two anti-parallel connected diodes in the feedback loop, but this is not acceptable here owing to the consequent increase in distortion.

In the present design, a control loop in which a FET, T₁, is arranged as a voltage-controlled resistor is used. For this purpose, the output voltage of the oscillator is taken from across R₆, rectified by D₁, and smoothed by C₅. The ensuing direct voltage is compared by control amplifier IC_{2b} with a reference voltage provided by IC₃. Since this IC is a band-gap diode, the reference voltage is highly stable even under border-line conditions. Part of the reference voltage is taken from the wiper of P₁ and applied to the non-inverting (+ve) input of IC_{2b}. The output of the control amplifier is applied to voltage-controlled resistor T₁ and thus controls the amplification factor of IC_{2a}. This arrangement ensures that the output of the signal generator is independent of the supply voltage.

The choice of time constants must of necessity be a compromise. This is because on the one hand the ripple on the direct voltage applied to the control amplifier must be as small as possible (since it is a non-linear phenomenon and so constitutes distortion), and this requires a long time constant (C₅–R₁₂). On the other hand, the circuit must be able to react rapidly to overdrive conditions, which also increase distortion, and this requires a short time constant. The solution is found in altering the value of the capacitance in the time constant: to this end, capacitors C₇, C₈, or C₁₈, depending on the selected frequency range, are switched into parallel with C₅. The lower the output frequency, the larger the capacitance and the slower the operation of the control circuit. Resistors R₅ and R₁₄ ensure that the capacitors are always charged to enable the control to react very quickly when another frequency range is selected.

Figure 1. Circuit diagram of the a.f. signal generator, which is based on a Wien bridge oscillator.

Diode D₁ must be a Schottky type to make certain that small output voltages from IC_{2a} do not get swamped by the threshold voltage of

the diode.

The choice of time constants must of necessity be a compromise. This is because on the one hand the ripple on the direct voltage applied to the control amplifier must be as small as possible (since it is a non-linear phenomenon and so constitutes distortion), and this requires a long time constant (C₅–R₁₂). On the other hand, the circuit must be able to react rapidly to overdrive conditions, which also increase distortion, and this requires a short time constant. The solution is found in altering the value of the capacitance in the time constant: to this end, capacitors C₇, C₈, or C₁₈, depending on the selected frequency range, are switched into parallel with C₅. The lower the output frequency, the larger the capacitance and the slower the operation of the control circuit. Resistors R₅ and R₁₄ ensure that the capacitors are always charged to enable the control to react very quickly when another frequency range is selected.

Parts list

Resistors:

- $R_1, R_6, R_{17} = 4.7 \text{ k}\Omega$
 $R_2 = 2.2 \text{ k}\Omega$ (see text)
 $R_9, R_{10}, R_{13}, R_{15} = 100 \text{ k}\Omega$
 $R_4, R_5, R_{14} = 22 \text{ k}\Omega$
 $R_7 = 220 \text{ k}\Omega$
 $R_8, R_{12} = 10 \text{ k}\Omega$
 $R_9 = 47 \Omega$
 $R_{11} = 150 \text{ k}\Omega$
 $R_{16} = 5.6 \text{ k}\Omega$
 $R_{18} = 100 \Omega$
 $R_{19} = 8.2 \text{ k}\Omega$
 $P_1 =$ horizontal multiterm pre-
 set, $50 \text{ k}\Omega$
 $P_2 =$ stereo slide potentiome-
 ter, $50 \text{ k}\Omega$, logarithmic
 $P_3 =$ potentiometer, $10 \text{ k}\Omega$,
 logarithmic

Capacitors:

- $C_1 = 100 \text{ nF}$
 $C_2, C_8 = 100 \mu\text{F}$, 16 V, radial
 $C_3, C_4 = 470 \mu\text{F}$, 16 V, radial
 $C_5 = 100 \mu\text{F}$, 16 V, radial
 $C_6 = 100 \mu\text{F}$, 3 V, radial
 $C_7 = 220 \mu\text{F}$, 16 V, radial
 $C_9 = 10 \mu\text{F}$, 16 V, radial
 $C_{10} = 10 \text{ pF}$
 $C_{11}, C_{15} = 220 \text{ nF}$
 $C_{12}, C_{14} = 22 \text{ nF}$
 $C_{13}, C_{16} = 2.2 \text{ nF}$, poly-
 styrene
 $C_{17} = 40 \text{ pF}$ trimmer
 $C_{18} = 470 \mu\text{F}$, 16 V, radial
 $C_{19} = 220 \text{ pF}$, polystyrene
 $C_{20} = 180 \text{ pF}$, polystyrene

Semiconductors:

- $D_1 = \text{BAT85}$
 $D_2 = 1\text{N4148}$
 $D_3 = \text{LED}$, high efficiency
 $T_1 = \text{BF256A}$

Integrated circuits:

- $\text{IC}_1 = \text{LF353}$
 $\text{IC}_2 = \text{TL072CN}$
 $\text{IC}_3 = \text{LM385LP1.2}$

Miscellaneous:

- $K_1 = \text{BNC socket}$
 $K_2, K_3 = \text{PCB pin}$
 $\text{BT}_1 = 9 \text{ V battery with clip}$
 $S_1 = \text{rotary switch, 3 poles, 4}$
 contacts
 $S_2 = \text{SPST switch}$

Control element T_1 has a non-linear characteristic and this will adversely affect the distortion. To keep this effect to a minimum, the potential across the FET is kept as low as possible by the addition of R_2 . In that way, only the linear part of the characteristic is used.

Feedback network R_3 - R_{15} enhances the overall linearity since it makes the level of the gate voltage only half that

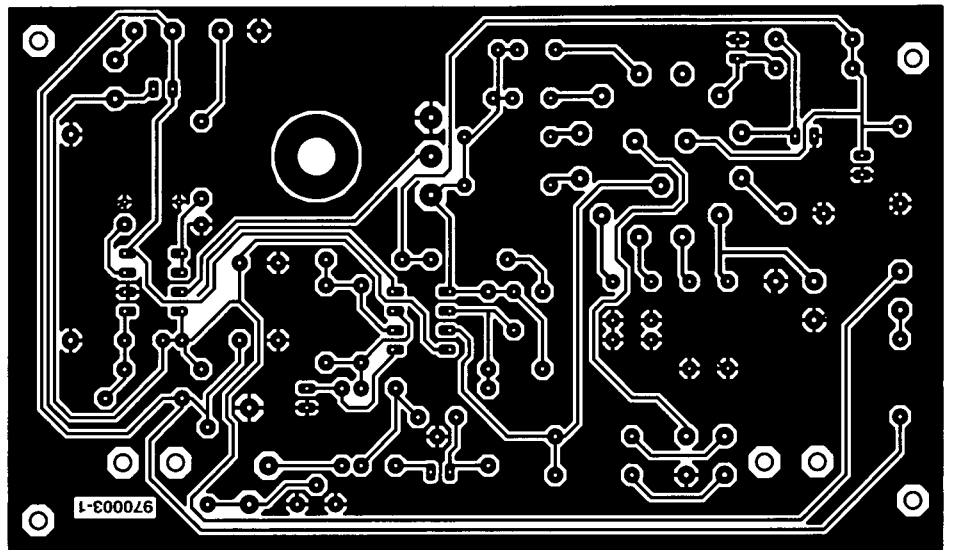
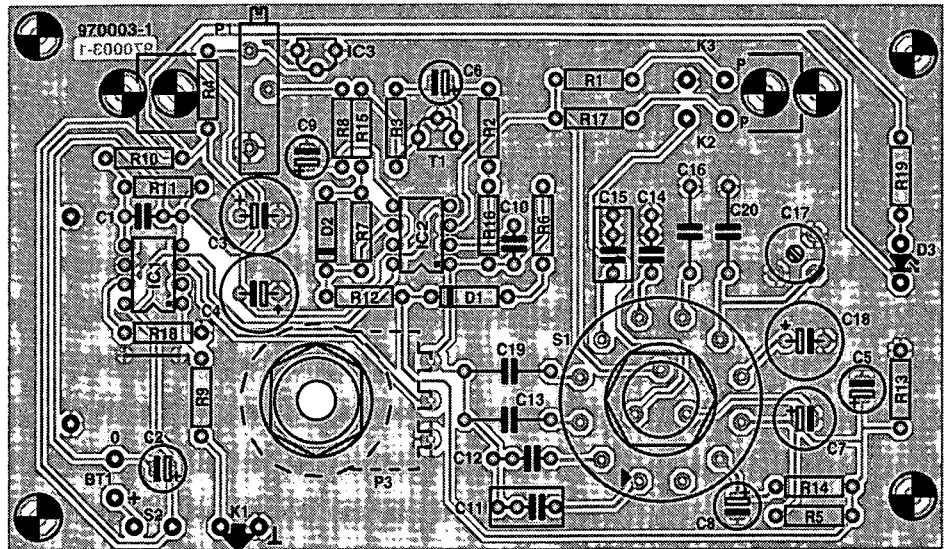


Figure 2. Layouts of the printed-circuit board for the a.f. signal generator.

of the drain voltage. Capacitor C_6 prevents the voltage to the control amplifier also being halved by the potential divider.

The potential at the wiper of P_3 , which sets the peak value of the output signal, is applied to buffer IC_{1a} . The logarithmic characteristic of the potentiometer enables fine setting of the level even at low amplitudes.

Offset compensation of IC_1 is not necessary, since the offset amounts to at most a few millivolts.

Op amp IC_{1b} provides a stable earth potential which, owing to the ratio R_{10}/R_{11} in the present design, is not set at $U_t/2$ but at $2U_t/3$. In this way, the battery has a slightly longer life. Any high-frequency interference in the high-resistance potential divider is decoupled by C_1 .

The supply (battery) voltage is held stable by a high-efficiency LED, D_3 , which draws a current of only 1 mA. Instead of the LED, a tiny profile

meter which draws an even smaller current may be used. In that case, the value of R_{19} must, of course, be altered accordingly.

CONSTRUCTION

The generator is best built on the printed-circuit board whose layout is shown in Figure 2. Completion of the board should not present undue difficulties nor require much time.

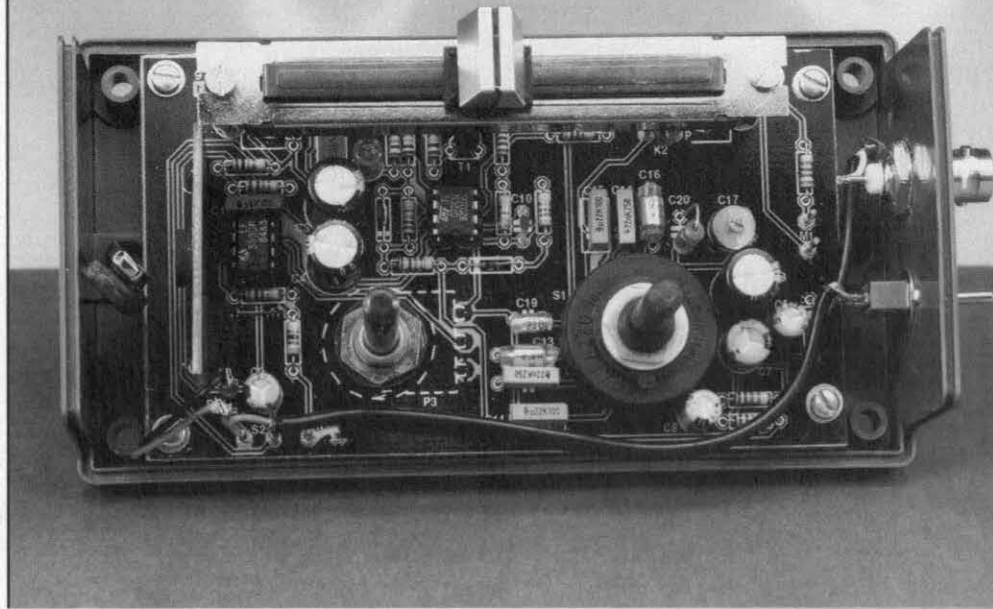
Mind the correct polarity of the relevant components and do not forget the wire bridge adjacent to R_{18} . The presets and rotary switch are to be mounted directly on to the board, but the slide potentiometer, LED, the BNC socket, the battery and operating switch must be fitted on PCB pins. If P_3 has a metal case, this must be earthed.

The battery is accommodated on a small piece of prototype board soldered to two additional PCB pins next to C_1 and the BT_1 0 terminal at the left-hand side of the board—see Figures 2 and 3. To prevent the battery sliding about, glue a battery clip on to the piece of board.

The slide potentiometer is to be fixed on 30 mm long spacers. The metal case of this component is

Figure 3. Completed prototype of the battery-operated signal generator (cover removed).

3



earthed via the fixing screws.

After all components have been soldered into place, carefully check all connections and the polarity of relevant components.

The completed board must be housed in a suitable metal case into which fixing holes for the on/off switch, BNC socket, and rotary switch, as well as holes through which the presets are to be operated, and a slot for the slide potentiometer, are made beforehand. A suggested front panel layout is given in Figure 4. Finally, wire up the generator: note that the cable to the BNC socket should be a screened audio type.

CALIBRATION

For testing and calibrating the generator, an oscilloscope, an a.f. voltmeter, and a digital multimeter are required. The oscilloscope and a.f. voltmeter must be connected in parallel to the output terminals of the generator, and the multimeter between the output of control amplifier IC₂₅ and earth.

Set the frequency to midway in the 150–1500 Hz range, P₃ fully open, and P₂ to the centre of its travel. Wait a few seconds for the capacitors to become fully charged and the output voltage to become stable. When, later, P₂ is adjusted or a different range is selected, wait a few seconds again for the circuits to stabilize.

Gradually adjust P₁ until the output voltage is 1 V r.m.s. Check that the oscillator remains enabled at the limits of the frequency range. If all is well, carry out the same procedure in ranges 15–150 Hz and 1.5–15 kHz.

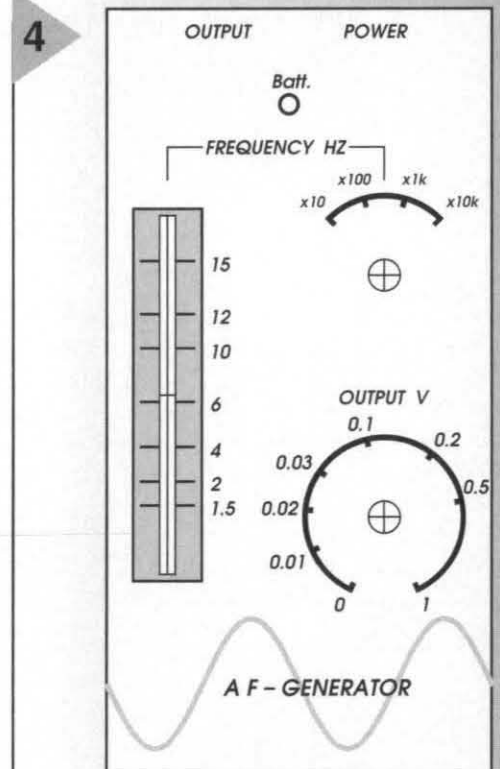
During the procedure, keep an eye on the output voltage of the control amplifier, which should nominally be about -0.9 V with respect to earth, but may vary between -0.6 V and -1.2 V. In no circumstances should it exceed -1.4 V or become positive. If the first is the case, reduce the value of R₂ as required (by about 50–100 Ω); in the latter case, increase the value of R₂.

During the calibration, the output voltage should not deviate more than about 0.2 dB from 1 V r.m.s. If it goes outside the range 0.977–1.023 V, unequal bridge capacitors are indicated. If it is too high, the values of C₁₁–C₁₃ are too high, or those of C₁₄–C₁₆ too low.

During the calibration of the upper frequency range, adjust C₁₇ until the generator output voltage at 150 kHz is the same as that in the other ranges.

Note that it may happen that the parasitic capacitance of P₂ causes the range limits to be slightly different from their nominal values. [970003]

Figure 4. Suggested front panel layout of the a.f. signal generator (shown at 70% of true size).



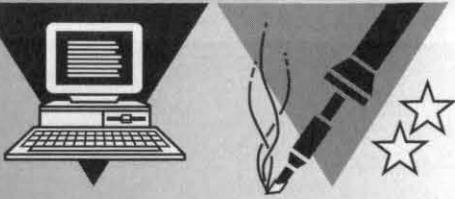
970003-F

Choice of components

For a circuit which has such demanding requirements as low supply voltage, low distortion, and low current drain, it is necessary to choose components with greater than usual care. Nevertheless, this does not mean that expensive or non-standard components are used: far from it. For instance, the op amps used are bog-standard Types TL072 and LF353. These devices combine a reasonably low current drain with good dynamic range, a high slew rate with low distortion, and a low price with good availability.

The dielectric of the capacitors in the Wien bridge has an important bearing on the distortion. Preferably, these capacitors should be polypropylene (MKP) or polystyrene types; the larger-values ones should be polycarbonate (MKC) types. If unavoidable, polyester (MKT) types may be used, but definitely NOT ceramic types. Moreover, the capacitors, pair by pair, should have a tolerance not greater than 5 per cent.

To ensure a linear frequency scale, preset P₂ must have a logarithmic characteristic. The wiper and high-resistance end of the device are interlinked. In this design, it is vital that the actual value of the preset is not much less than 50 k Ω . The tolerance of these presets is normally about 20%, and this might cause the actual value to drop below 45 k Ω . If that is so (measured!), the values of R₁ and R₁₇ must be reduced to 4.2 k Ω or even 3.9 k Ω .



EPROM programmer

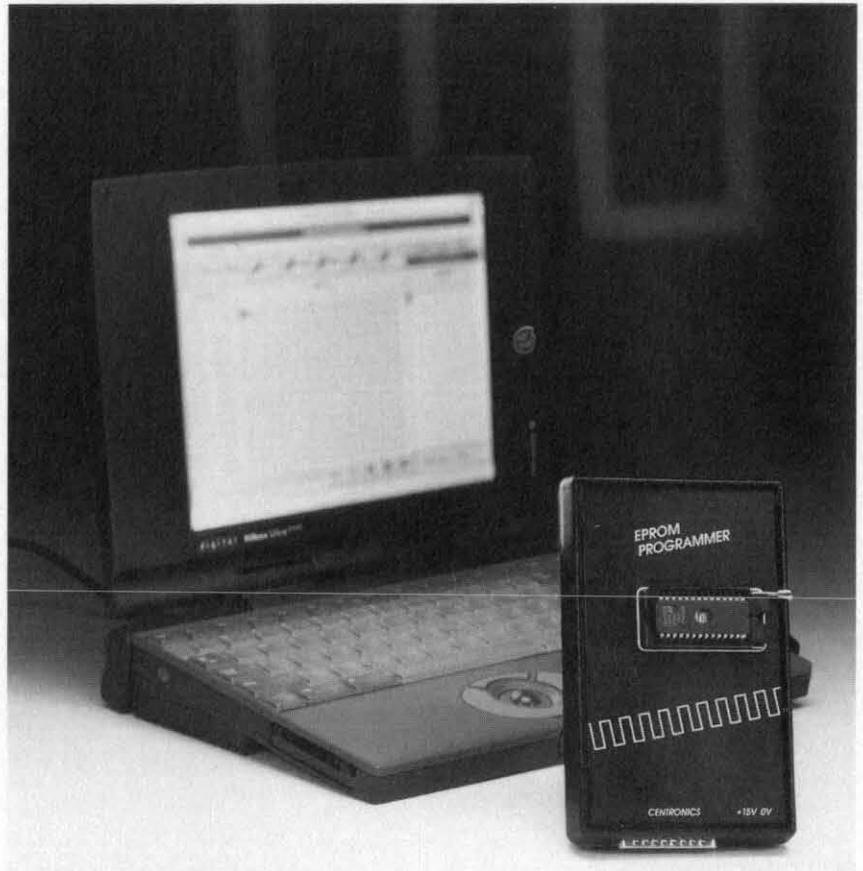
an affordable byte-writer

The design of the versatile EPROM programmer described in this article was among the winning entries of our 1996/97 *Software for Electronics Competition*. Since then, a suitable circuit board has been designed, and the software was tweaked here and there in cooperation with the author. The result is a circuit which may be connected to the printer port on any modern PC, and enables the DIL versions of the popular EPROM series 27(C)64, 27(C)128, 27(C)256 and 27(C)512 to be programmed.

Design by A. Rijfkoel

Main specifications

- ▶ programs EPROMs 2764, 27128, 27256 and 27512
- ▶ EPROMs may be read for comparison with data files and other EPROMs
- ▶ simple supply via mains adaptor
- ▶ software-controlled via EPP printer port
- ▶ software suitable for Windows 3.1 / 95
- ▶ HEX/ASCII editor allows EPROM data to be modified



Despite rapid developments in competing technologies, EPROMs are still widely used in computer and micro-processor systems. EPROMs allow data and programs to be stored in a quasi-permanent memory for at least ten years. After being programmed, the memory may be read out as if it were a mask-programmed ROM. If the code in the EPROM needs to be modified or updated, for example, to add new features to a system, the

device may be erased by exposing it to intense ultra-violet light for half an hour or so. Next, the EPROM may be re-programmed.

Programming systems for EPROMs are commercially available. In addition to the programming hardware, these units often contain an editor which allows the contents of the EPROM to be modified. Unfortunately, the cost of such a ready-made system often exceeds the budget of individual hobbyists and even that of small companies.

Fortunately, there is an alternative way to tackle EPROM programming and editing. The programmer described in this article enables anyone with reasonable construction skills to build his/her own system. Any reasonably up-to-date PC of the 486 or Pentium class should have an advanced bidirectional printer port which may be programmed to function as an EPP (Enhanced Parallel Port) or ECP (Enhanced Communication Port). Thanks to the enhanced printer port,

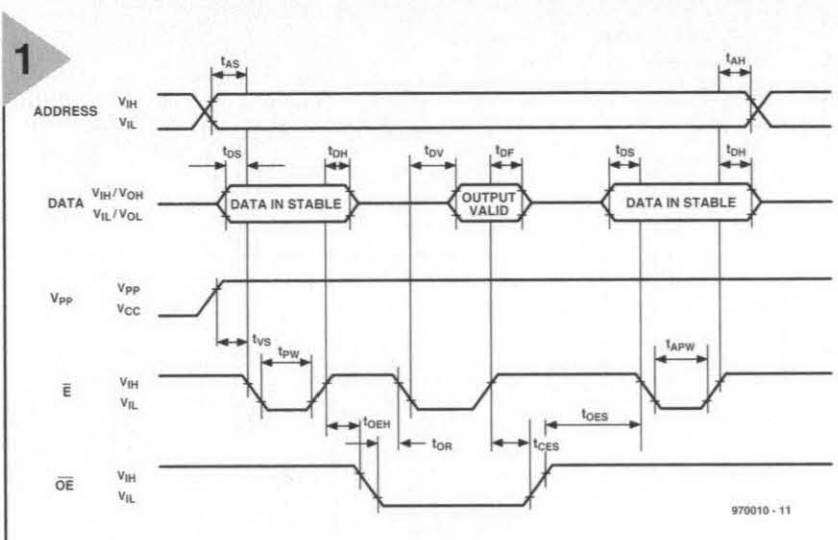


Figure 1. This timing diagram shows the order in which various signals and voltages have to be applied for an EPROM to be loaded with data.

which has been supplied as a standard feature on PCs produced during the past few years, bidirectional communication is possible, allowing a PC to drive external hardware in a simple and efficient way.

The software developed for the programmer employs the EPP on your PC, and runs under Windows 3.1, Windows 3.11 or Windows 95. In addition to the relevant programming algorithms, the software also comprises an editor for text as well as data.

ABOUT EPROMS

An EPROM (Erasable Programmable Read Only Memory) is a memory component which allows digital information to be stored quasi-permanently with the aid of a programming algorithm and a programming voltage. The timing diagram pertaining to the elementary structure of an intelligent programming routine as used to 'burn' an EPROM is shown in Figure 1. First, the desired address is placed on the address bus, and the programming voltage, V_{pp} (12.5 V), is switched on. Next, the data to be programmed is placed on the data bus. The actual programming is started by applying a 1-ms pulse to the \bar{E} (enable) input of the EPROM. Next, the data are read back from the EPROM (\bar{OE} and \bar{E} active), and compared against the data to be programmed. If the two data words are different, another 1-ms pulse is applied to the device. This procedure may be repeated up to 20 times. When the EPROM has copied the data correctly, a series of additional programming pulses is given. The number of additional pulses is equal to that applied before (see also the flow diagram in Figure 2).

Several variants exist of this basic programming method. Some manufacturers, for example, use a supply

voltage of 6 V instead of 5 V during programming, while others recommend a maximum of 25 1-ms pulses. Still other variants employ a programming pulse with a length of 0.1 ms.

In practice, the programming algorithm appears to be less critical than suggested by the manufacturers, although, of course, proper operation of an EPROM is only guaranteed if the maker's particular variant of the programming algorithms has been applied in the strictest way!

In practice, things are not as strict as suggested by the datasheets: for example, even the older 50-ms types may often be programmed successfully using 1-ms pulses. In any case, they are not damaged.

The most important difference between intelligent and conventional programming algorithms is the length of the programming pulse. With 'older' EPROMs, a pulse with a fixed length of 50 ms was generated to ensure that the data was stored properly in the chip. Later, as EPROMs got a much larger storage capacity, intelligent programming algorithms appeared on the scene, allowing the programming time to be cut drastically.

CIRCUIT DESCRIPTION

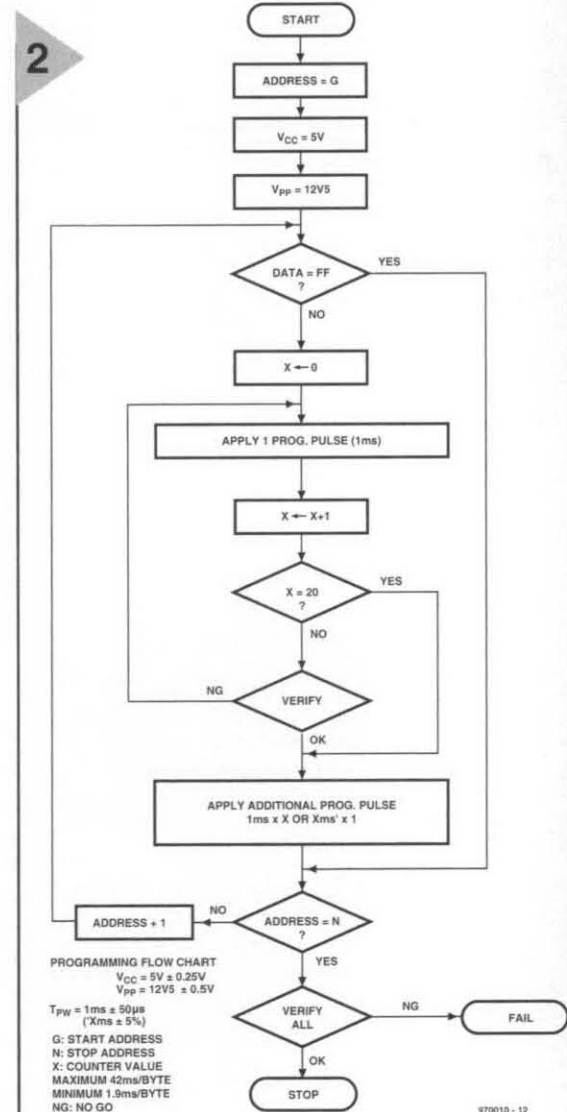
The circuit diagram of the EPROM programmer is shown in Figure 3. The 8243 is a chip not used before in *Elektor Electronics* circuits. The 8243 (from Intel) is an Input/Output Expander

Figure 2. Flow diagram showing an algorithm which allows EPROMs to be programmed intelligently.

designed for the MCS-48 family of microcontrollers. The chip, whose internal diagram is shown in Figure 4, offers four 4-bit I/O ports. Four 2-bit port control commands are available: read, write, ORLD and ANLD. The coding of these commands and the addresses they affect are listed in Table 1.

Because P23 is connected to ground, the registers contained in IC1 may only be read and written. The logic-operator commands, ORLD and ANLD, are not used either. The \bar{INIT} line of the Centronics bus selects between reading and writing, while strobe and autofeed are responsible for the register selections. Port inputs P20 through P23 have a double function. The functional mode is determined by the level at the PROG input. The instruction code and the port address are stored in the chip on the high-to-low transition of the level applied to the PROG input. A low-to-high transition at this pin causes data applied to pins P20 through P23 to be copied.

With a read instruction, the command applied to pins P20 through P23 is latched internally, and then exe-



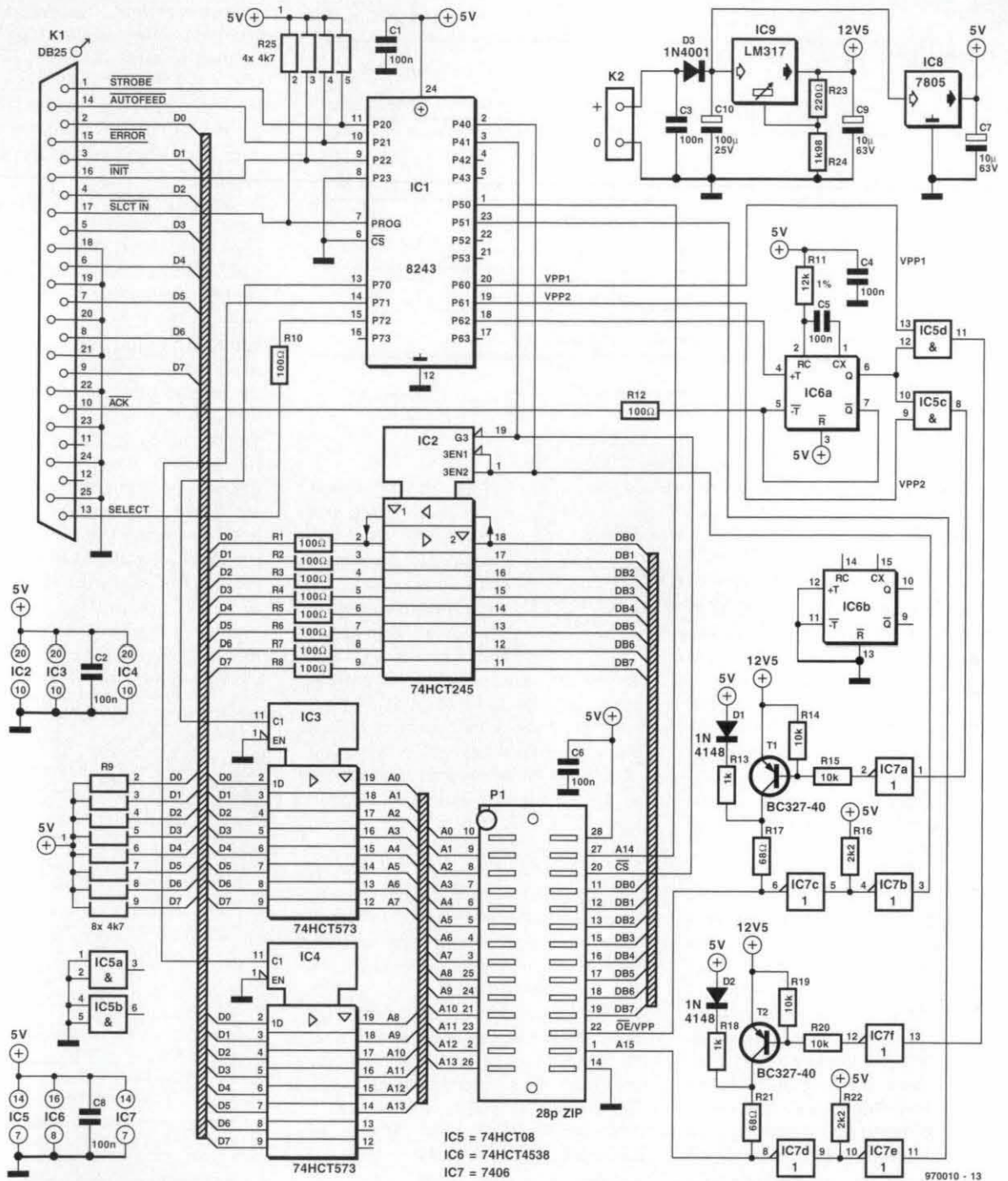


Figure 3. Circuit diagram of the EPROM programmer. This byte-writer is designed for connection to an EPP-mode printer port as available on most modern PCs.

cutted. The selected output port (P4, P5, P6 or P7) goes tri-state, and reads the data applied to the pins. These data re-appear at pins P20 through P23, which are programmed to act as outputs (and no longer as inputs) while PROG is held low. The read command is terminated by a low-to-high transition at the PROG input.

At any time, only three bits are used of the four ports P4, P5, P6 and P7. These port outputs carry out different tasks in the circuit — more about them further on.

Buffers IC2, IC3 and IC4 are connected to the printer port via the data inputs. Because changing the data direction of IC2 may involve a short delay, and is not guaranteed when the supply is switched on, eight 100-Ω resistors are connected in series with the A pins of this IC. The data inputs have pull-up resistors. Address buffers IC3 and IC4 are used to store the EPROM address. IC2 buffers the 8-bit wide data exchanged between the programmer and the PC. The buffer out-

puts are connected directly to the EPROM to be programmed. The storing of address information is controlled by drive signals at port pins P70 and P71, while the direction control is handled by I/O line (output) P40. Furthermore, P40 controls the enabling of the \overline{OE} signal (read/write) for the EPROM. The enabling of IC2 is carried out by means of port line P41.

The 1-ms programming pulse is generated by IC6a, an integrated monostable multivibrator. This IC is set to non-retriggerable mode (\overline{Q} connected to \overline{T}) using a monotime of 1ms. Via the ACK line, the computer checks if the monotime has elapsed. The start pulse which ensures the generation of

the programming pulse originates from pinP62 of IC1. The other two inputs of port6, P60 and P61, determine the voltage level (GND, V_{CC} or 12.5V) to be applied to pin22 of the EPROM. The actual switching over is handled by open-collector buffers in IC7, transistors T1 and T2, and a number of resistors.

The last section of the circuit to be discussed here is the power supply. It is based on an inexpensive mains

adapter with a nominal direct output voltage of 12 V. In practice, such an adapter will easily supply 15 V. Diode D3 acts as a polarity reversal protection, while IC9, an LM317, drops the voltage to a stabilized 12.5 V. Next, IC8 steps the voltage down to 5 V for the logic ICs.

BUILDING THE PROGRAMMER

The artwork of the double-sided

New ports, new ways

This is the first time the EPP mode of the PC's parallel port is used for an Elektor Electronics project. The conventional printer connection is best known as the Centronics port. It makes use of 8 unidirectional datalines and a number of control signals. In theory, the datalines may also be implemented as open-collector outputs with this port. Unfortunately, that is far from ideal for advanced control applications. Because the parallel port is increasingly used as a multi-purpose (fast) communication port, computer manufacturers have added functionality to the relevant interface.

EPP Register Allocation

Port name	offset	mode	R/W	Description
SPP data port	+0	SPP/EPP	W	standard EPP port
SPP status port	+1	SPP/EPP	R	reads levels on status lines
SPP control port	+2	SPP/EPP	W	controls output drive lines
EPP address port	+3	EPP	R/W	generates interlocked read/write pulse for address
EPP data port	+4	EPP	R/W	generates interlocked read/write pulse for data
Not Defined	+5...+7	EPP	-	misc. usage, also available for 16- and 32-bit.I/O

The classic printer port (SPP or Standard Parallel Port) contains three registers. The base address (register 1) is used to write 8 databits to the outside world. Via base address+1 (register 2), 5 databits may be read. Base address+2 (register 3), finally, offers the possibility to write 4 databits to the outside world.

The new generation of printer ports supports this configuration, but offers additional functionality. The concept was developed by renowned manufacturers like Intel, Xircom and Zenith Data Systems. Their intention was to introduce an advanced design which could replace the existing printer port. Based on the concept, Intel developed an interface chip, the 82360. Meanwhile, the matter of standardization has been taken up by the IEEE-1284 committee.

As the present construction project uses only a small part of the new options for the printer port, a full discussion of all available features is beyond the scope of this article. If you want to know more about the possibilities of ECP and EPP, consult the Internet pages at <http://www.fapo.com>, where the IEEE-1284 specification is discussed in great detail.

Limited use

What do we do with an advanced printer port in this wonderful project for home construction? In principle, only the bidirectional communication option is employed. This is achieved by setting the fifth bit in the third register. This bit, called PCD, determines the direction of the data flow. Before that can be done, however, we have to tell the port whether it has to function in SPP or ECP mode. That selection is made by first writing a code to the configuration register (ECR) which is found at the location having offset 402H with respect to the I/O address of the port. In older computers, this location is not in use, so no unexpected things happen in such systems when the software writes to this address.

4

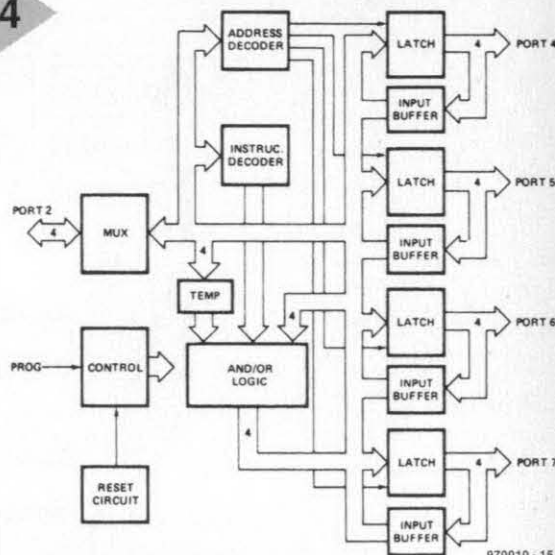


Figure 4. Architecture of Intel's 8243 input/output expander.

Table 1. 8243 command and address encoding

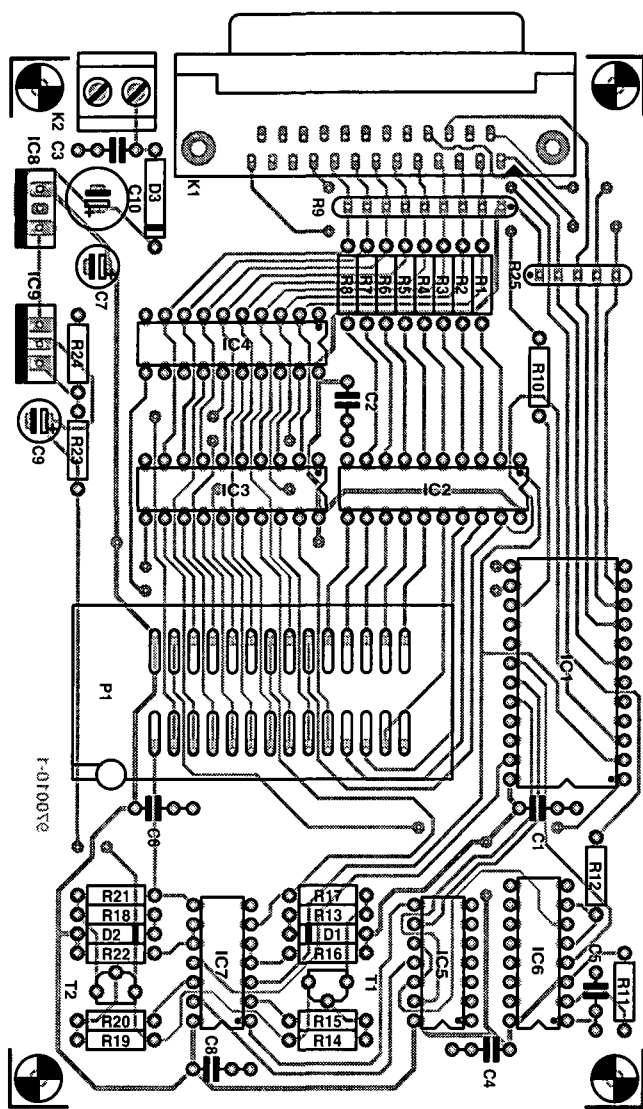
P21	P20	Address code
0	0	Port 4
0	1	Port 5
1	0	Port 6
1	1	Port 7
P23	P22	Instruction code
0	0	Read
0	1	Write
1	0	ORLD
1	1	ANLD

through-plated printed circuit board designed for the EPROM programmer is shown in Figure 5. The size of the board is such that it may be fitted in an ABS enclosure type HP-BC from PacTec. The four moulded pillars in the corners of the case have to be cut off almost entirely, so that the board can be 'sunk' into the case. A small part of the moulded pillars has to be left intact. If not, the screws used to fix the cover can not be secured properly.

Because of the recessed mounting of the board, Centronics connector K1 is neatly positioned in the centre of the side panel.

Next, mount the connector and the PCB terminal block (K2) on the board, and cut the required clearances in the case. The clearance for K1 should enable the connector to protrude. For K2, drill two small holes through which the supply wires are passed.

Fit all the parts on to the board, but



Track layouts shown at 75% of actual size

COMPONENTS LIST

Resistors:

R1-R8,R10,R12 = 100Ω
 R9 = 8 × 4kΩ7 SIL array
 R11 = 12kΩ
 R13,R18 = 1kΩ
 R14,R15,R19,R20 = 10kΩ
 R16,R22 = 2kΩ2
 R17,R21 = 68Ω
 R23 = 220Ω
 R24 = 1kΩ98
 R25 = 4 × 4kΩ7 SIL array

Capacitors:

C1-C6,C8 = 100nF
 C7,C9 = 10μF 63V radial
 C10 = 100μF 25V radial

Semiconductors:

D1,D2 = 1N4148
 D3 = 1N4001
 T1,T2 = BC327-40
 IC1 = 82(C)43
 IC2 = 74HCT245
 IC3,IC4 = 74HCT573
 IC5 = 74HCT08
 IC6 = HC(T)4538
 IC7 = 74(LS)06
 IC8 = 7805
 IC9 = LM317T

Miscellaneous:

K1 = sub-D plug, 25-pin, angled pins
 K2 = 2-pin PCB terminal block
 P1 = 28-way ZIF socket (Aries, Farnell)
 Printed circuit board, order code 970010-1
 Control software: on CD-ROM 'Electronics Software 96-97', order code 976003-1.

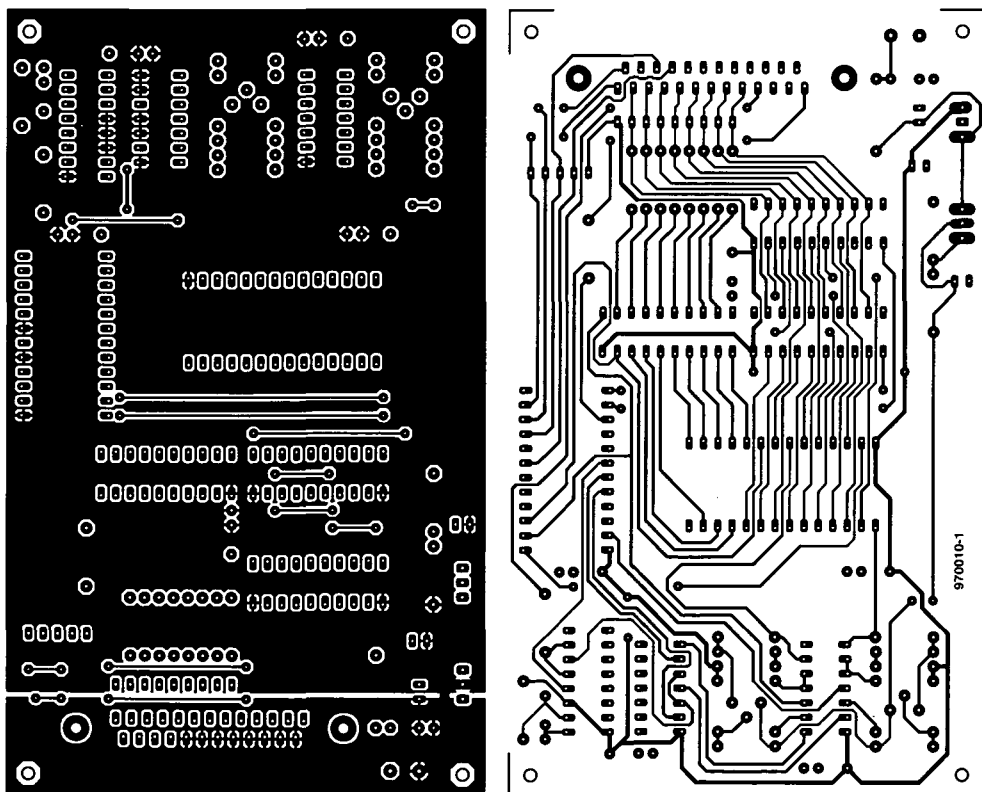


Figure 5. Copper track layout (two sides) and component mounting plan. At the centre of the board is a ZIF socket which accepts the EPROM to be programmed.

none of the ICs, except IC8 and IC9. Connect the mains adapter, and check that there is a voltage of at least 15 V across C10. Next, measure the voltage across C9 (this should be 12.5 V), and that across C7 (5 V). These two voltages should be accurate within 0.25 V. If necessary, the voltage of 12.5 V may be changed a little by changing the value of R24. If the voltages are correct, you may fit the ICs on the board, except, of course, the EPROM to be programmed.

Use a Centronics extension cable (1 × D25 plug, 1 × D25 socket) to connect the EPROM programmer to the LPT1 port on your PC. LPT1 should be the

Eprom Programmer				
ADDRESS		DATA		ASCII
DEC	HEX			
00000	\$0000	3A	31 30 30 33 39 46 30 30 34 33 34 43 34 46 34	410039F00434C4F4
00016	\$0010		33 34 42 32 30 33 32 33 31 32 46 33 31 33 31 32	34B2032312F31312
00032	\$0020		46 33 39 33 36 34 44 34 31 41 32 0D 0A 3A 31 30	F39364D41A200:10
00048	\$0030		30 33 41 46 30 30 34 31 34 45 34 34 34 31 34 37	03AF00414E444147
00064	\$0040		32 30 32 30 32 31 34 34 34 39 34 45 35 33 34 34	20202144494E5344
00080	\$0050		34 31 34 37 32 30 36 38 0D 0A 3A 30 32 30 33 42	4147206800:0203B
00096	\$0060		46 30 30 32 30 32 31 46 42 0D 0A 3A 31 30 30 30	F002021FB00:1000
00112	\$0070		30 45 30 30 43 32 38 43 38 35 38 41 31 45 38 35	0E00C28C858A1E85
00128	\$0080		38 43 31 44 41 45 31 44 41 46 31 45 37 43 31 30	8C1DAE1DAF1E7C10
00144	\$0090		37 44 31 42 37 44 0D 0A 3A 31 30 30 30 31 45 30	7D1B7D00:10001E0
00160	\$00A0		30 45 46 32 44 46 44 45 45 33 43 46 43 38 43 31	0EF2DFDEE3CFC8C1
00176	\$00B0		44 38 44 31 45 38 35 31 45 38 41 38 35 31 44 38	D8D1E851E8A851D8
00192	\$00C0		43 45 34 0D 0A 3A 31 30 30 30 32 45 30 30 44 32	CE400:10002E00D2
00208	\$00D0		38 43 45 35 31 37 43 33 39 34 30 46 35 30 30 34	8CE517C3940F5004
00224	\$00E0		30 35 31 37 38 30 32 44 37 35 31 37 30 30 35 39	0517802D75170059
00240	\$00F0		0D 0A 3A 31 30 30 30 33 45 30 30 45 35 31 38 43	00:10003E00E518C

Bidirectional mode Data size: 3018

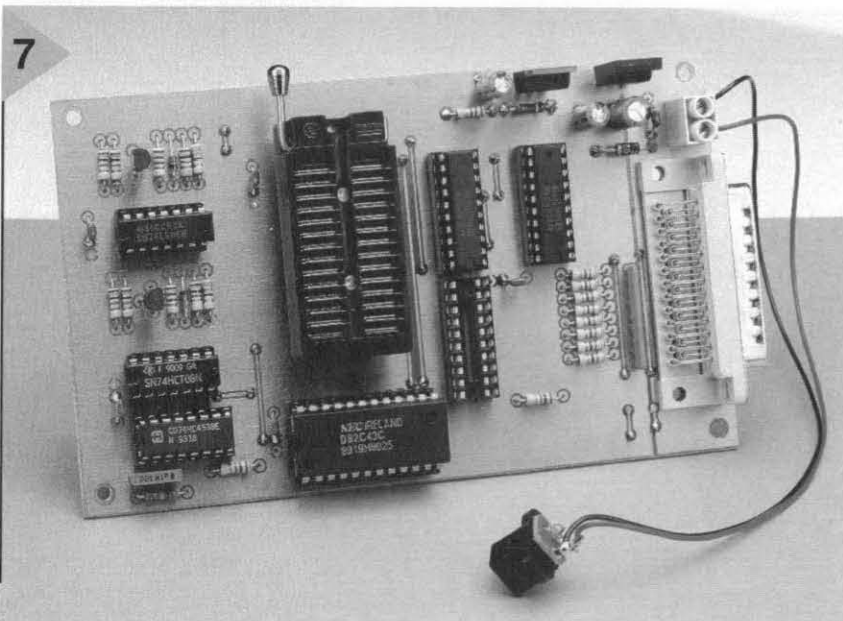
Figure 6. Screenshot of the Windows application software used with this project. The software operates under Windows 3.1, 3.11 and 95.

port with base address 378H.

THE CONTROL SOFTWARE

The control software written for the EPROM programmer may be found on the CD-ROM called Electronics Software 96-97, in the subdirectory NL\01. The actual name of the control software is **prommer.exe**, and the CD-ROM may be obtained from the Publishers under order code 976003-1 (see

Figure 7. Our prototype of the EPROM programmer.



Readers Services page).

Before you use the software, make sure that the BIOS reports SPP/EPP mode or EPP mode enabled for the parallel port at 378H. If necessary, change to SPP/EPP using the computer's BIOS setup program. On older computers, the mode may not be available, in which case you have to buy a separate EPP printer port insertion card.

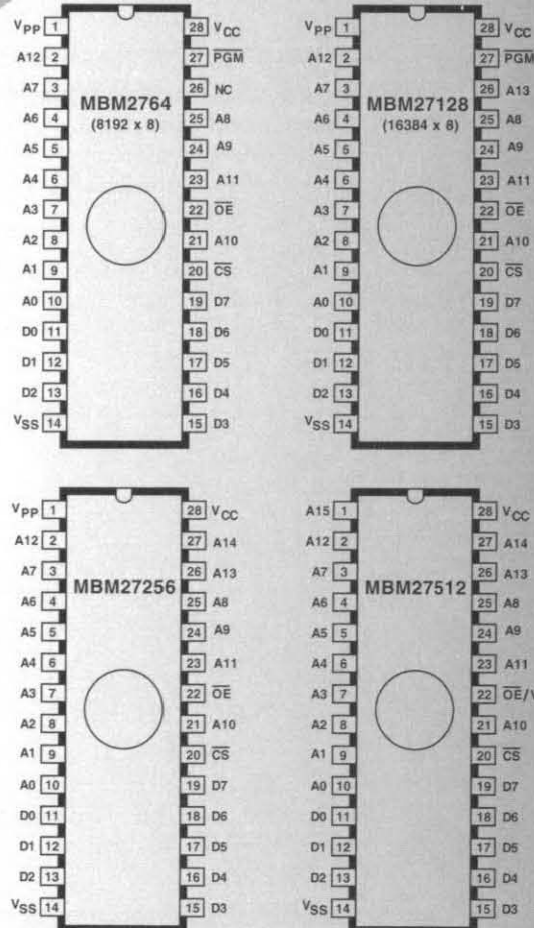
Next, copy the program **prommer.exe** from the CD-ROM to a suitably named subdirectory on the hard disk, and launch it in the usual way. The software first checks for the presence of the hardware.

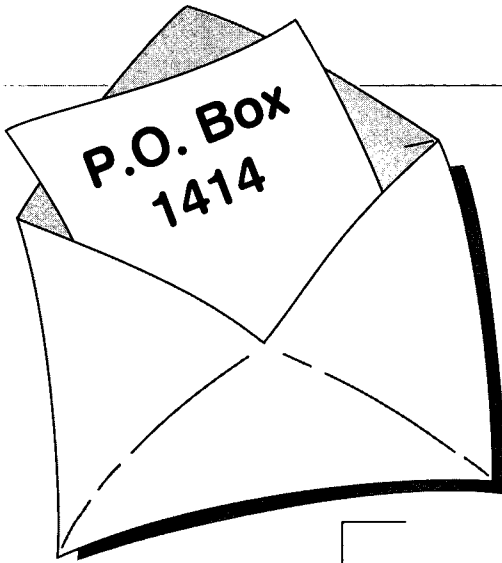
To verify the presence and proper functioning of the interface, the software first sends a short pulse to the Centronics port, via IC1 (the 8243) and resistor R10. If the programmer board is not detected, an error report appears ('no hardware'). If everything is all right, the message 'bidirectional mode' appears. This means that the circuit is ready for use. The message 'bidirectional mode' is used because software

is also suitable for an unidirectional version of programmer which uses modified hardware. The circuit diagram of this version may be found on the Competition CD-ROM, along with the copper track layout of the associated printed circuit board (not available ready-made through our Readers Services). (970010)



Figure 8. Pin-outs of the 27(C)64, 27(C)128, 27(C)256 and 27(C)512 EPROMs.





design offering an EPP/SPP selection in the BIOS, it is recommended to use the design as published in the March 1997 issue.

The PCB whose artwork is printed here is not available ready-made through our Readers Services.

Unidirectional version of EPROM Programmer

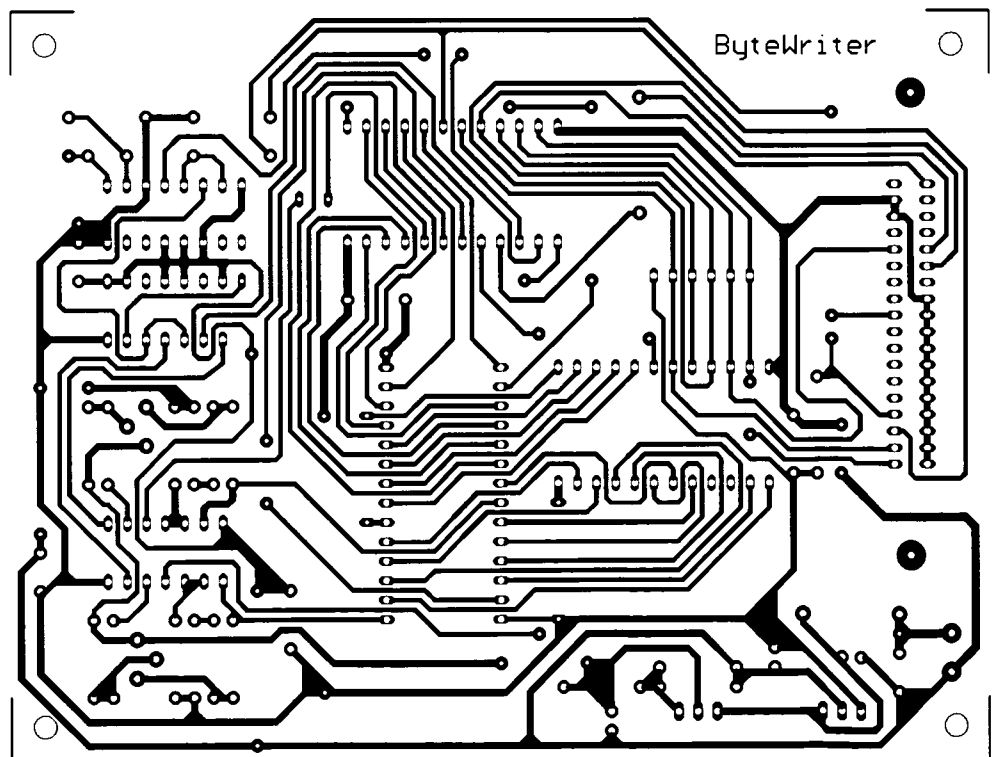
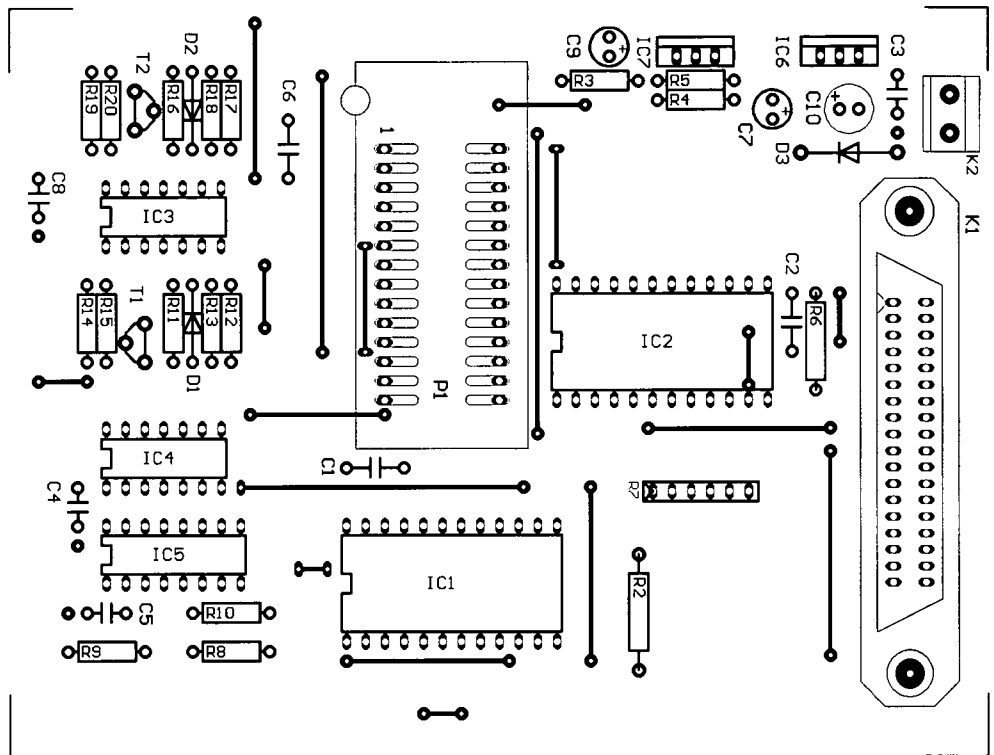
The EPROM programmer published in your March 1997 magazine can only be used with PCs whose printer port can be set to **EPP mode**. My PC is a rather old type with just an SPP port. Reluctant to invest in an extra insertion card, I designed a printed circuit board for the unidirectional version of the programmer, as described by the author, Mr. Rijkogel, on the 'Software for Electronics 96-97' CD-ROM which I obtained from Elektor Electronics.

Since this PCB design may be of interest to other readers of your magazine, I am pleased to offer it for publication at your earliest convenience.

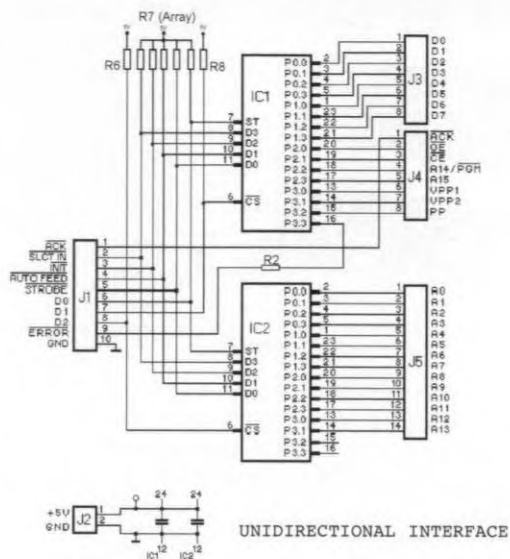
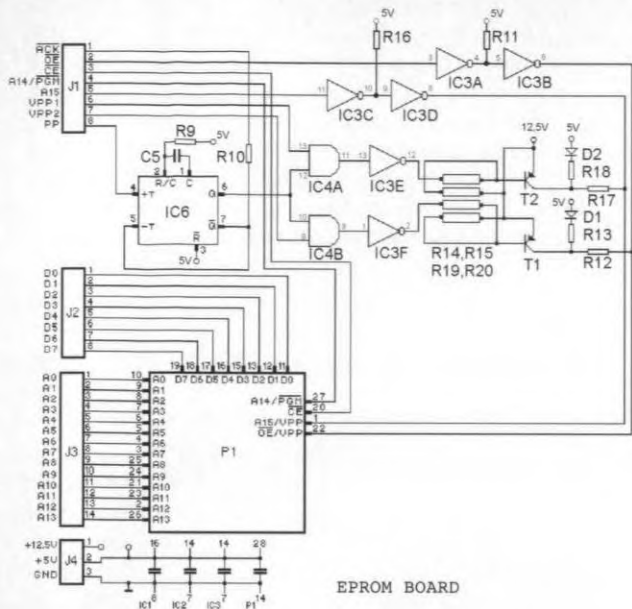
P. Heck

We are very grateful for your PCB design as we believe this may help several readers wishing to build the unidirectional version of the programmer. There is also a small modification in the circuit diagram (with respect to the one found on the CD-ROM), so we'd better print that as well.

A built up circuit board sent to us by Mr. Heck was tested in our design laboratory and worked perfectly on several computers (including desktop machines and one laptop), using SPP mode printer ports and, of course, the software that may be found on the CD-ROM (PROMMER.EXE). So, if you have an older PC, this may be a good work around. If your PC is of a more recent



P.O. Box 1414



COMPONENTS LIST

Resistors:

R1 = not fitted
 R2, R10 = 100Ω
 R3 = 220Ω
 R4 = 3kΩ
 R5 = 4kΩ
 R6, R8 = 4kΩ

R7 = 4kΩ
 R9 = 12kΩ
 R11, R16 = 2kΩ
 R12, R17 = 68Ω
 R13, R18 = 1kΩ
 R14, R15, R19, R20 = 10kΩ

Capacitors:

D1, D2 = 1N4148

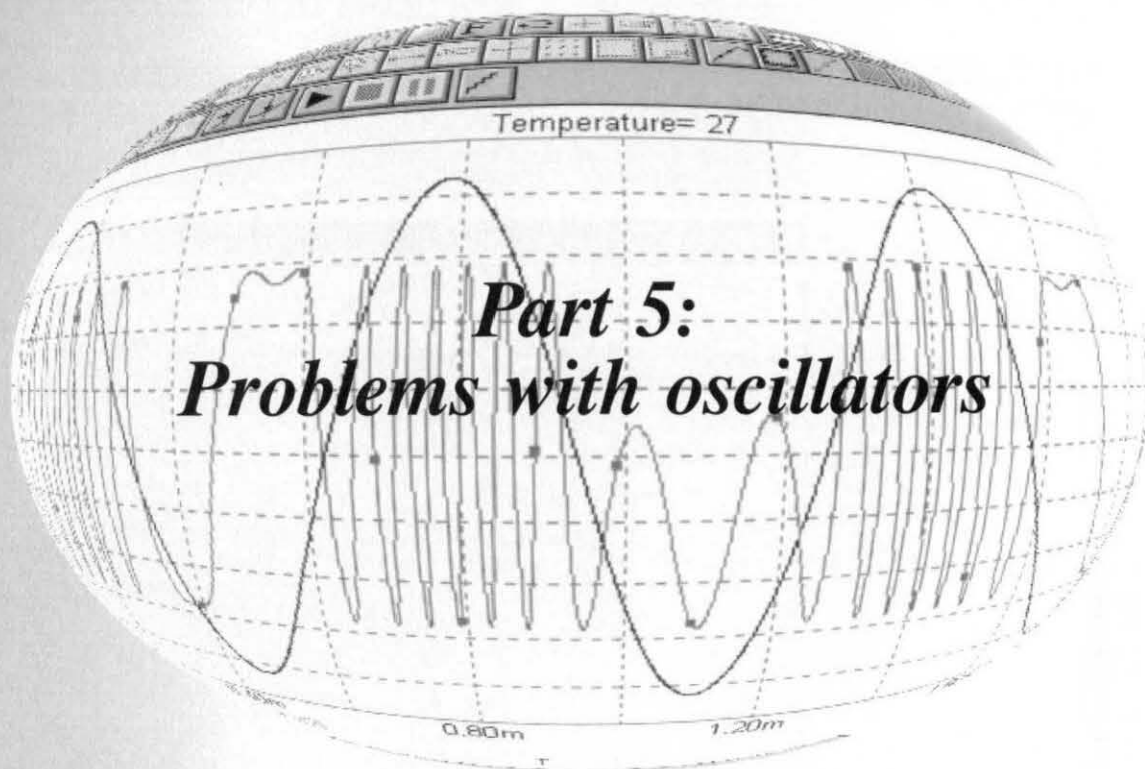
D3 = 1N4001
 T1, T2 = BC327-40
 IC1, IC2 = 82(C)43
 IC3 = 74(LS)06
 IC4 = 74HCT08
 IC5 = 74HC(T)4538
 IC6 = 7805
 IC7 = LM317T

Miscellaneous:

K1 = 25-pin sub-D plug, PCB mount, angled pins
 K2 = 2-way PCB terminal block, raster 5mm
 P1 = 28-way ZIF socket
 PCB not available ready-made

HANDS-ON ELECTRONICS

a short course in circuit simulation



The fifth and final part of this short course investigates problems that may be encountered with all kinds of oscillator and shows how to analyse such problems.

The first circuit chosen for this month's investigations is a relaxation oscillator based on an n-p-n BJT and a p-n-p BJT (Figure 39). It can be used for purposes ranging from flashing an LED to producing an audio-frequency signal. The rate of oscillation depends on the value of C_1 and the ratio of R_1 to R_2 . Assemble the circuit, choosing the pair of transistor models shown, or use other models from the selection box on the right of the Components window. Select Analysis → Transient Analysis then, in the Transient Analysis Limits window, enter Time Range 0.3s, Maximum Time Step 1m, and select Auto Scale Ranges. Set up the plot details boxes to plot curves, for V(1), V(2) and V(5)-V(1) (the pd across C_1) against time T.

Running the analysis produces a disappointment. Instead of three interesting waveforms, we have three horizontal lines across the screen. V(1) is constant at 4.1 V, V(2) is constant at 0.9V, and V(5)-V(1) is constant at 4.2 V. The oscillator is not oscillating. Click on the Numeric Output button to find out why. The Numeric Output screen shows the results of the DC Operating

Point analysis, which is undertaken automatically before a Transient Analysis. It produces a set of node voltages and branch currents to act as a starting point for the Transient Analysis. The Numeric Output shows that the node voltages are:

$$\begin{aligned} V(1) &= 4.14V & V(2) &= 0.882V \\ V(3) &= 8.33V & V(4) &= 9V \\ V(5) &= 8.33 \end{aligned}$$

There is zero pd across C_1 , a sure sign that nothing is happening or will happen. The window also tells us about the operating conditions for the transistors, including the facts that:

$$\begin{aligned} \text{For Q1 (npn): } & v_{BE} = 0.0882V \text{ and } i_C = 4.9mA \\ \text{For Q2 (pnp): } & v_{BE} = -0.669V \text{ and } i_C = 0.9mA \end{aligned}$$

The voltage levels in the circuit are such that it is almost ready to oscillate, but not quite.

Situations such as this often arise when SPICE analyses oscillator circuits, particularly those of relaxation oscillators. It may also occur in circuits with

39

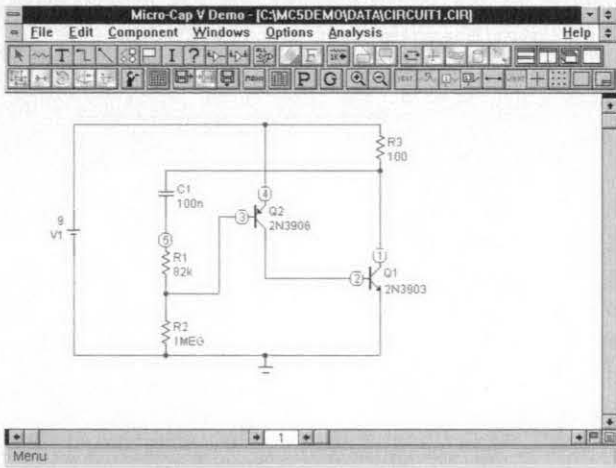


Figure 39. Relaxation oscillator based on an n-p-n BJT and p-n-p BJT.

various kinds of feedback. The Operating Point analysis takes the circuit to a stable state, maybe a rather uncertain one but nevertheless stable, so that the Transient Analysis never starts oscillating. Such a state may not occur in a real circuit because slight leakages or variations of current, perhaps resulting from component heating, which are not allowed for in the models used in the analysis, would eventually produce voltages that would cause oscillations to begin. On the other hand, this circuit might genuinely be a non-starter.

SYMMETRY

A similar latch-up occurs in the astable circuit of Figure 40. Here the paired resistors, capacitors and transistors are identical and the Operating Point

Analysis produces symmetrical voltages and currents. It goes into a stable state, and oscillation never begins. In a real circuit there are always slight differences between nominally identical components, and the asymmetry of the voltages and currents is sufficient to ensure that the circuit goes straight to one of its two astable states and, from there, oscillation begins. One solution to this problem is to deliberately introduce asymmetry. An obvious technique is to make one of the resistors larger than its symmetrically opposite one. The reader might assemble this astable and try to get it started by modifying one of the component values. It is not always easy to find a value that will bring about oscillation.

INITIAL CONDITIONS

Altering resistor values in Figure 39 might induce that oscillator to start more readily, and this is left as an exercise for the reader. The main drawback of this technique is that one of the resistor or other values has been made incorrect, which may affect the frequency, the mark-space ratio or other characteristics. Fortunately, SPICE provides another way of en-

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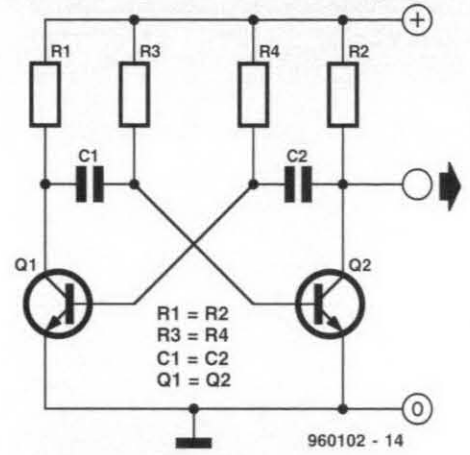


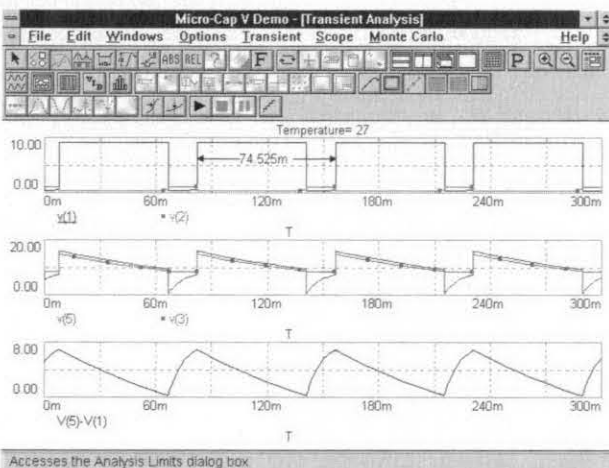
Figure 40. Basic circuit of astable oscillator.

suring that the circuit starts oscillating. This is done by stipulating certain initial conditions to take effect before the Transient Analysis begins. By reasoning or (sometimes) guesswork, we set one or more node voltages to values that we think will set the circuit oscillating. In this circuit, it might help to turn Q₂ fully on. Do this by bringing its base voltage (node 3) lower than the quiescent 8.33 V. If we make it 7 V, Q₂ is turned fully on, causing a full collector current to flow through Q₂, to become the base current of Q₁ and turn that transistor fully on too.

Initial conditions are set by using the .IC command. Exit the analysis, then display the Text window by clicking on the small square at the bottom right corner of the Schematic window. There you will see the model statements for the transistors.

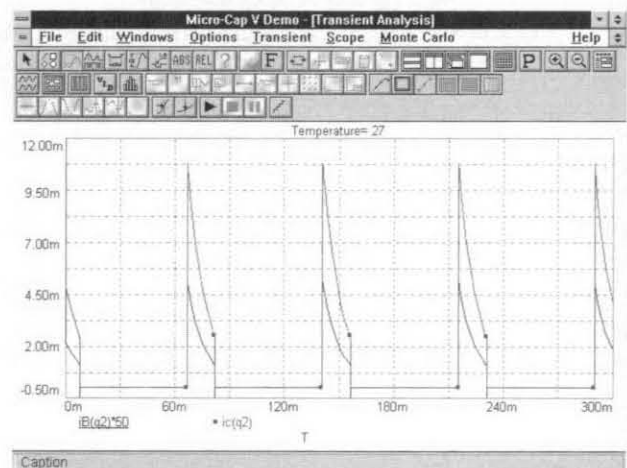
Figure 41. Set of graphs showing how the relaxation oscillator in Figure 39 works.

41



Accesses the Analysis Limits dialog box.

42



Caption

43

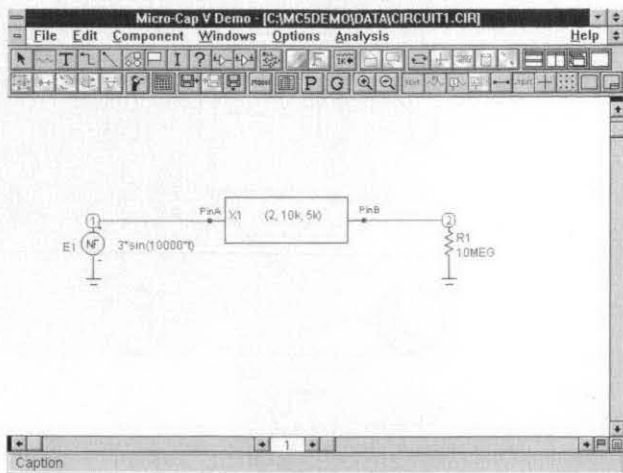


Figure 43. Basic circuit for illustrating how a macro can be inserted.

Below these type:

$$.IC V(3) = 7$$

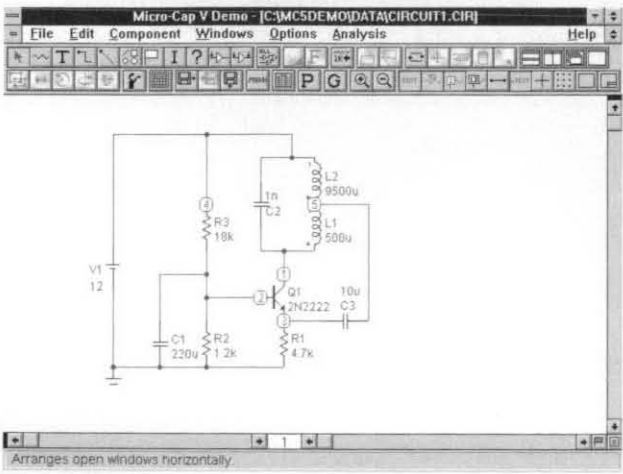
When the analysis is called, the voltage at node 3 is set to 7 V for the Operating Point and the voltages at other nodes calculated accordingly. To find out what difference this makes, go to the Transient Analysis Limits window and check the Operating Point Only box, then Run. Clicking on the Numeric Output button produces the operating point analysis, but now with different results:

$$\begin{aligned} V(1) &= 2.07V & V(2) &= 2.89V \\ V(3) &= 7.00V & V(4) &= 9V \\ V(5) &= 7.00V \end{aligned}$$

Q₂ is clearly fully on, as can be confirmed by its vBE, which is 2 V and its collector current, which is 1.27 A. This introduces a note of caution, for this is a large current, more than a 2N3906 is

Figure 45. Circuit diagram of typical Hartley oscillator.

45



Arranges open windows horizontally.

44

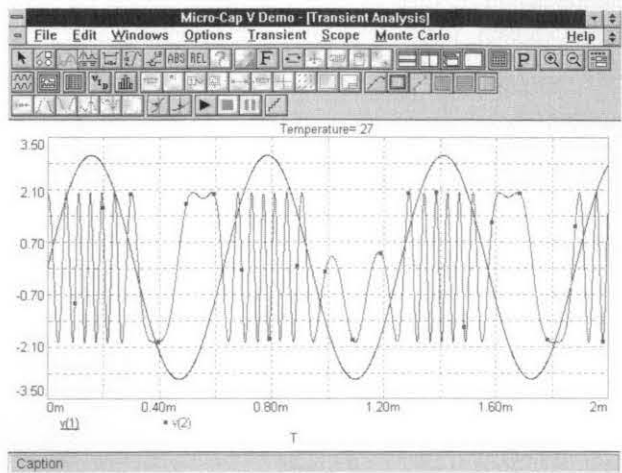


Figure 44. Showing the effect of the output of E1 on the output frequency of X1 in Figure 43.

rated for. This illustrates how much safer it is to work with a simulator. Applying 7 V to a real circuit to kick it into action could well burn out both transistors instantly. But we shall need to check that such large currents never occur when the circuit is oscillating normally.

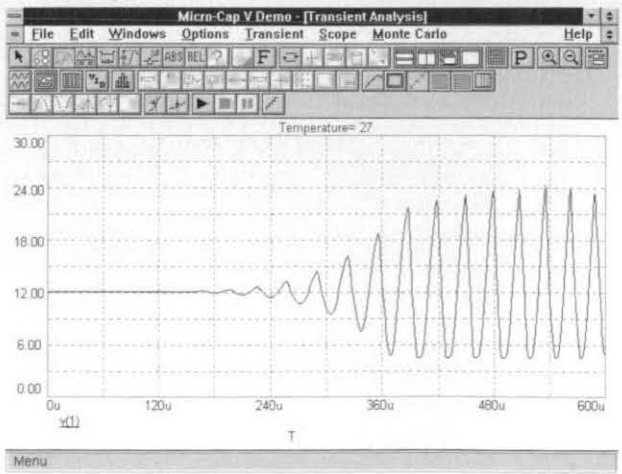
To see if we have managed to get the circuit oscillating, go to the Transient Analysis Limits window, deselect the Operating Conditions Only box, then Run. The result clearly shows that the oscillator is running. The most useful set of curves for understanding how the oscillator works is plotted in three graphs (Figure 41), all against time (T). To make the plots distinguishable when printed in black, we have clicked on the Tokens button (middle row, 4th from right). Graph 1 shows V(1) and V(2), from which it can be deduced that Q₁ and Q₂ are both OFF at the same time, that is when V(1) is high and V(2) is slightly raised owing to current flowing from Q₂ to Q₁. When Q₁ turns OFF, there is a sharp rise in V(1), which leads to V(5) being pulled sharply up (to 16 V). R₁ and R₂ act as a potential divider, so V(3) is pulled up sharply too, and Q₂ is turned off. This cuts off the base current to Q₁, keeping it turned OFF. This is one of the stable states. Then V(5) gradually falls as charge leaks away

through R₁ and R₂ to ground. Eventually V(5) and V(3) fall to a level at which Q₂ turns on again. It supplies base current to Q₁, turning it on. Q₁ and Q₂ are both ON at the same time, which is the other stable state. Turning Q₁ ON reduces V(1) sharply, pulling down V(5). But V(3) remains at about 8.4 (one diode drop below 9 V), so C₁ is gradually charged again. Eventually V(3) rises above 8.4 V, turning off Q₂, and thus turning off Q₁. The cycle is complete. Using the Horizontal measure mode on Graph 1 allows the period of the oscillation to be determined as 74.525 ms, or 13.4 Hz. The third graph in Figure 41 shows the changes in pd across C₁ as it is alternately charged and discharged, the waveform clearly showing the exponential rise and fall of pd.

Figure 41 demonstrates how useful a simulator can be when trying to discover how a circuit operates. We can also use it to investigate whether volt-

Figure 46. Showing how the Hartley oscillator reaches its peak output.

46



Menu

ages and currents are always at safe levels. There is a query about the large current through Q_2 ; does this ever reach such high levels in normal oscillation? To answer this question, repeat the analysis, plotting $iB(Q2)$ and $iC(Q2)$ which are respectively the base and collector currents of Q_2 (Figure 42). The graphs show that the collector current peaks at 10.75 mA, which is well within the rating for a 2N3906. On the original plots the base current was too small for measurement but plotting $iB(Q2)*50$ magnifies the scale, and we can now read that the maximum base current is about 0.1 mA. Similar plots can be used to check other circuit variables. For example, plotting $i(R3)*(V(1)-V(4))$ shows how power dissipation in the load resistor (R_3) varies during the cycle. Carry out this check to see what maximum power dissipation must be allowed for in the load circuit, here represented by R_3 .

PULSE SOURCE

Use this to instantly increase the power supply to the oscillator from 0 V to 9 V. This checks whether the oscillator will actually oscillate when switched on, without the use of the 7 V initial kick. With the Select cursor, click on the battery V1, then press the Delete key to remove it from the circuit. From the Component menu select Pulse Source and position this in the gap left by the battery. From the box on the right, select the PULSE model. In the text area you will now find its uncompleted model statement:

```
.MODEL PULSE PUL( )
```

First of all delete the .IC statement on the line above to remove the initial kick, then enter these parameters in the brackets in the pulse model:

```
VZERO=0    VONE=9
P1=100m    P2=100m
P3=300m    P4=300m
P5=300m
```

The Help screen gives the meaning of the parameters under 'Pulse source'. The result is that the oscillator is switched on after a 100 ms delay. Plot the transient to see if the oscillator really does start when powered up in the normal way. The fact that the capacitor begins with zero charge causes an initial flow of current which makes oscillation begin.

MACROS

In Part 3 we saw how a device such as an op amp can be modelled from SPICE primitives (resistors, capacitors, transistors etc) by defining a subcir-

cuit. The subcircuit needs to be defined only once, but it may be referred to by name in the netlist as many times as it is needed. Subcircuits are part of SPICE and, when defined, all subcircuits operate according to the same parameters. If we need similar subcircuits operating with different parameters, we must define each as a subcircuit with its own name and parameter set. The concept of a macro is similar, though not included in SPICE. The netlist of a macro is defined once and for all, after which we define its parameters every time we use it. In this sense, the macro is more like one of the primitives, such as a resistor. Every time we place a resistor on a schematic we state its resistance and optionally its temperature coefficient. We do the same for macros. Macros, like subcircuits, are built from several or even many primitives and MC5 provides a useful range of them, also referring to them as Analog Behavioral Building Blocks. Some of these, such as the amplifier AMP and the voltage controlled oscillator VCO, are applicable to most analogue circuits. Others such as DIV, which produces the result of dividing one analogue signal by another, or SLIP, which models hysteresis, are more appropriate to models of systems. The exact way that their functions are realised in terms of electronic components is left unstated. This is a black-box approach to modelling systems.

As an example of a macro we will look at VCO, which is in line with the oscillator circuit theme for this month. You can examine its structure by clicking on File → Open → VCO.CIR. The VCO consists of a voltage controlled source, input at PinA, the output of which appears across resistor. The capacitor acts as an integrator and a voltage controlled voltage source produces at its output PinB a cosine wave modified in frequency according to the pd across the capacitor. There are three parameters: the amplitude of the output signal in volts vp, the centre frequency in hertz f_0 , and the frequency sensitivity in hertz per volt, k_f . To include this macro in a circuit (Figure 43), click on Component → Analog Primitives → Macros → VCO. After you place the VCO, the Component window asks for VALUE. The first item, VCO is already entered. After this type (2, 10K, 5K). These are the parameters defining amplitude 2 V, centre frequency 10 kHz and frequency sensitivity 5 kHz/V.

E1 is a Function Source, type NFV. After placing this, key in its VALUE, $3*\sin(10000*t)$. This produces a sine wave, amplitude 3 V, frequency $10000/2\pi = 1592$ Hz, for frequency-modulating the output of the VCO. R_1 is a load resistor.

To see the VCO output, run a Transient Analysis. The settings are: Time Range = 2 m, Maximum Time Step = 1 u (to obtain smoother curves), Auto Scale Ranges box checked. Plot V(1) and V(2) against time. The result is Figure 44 in which we can see V(1) the sinusoidal output of E1 and the effect it has on the frequency of the output V(2) from X1. Experiment by varying the frequency and amplitude of the modulating signal and by varying the parameters of the VCO.

HARTLEY OSCILLATOR

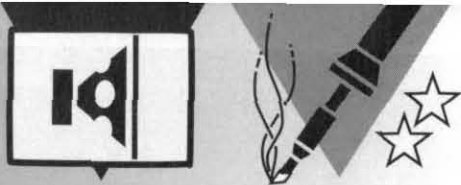
This is one of the traditional capacitor-inductor oscillators, which generates a sine wave. It is based on a capacitor-inductor resonant network (Figure 45) which is tapped to provide feedback and maintain the circuit in oscillation. The base voltage is held fairly steady by C_1 . The feedback through C_3 to the emitter affects the base-emitter voltage. This circuit requires a kick to start it (usually provided when the power supply is turned on). This is because the circuit relies on feedback through C_3 from the resonating network, a dynamic process, which is not provided in the quiescent Operating Point Analysis. Here we start it by specifying:

```
.IC V(2)=5
```

This turns the transistor fully on, causing a large pd across the resonant loop, which starts the loop resonating. Output is taken from the collector, node 1. In the Transient Analysis Limits window set Time Range to 0.6 m and Maximum Time Step to 1 u. Running produces Figure 46 in which we can see the sinusoidal oscillations gradually building up to maximum amplitude. Usually the output from this oscillator is taken from a coil wound on the same core as L_1/L_2 . In a real circuit, L_1/L_2 would be a single coil tapped part of the way along its length.

It is interesting to investigate the circuit, particularly by changing the value of C_2 and the values of L_1/L_2 . The effect of varying the feedback capacitor C_3 is somewhat unpredictable because, if large, it may load the loop and alter its resonant frequency. If small, it may provide insufficient feedback for sustained oscillation. Find out if this circuit begins to oscillate when switched on, without needing a kick. Investigations of this circuit are left to the reader as hands-on experience in using MC5.

[960102-V]



μ P-controlled mixer board

No more noisy controls – ever!

The audio mixer board presented in this article cannot be compared with any mixer board previously published in this magazine. In a way, it is the prelude to a new era in audio engineering. All controls are operated by integrated digitally controlled amplifiers (DCAs). The position of the slide potentiometers is converted by a microprocessor into a control signal for the DCAs. It is even possible to do away with the potentiometers and microprocessor and leave the control of the mixer board to a PC, but this will be the subject of a future article.

Design by T. Giesberts



Parameters

- ▶ 8 controlled audio inputs
- ▶ all input signals can be directed to the left-hand or right-hand output
- ▶ maximum attenuation 63 dB in 1 dB steps
- ▶ mute function
- ▶ automatic muting at power up
- ▶ buffered line inputs and outputs; external amplifiers not required
- ▶ signal-to-noise ratio 82 dB with 10 dB headroom
- ▶ distortion (THD+N) 0.007%
- ▶ standard 3-wire serial interface
- ▶ number of channels may be expanded
- ▶ wide range of applications: multimedia systems; PC sound cards; studio mixers; musical instruments, and many more

Wherever there is a battle between digital and analogue technologies, the outcome is almost certain to be in favour of the digital. Analogue will live on, but only in some specialist uses. So, we have digital recording, digital control, digital television, digital mobile telephones, and more. Nevertheless, it may still come as a surprise to some to find a design for a digital mixer board, which many consider a traditional stronghold of analogue audio engineering. True, you will still find a number of slide potentiometers, but these operate with direct voltages only, not audio signals. The circuit consists of

just two ICs, one of which is entirely digital and the other is a hybrid: part digital, part analogue. There are no transistors or op amps – nevertheless, it works like a dream!

INTRODUCTION

The circuit is based on an 8x2 digitally-controlled audio mixer Type SSM2163 from Analog Devices. Each of the eight inputs can be mixed under digital control to a stereo output. A simplified block diagram of the device is shown in **Figure 1**. Each input channel can be attenuated by up to 63 dB in 1 dB intervals, and also fully muted. Furthermore, any input can be assigned to

either or both outputs. A standard 3-wire serial interface is used as well as a Data Out terminal to facilitate daisy-chaining of multiple mixer ICs.

The control signal for the mixer board is provided by a Type ST62T25 microcontroller. This device rapidly scans the potential at the wipers of the potentiometers and converts this information into an 8-bit code. The controller also monitors the position of two switches at each input so that the operator can arrange for the relevant input signal to be applied to the left-hand or right-hand channel or both. This information is contained in the control code.

THE SSM2163

The SSM2163 consists of an analogue (signal processing) section and a digital (control) section. The channel attenuation level and mixer functions are controlled by digital registers, which are loaded via a serial interface. A hardware mute input is included to asynchronously force all inputs into the muted state.

chronously force all inputs into the muted state.

Analogue section

The analogue signal path is shown in Figure 2. Each input has a nominal impedance of 10 k Ω . Each input therefore appears as a digitally programmable 10 k Ω potentiometer. The SSM2163 input impedance remains constant as the attenuation level changes. So, the sources that drive the device do not have to drive complex and variable impedances.

The attenuated input is applied to the left-hand and right-hand channel inputs of the mixer. Each mixer channel consists of an analogue switch and a buffer amplifier. If the channel is selected (via the appropriate bit in the mixer control register), the analogue switch is turned on. The buffer amplifier is included after the analogue switch so that the gain of each channel will not be affected by the potentiometer setting or by the on-resistance [RDS(ON)] of the switch.

Each mixer channel that is ON is then summed into its respective (left-hand or right-hand) mixing summing

amplifier. (If both the mixer channels are ON, the attenuated analogue input will be applied to both the Left and Right summing amplifiers). The buffered output of the summing amplifier will supply a current of $\pm 500 \mu\text{A}$ to an external load.

Digital interface

The digital interface consists of two banks of eight data registers with a serial interface (Figure 3). One register bank holds the left/right mixer control bits, while the other register bank holds the 6-bit attenuator value.

To access the SSM2163, the controller writes a value to the serial shift register which selects the appropriate input channel register for subsequent attenuator-load operations. There are two ways: if bit 7 (MSB) is 1, the SSM2163 interprets the byte as an address; if bit 7 is 0, the SSM2163 interprets the byte as a data byte. Normally, the address byte is sent first. This indicates in which of the eight input channels the attenuation is to be altered and whether the signals are applied to the left-hand or right-hand channel or to both. Next, a data byte is sent that determines the degree of attenuation of the selected channel. Normally, this is followed by an address byte and a data byte for another channel. It is also possible, however, to write a sequence of data bytes. The selected channel remains the same, of course, but its attenuation changes with every data byte. This arrangement enables fading in and out without the necessity of writing the address every time. If, for instance, during the

1

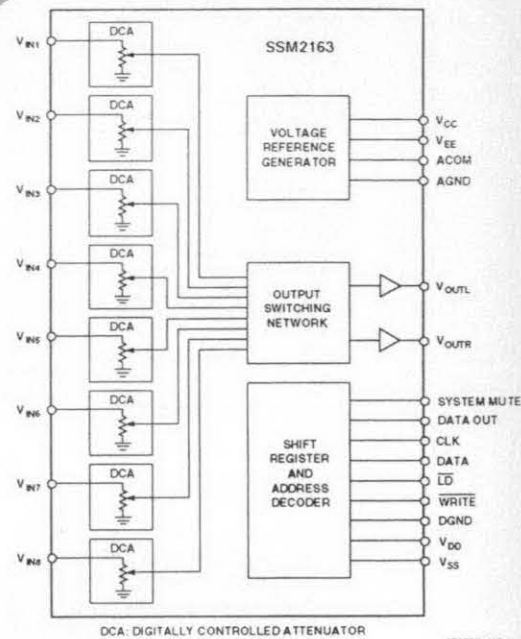


Figure 1. Simplified block diagram of digitally controlled audio mixer Type SSM2163.

fading out of a channel a series of values is sent to the same address, a single write operation to the address register

suffices.

When the mute input is made high, all channels are muted: this action does not affect the set attenuation values, which are retained. Switch-on

noises are obviated by forcing all inputs into the muted state at that instant.

Serial data control inputs

The SSM2163 provides a simple 3- or 4-wire serial interface. Data is input on the DATA IN

2

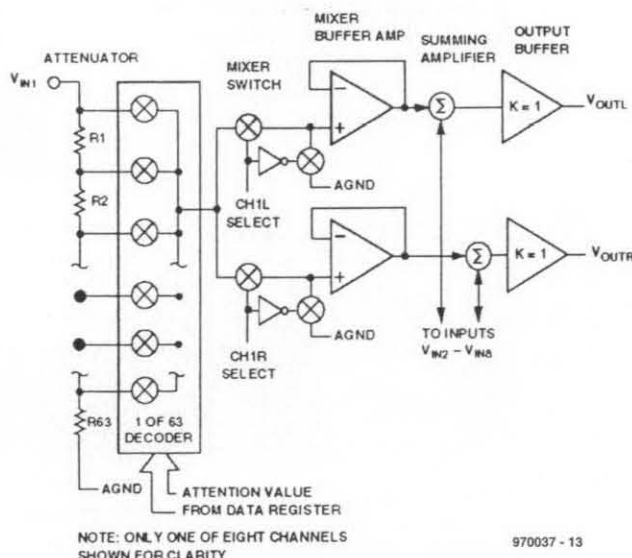


Figure 2. The analogue signal path of the SSM2163. It contains the variable attenuator and the switches that determine whether the input signal is applied to the left-hand or right-hand channel.

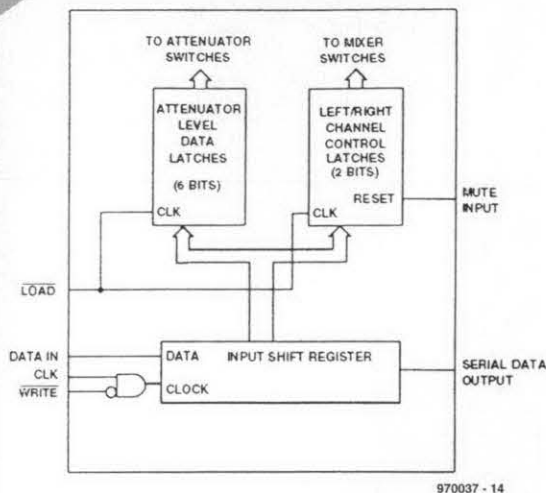


Figure 3. Block diagram of the digital serial data interface of the SSM2163.

pin, while CLK is the serial clock. Data can be shifted into the SSM2163 at clock rates up to 1 MHz.

The shift register clock, CLK, is enabled when the WRITE input is low. The WRITE pin can therefore be used as a chip select input. However, the shift register contents are not transferred to the register banks until the leading edge of LOAD. In most cases, WRITE and LOAD will be tied together, forming a traditional 3-wire serial interface. The process is clarified by the three-wire mode timing diagram in Figure 4.

To enable a data transfer, the WRITE and LOAD inputs are driven low. The 8-bit serial data, formatted MSB first, is input on the DATA IN input and clocked into the shift register on the leading edge of CLK. The data is latched on the leading edge of WRITE and LOAD. If the data is an address, the mixer control is updated. If the data is an attenuator value, the leading edge of WRITE and LOAD will update the appropriate attenuator

value.

MUTE input

The MUTE pin, which is active high, provides a hardware input to force all the channels asynchronously into the muted state at any time. Most μ C pins are in high impedance state or configured as inputs at power-up, so the SSM2163 will automatically be muted at switch-on. The mute function does not affect the attenuator values stored in the attenuator control registers.

Serial data input format

As mentioned previously, data is written to the SSM2163 in two 8-bit bytes. The serial data format is shown in Figure 5. The first byte sent contains the channel address and the Left/Right

attenuation level can be varied by sending additional data bytes. For instance, fading a channel be accomplished by simply increasing the data value sent to the SSM2163.

CIRCUIT DESCRIPTION

All connection between the inputs at the left and the outputs at the right of the circuit diagram in Figure 6 are interconnected by screened cable. The screen of this cable is earthed.

Diode D_2 is arranged to make it light when data are being sent to IC₂. Controller IC₁ provides the requisite control signals, for which purpose I/O pins PA₀, PA₁, and PA₂ are the DATA, CLK and WRITE-LOAD outputs respectively. The 16 I/O pins at the left of the IC function as analogue inputs.

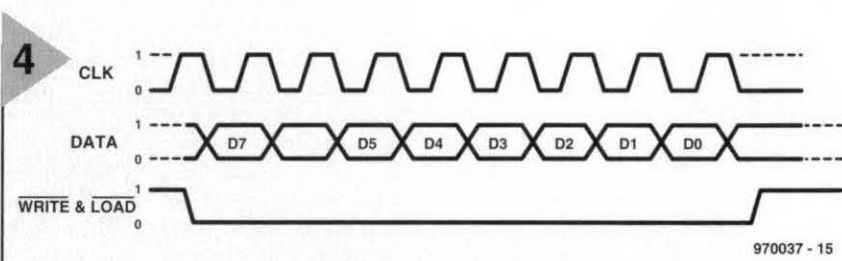


Figure 4. Timing diagram of the three-wire mode of operation.

output mixer control bits. The address byte is identified by the MSB being high.

The second byte contains the data, that is, the attenuator value. The six LSBs of this byte set the attenuation level from 0 dB to -63 dB. The MSB of the data byte must be a logic zero.

The standard format for data sent to the SSM2163 is an address byte followed by a data (attenuator level) byte. In some cases, however, only one byte needs to be sent. For instance, attenuation levels are not affected by the MUTE input. To turn a muted channel on, simply send an address byte with the left-to-right mixer bit set. The addressed channel will immediately be enabled, using the previously set attenuation level. Furthermore, once a channel is addressed, the

These pins are sampled in turn; the input data so found is converted into a control signal for IC₂.

It will be seen that the inputs into IC₁ are all direct voltages. The attenuation level as well as the left/right information for each channel is set with the aid of potential dividers. The wipers of the slide potentiometers with which the attenuation of the input signals is set are linked to 'P1', 'P2', and so on, respectively. The other terminals of the potentiometers are connected to +5 V and 0 respectively. When the potentiometers are almost closed, the voltage is low and the attenuation great. When they are gradually opened, the potential at their wiper rises and the attenuation is reduced.

A potential divider consisting of three

Figure 5. Clarification of how two 8-bit bytes are constructed.

SELECTION	MSB				LSB				MSB				LSB				
	ADDRESS MODE								DATA MODE								
	ADDRESS				DATA				DATA				ATTENUATION				
INPUT CHANNEL 1	1	X	X	X	0	0	0	0	0	X	X	X	0	0	0	0	0dB
INPUT CHANNEL 2	1	X	X	X	0	0	0	1	0	X	X	X	0	0	0	1	-1dB
INPUT CHANNEL 3	1	X	X	X	0	0	1	0	0	X	X	X	0	0	0	0	-2dB
INPUT CHANNEL 4	1	X	X	X	0	0	1	1	0	X	X	X	.	.	.	.	.
INPUT CHANNEL 5	1	X	X	X	0	1	0	0	0	X	X	X	.	.	.	.	.
INPUT CHANNEL 6	1	X	X	X	1	1	0	1	0	X	X	X	.	.	.	.	.
INPUT CHANNEL 7	1	X	X	X	1	1	0	0	0	X	X	X	.	.	.	.	.
INPUT CHANNEL 8	1	X	X	X	1	1	1	0	0	X	X	X	.	.	.	.	.
	OUTPUT SELECT				INPUT SELECT												
	1 = SELECTED, 0 = NOT SELECTED																
	X = "DON'T CARE", SHADED AREA = DATA																

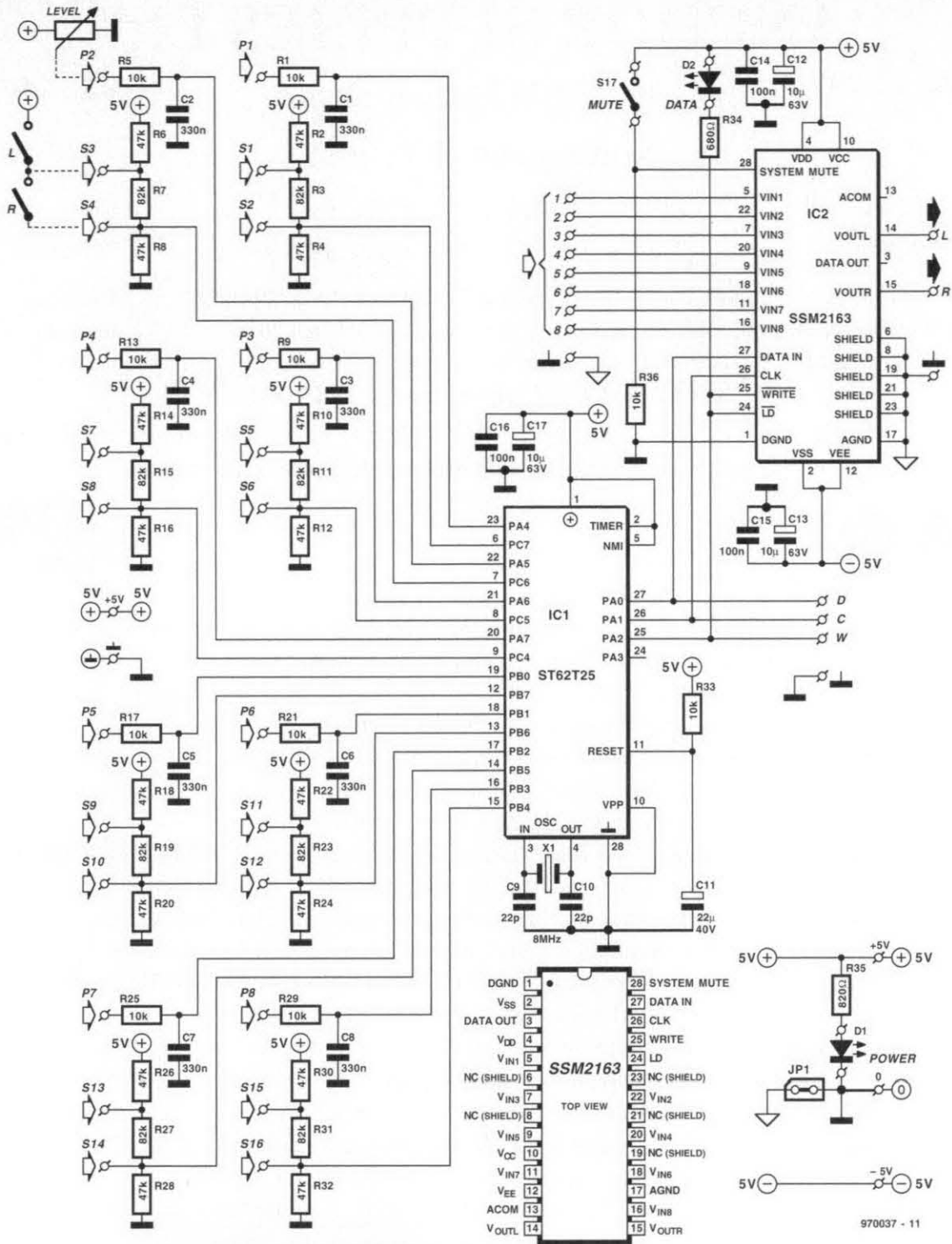


Figure 6. Circuit diagram of the mixer board. The dashed lines near Channel 2 indicate how the potentiometer and switches for the left-hand and right-hand channels must be connected.

resistors is provided for the left/right information for each channel. The individual resistors are switched with the aid of two switches. For

instance, in the case of channel 2, it is easily calculated that when both switches are open, the voltage at the

junction of R₇ and R₈ is about 1.3 V. The input signal is then not transferred to the output of the mixer board. When S₃ is closed and S₄ is open, the potential at junction R₇-R₈ is about 1.8 V and the input signal is

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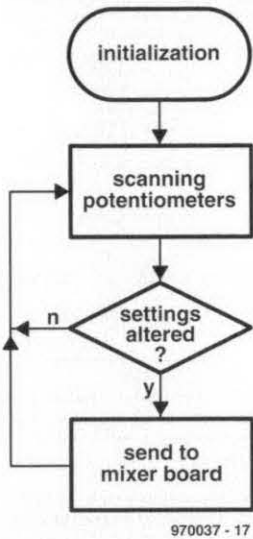
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microcontroller control

The microcontroller used in the mixer board is a Type ST62T25 from SGS-Thomson. This device has 20 I/O lines which can be switched at will when the program is running to form an input or output in various configurations. Sixteen of them may be linked to the internal analogue-to-digital converter (ADC) to form the lines via which the positions of the slide potentiometers and the switches are written.

The positions of the slide potentiometers and the switches are continuously sampled by the software, which also processes the results of the analogue-to-digital conversions and stores them in the internal RAM. When even one of these settings differs from the previous one, the microcontroller passes all data to the mixer IC.

The allocation of the port lines to potentiometers and switches looks rather untidy on the circuit diagram; this results from the requirement of making the layout of the printed-circuit board as straightforward as possible. Note that PA₀-PA₃ cannot be linked to the ADC.



970037 - 17

Analogue-to-digital

The simplest way of operating the ADC of the ST62 controllers is starting the conversion and waiting in a loop until the EOC (end-of-conversion) bit goes high, whereupon the normal process of the program can be continued. From a software point of view, this may be all right, but it appears that owing to internal and external noise it is impossible to obtain an accuracy of even 6 bits. The use of a WAIT command, which disables a large part of the processor, brings about a real improvement. The ADC generates an interrupt when the EOC goes high and this re-enables the processor.

The SSM2123 uses only six bits to set the attenuators and there is therefore nothing against ignoring the two LSBs of the ADC. Yet, this is not sufficient to achieve a stable setting of the mixer IC over the whole control range of the potentiometers: in

some situations D₂ flashes to indicate that new data are being transferred. This is, of course, self-evident, because even if the two LSBs are ignored they continue to exert some influence. If bit 1 is high, a variation of just one LSB is sufficient to affect higher, relevant bits.

There are ways and means of solving this. For instance, it would be possible to sample a potentiometer a couple of times in succession and average the results. In the present design, a simple means is used: the entire 8-bit ADC value is retained, while the next sample is accepted only if its value differs by more than two LSBs from the previous one. This matter is less problematical when the state of the switches is written: in that case only four results are possible: some noise and a slight accuracy in the potential divider do not matter much

Digital to the mixer IC

Sending data to the SSM2163 is fairly straightforward. Three lines from port A of the ST6225 carry the CLK, WRITE and data signals. Unfortunately, with this configuration of the port, this cannot be effected with direct setting and resetting of the port bits. Because of space considerations, this cannot be further explained here.

applied to the left-hand channel. When S₄ is closed and S₃ open, the potential at junction R₇-R₈ is about 2.5 V and the input signal is applied to the right-hand channel. When both switches are closed, the potential across R₈ is 5 V and the input signal is applied to both outputs (mono).

To carry out these tasks, a special program is loaded in the ST62T25. The manner in which this device converts the direct voltages at the inputs into a

control signal for IC₂ is described in the box on p. xx.

Circuit IC₁ is supplied by an asymmetrical voltage of 5 V, and IC₂ by a symmetrical line of ±5 V. Diode D₁ functions as on/off indicator. Jump lead JP₁ enables the screen of the cables to be linked to the negative supply line. This may be useful if hum occurs, unlikely though that may be. [970037]

(to be continued)

In passing ...

Sitting in a small restaurant the other day, I was intrigued to overhear a conversation between a small group of people at the next table about the relative merits or otherwise of digital cameras (apparently one of them had been given one as a Christmas present). It was argued that pictures from a digital camera are nowhere near as good as those from a 'real' camera. In a sense, this is true, of course, because a good-quality colour transparency requires about 80 million pixels (the tiny individual spots that all pictures are made up of), whereas a digital camera manages not much more than a few hundred thousand pixels (since its CCD - charge-coupled device - contains only that number of diodes). A simple 8-bit image allows each pixel to have 256 possible shades of grey or basic colours. With 24-bit colour (which most graphics programs use) each pixel can have more than 15 million different colour possibilities. Now, the memory in a digital camera just cannot cope with this: even a dozen 24-bit colour snapshots, each made up of only 200,000 pixels, will occupy 7.2 MB of memory (may be compressed by, for instance, JPEG to about 2 MB). A picture of the quality needed by a magazine such as ours would take up 60-80 MB. However, in publishing, a dark-room is a thing of the past. Colour-negative and transparency film is now normally machine-processed and scanned directly into digital files. The pictures are then edited on a computer screen and inserted directly into the electronic page make-up. Consequently, many professional photographers are already using digital cameras for situations where speed is important.

It is fairly certain that in the not too distant future there will be more digital cameras around than optical ones, in spite of the former's current imperfections. After all, the average person will only want to take snapshots, not become a photographic artist. If you are not convinced of this, look at the number of camcorders around which operate on the same principle as the digital still camera.

LS/975024

8243

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DATASHEET 03/97

MCS-48® Input/Output Expander

Manufacturer

Intel Corp., 3065 Bowers Avenue,
Santa Clara, CA 95051,
U.S.A. Mail Stop SC6-325.
Internet: www.intel.com



Application example

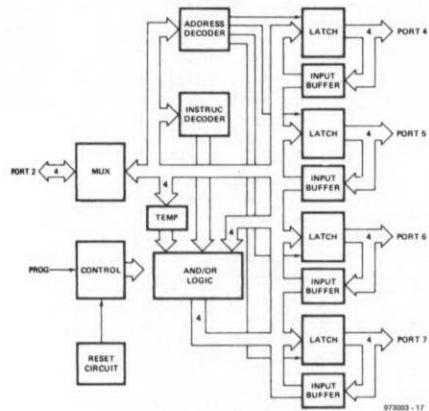
EPROM Programmer, *Elektron Electronics* March 1997.

Features

- Low Cost
- Simple Interface to MCS-48® Microcomputers
- Four 4-bit I/O Ports
- AND and OR Directly to Ports
- 24-pin DIP
- Single 5 V Supply
- High Output Drive
- Direct Extension of resident 8048 I/O Ports

Device description

The Intel® 8243 is an input/output expander designed specifically to provide a low cost means of I/O expansion for the MCS-48® family of single-chip microcomputers. Fabricated in 5 volts NMOS, the 8243 combines low cost, single supply voltage and high drive current capability.



The 8243 consists of four 4-bit bidirectional static I/O ports and one 4-bit port which serves as an interface to the MCS-48 microcomputers. The 4-bit interface requires that only 4 I/O lines of the 8048 be used for I/O expansion and also allows multiple 8243's to be added to the same bus.

The I/O ports of the 8243 serve as a direct extension of the resident I/O facilities of the MCS-48 microcomputers and are accessed by their own MOV, ANL and ORL instructions.

Power-On Initialization

Initial application of power to the device forces input/output ports 4, 5, 6 and 7 to the tri-state and port 2 to the input mode. The PROG pin may be either high or low when power is applied. The first high to low transition of PROG causes the device to exit the power-on mode. The power-on sequence is initiated if Vcc drops below 1V.

Write Modes

The device has three write modes. MOVD Pi,A directly writes new data into the selected port and old data is lost. ORLD Pi,A takes new data, OR's it with the old data and then writes it to the port. ANLD Pi, A takes new data, AND's it with the old data and then writes it to the port. Operation code and port address are latched from the input port 2 on the high to low transition of the PROG pin. On the low to high transition of PROG, data on port 2 is transferred to the logic block of the specified output port.

After the logic manipulation is performed, the data is latched and outputted. The old data remains latched until new valid outputs are entered.

Read Mode

The device has one read mode. The operation code and port address are latched from the input port 2 on the high to low transition of the PROG pin. As soon as the read operation and port address are decoded, the appropriate outputs are tri-stated, and the input buffers switched on. The read operation is terminated by a low to high transition of the PROG pin. The port (4, 5, 6 or 7) that was selected is switched to the tri-state mode while port 2 is returned to the input mode.

Normally, a port will be in an output (write mode) or

AD633

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Analogue, Special Function



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Application example

General-purpose electronic fuse, *Elektron Electronics* March 1997.

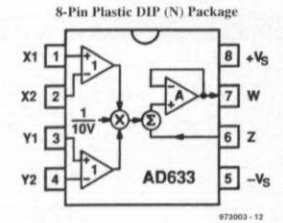
Device description

The AD633 is a functionally complete, four-quadrant, analogue multiplier. It includes high impedance, differential X and Y inputs and a high impedance summing input (Z). The low impedance output voltage is a nominal 10-V full scale provided by a buried zener. The AD633 is laser calibrated to a guaranteed total accuracy of 2% of full scale. Non-linearity is typically less than 0.1% and noise referred to the output is typically less than 100 μV_{rms} in a 10 Hz to 10 kHz bandwidth. A 1 MHz bandwidth, 20 V/μs slew rate, and the ability to drive capacitive loads make the AD633 useful in a wide variety of applications where simplicity and cost are key concerns.

The AD633's versatility is not compromised by its simplicity. The Z-input provides access to the output buffer amplifier, enabling the user to sum the outputs of two or more multipliers, increase the multiplier gain, convert the output voltage to a current, and configure a variety of applications.

The AD633 is available in an 8-pin plastic mini-DIP package (N) and 8-pin SOIC (R) and is specified to operate over the 0°C to +70°C commercial temperature range.

Connection and Block Diagram (JN)



Functional Description

The AD633 is a low cost multiplier comprising a translinear core, a buried Zener reference, and a unity-gain connected output amplifier with an accessible summing diode. As shown in the Connection Diagram, the differential X and Y inputs are converted to differential currents by voltage-to-current converters. The product of these currents is generated by the multiplying core. The zener reference provides an overall scale factor of 10 V. The sum of (X·Y)/10+Z is then applied to the output amplifier. The amplifier summing node Z allows the user to add two or more multiplier outputs, convert the output voltage to a current, and configure various analogue computational functions, including multiplication, squaring and frequency doubling, inverse functions, linear amplitude modulation, and low/high-pass filtering. Inspection of the block diagram shows the overall transfer function to be:

$$W = \frac{(X_1 - X_2)(Y_1 - Y_2)}{10V} + Z$$

Squaring and Frequency Doubling

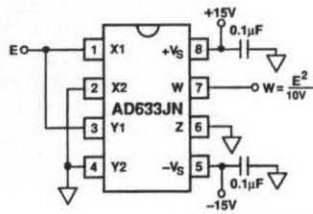
As illustrated below, squaring of an input signal, E, is achieved simply by connecting the X and Y inputs in parallel to produce an output of E²/10 V. The input may have either polarity, but the output will be positive. However, the output polarity may be reversed by interchanging the X or Y inputs. The Z input may be used to add a further signal to the output.

AD633

Integrated Circuits
Analogue, Special Function

DATASHEET 03/97

Model	AD633J	Specifications (T _A = +25°C, V _S = ±15V, R _L = 2 kΩ)			
TRANSFER FUNCTION	$W = \frac{(X_1 - X_2)(Y_1 - Y_2)}{10V} + Z$				
Parameter	Conditions	Min.	Typ.	Max.	Unit
Total Error	-10 V ≤ X, Y ≤ +10 V		±1	±2	% Full Scale
T _{min} to T _{max}			±3		% Full Scale
Scale Voltage Error	SF = 10.00 V Nominal		±0.25%		% Full Scale
Supply Rejection	V _S = ±14 V to ±16 V		±0.01		% Full Scale
Non-linearity, X	X = ±10V, Y = +10 V		±0.4%	±1	% Full Scale
Non-linearity, Y	Y = ±10 V, X = +10 V		±0.1	±0.4	% Full Scale
X Feedthrough	Y nulled, X = ±10 V		±0.3	±1	% Full Scale
Y Feedthrough	X nulled, Y = ±10 V		±0.1	±0.4	% Full Scale
Output Offset Voltage			±5	±50	mV
DYNAMICS					
Small Signal BW	V _O = 0.1 V _{rms}		1		MHz
Slew Rate	V _O = 20 V _{p-p}		20		V/μs
Settling Time to 1%	ΔV _O = 20 V		2		μs
OUTPUT NOISE					
Spectral Density			0.8		μV/√Hz
Wideband Noise	f = 10 Hz to 5 MHz		1		mV rms
	f = 10 Hz to 10 kHz		90		μV rms
OUTPUT					
Output Voltage Swing			±11		V
Short Circuit Current	R _L = 0 Ω		30	40	mA
INPUT AMPLIFIERS					
Signal Voltage Range	Differential Common Mode		±10 ±10		V
Offset Voltage X, Y			±5	±30	mV
CMRR X, Y	V _{CM} = ±10 V, f = 50 Hz		60	80	dB
Bias Current X, Y, Z			0.8	2.0	μA
Differential Resistance			10		MΩ
POWER SUPPLY					
Supply Voltage Rated Performance Operating Range			±8	±15	V
Supply Current	Quiescent		4	6	mA



When the input is a sine wave $E \sin \omega t$, this squarer behaves as a frequency doubler, since

$$\frac{(E \sin \omega t)^2}{10V} = \frac{E^2}{20V} (1 - \cos 2 \omega t)$$

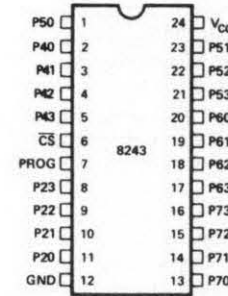
973003 - 15

8243

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Pin Configuration



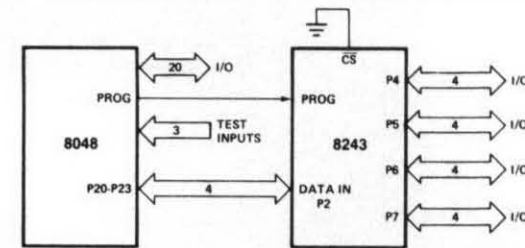
973003 - 18

an input (read mode). If modes are changed during operation, the first read following a write should be ignored; all following reads are valid. This is to allow the external driver on the port to settle and the first read instruction removes the low impedance drive from the 8243 output. A read of any port will leave that port in a high impedance state.

Pin Description

Symbol	Pin No.	Function
PROG	7	Clock Input. A high to low transition on PROG signifies that address and control are available on P20-P23, and a low to high transition signifies that data is available on P20-P23.
CS	6	Chip Select Input. A high on CS inhibits any change of output or internal status.
P20-P23	11-8	Four (4) bit bi-directional port contains the address and control bits on a high to low transition of PROG. During a low to high transition, it contains the data for a selected port if a write operation, or the data from a selected port before the low to high transition if a read operation.
GND	12	0 volt supply
P40-P43	2-5	Four (4) bit bi-directional port
P50-P53	1, 23-21	May be programmed to be input
P60-P63	20-17	(during read), low impedance
P70-P73	13-16	latched output a (after write), or a tri-state (after read). Data on pins P20-P23 may be directly written, ANDed and Ored with previous data.
V _{CC}	24	+5 volt supply

P21	P20	Addr. Code	P23	P22	Instr. Code
0	0	Port 4	0	0	Read
0	1	Port 5	0	1	Write
1	0	Port 6	1	0	ORLD
1	1	Port 7	1	1	ANLD



973003 - 19



focus on: mobile telephones

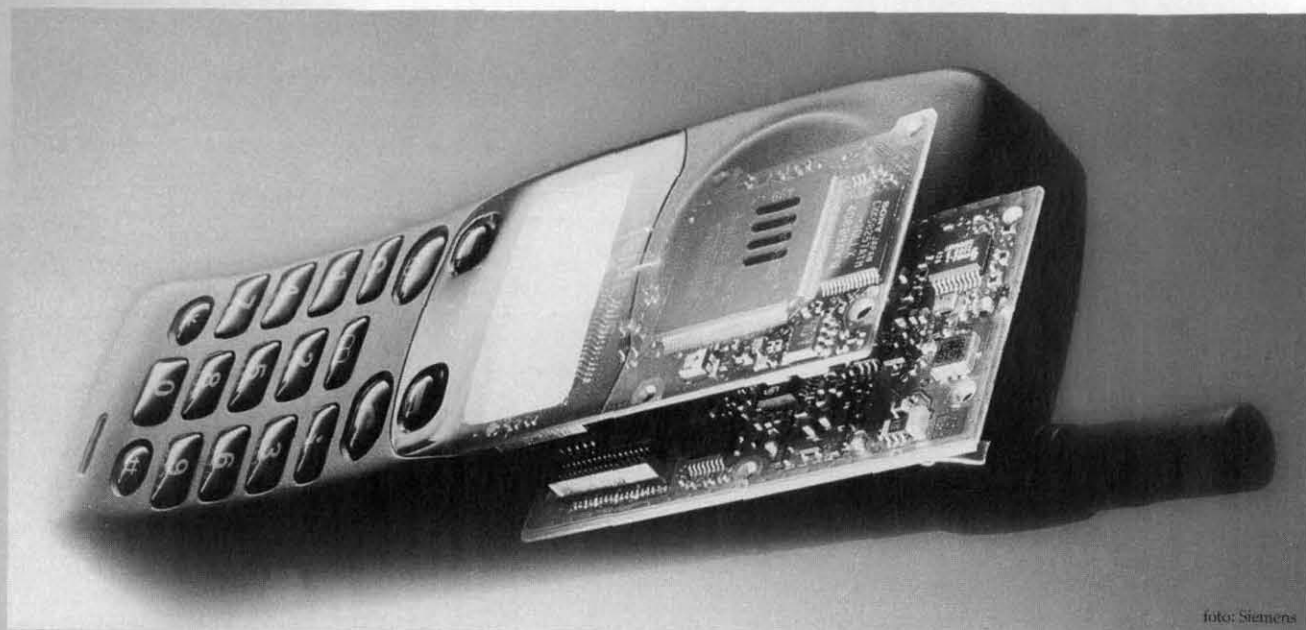


foto: Siemens

Mobile communication has taken the world by storm, with unprecedented acceptance by the general public. A few years ago, a carphone would set you back thousands of pounds. Today, a mobile telephone is offered as a gift if have your photographs developed or new tyres fitted on your car. Yet, there is relatively little technical information on these handy gizmos. This article discusses the basic setup of a cellular telephone network, and how it operates. Special attention is given to today's and tomorrow's GSM networks.

By our editorial staff

Today's mobile communication is dominated by a digital system: GSM. Initially, the acronym stood for Groupe Spéciale Mobile. Later, this was changed to Global System for Mobile Telecommunication, a standard for digital mobile telephones, developed in Europe. The term *mobile telephone* refers to the use of portable telephones (not including 'cordless' telephones) which fit in your pocket. In the times before GSM, mobile communication was based on analogue networks. Partly because they used pretty hefty transmitter power levels, the first wireless telephones were fairly bulky units which really deserved the description 'moveable' rather than portable. However, analogue telephone technology has seen great improvements, and is still widely used. Let's go back in time for a bit.

The first experiments in mobile communication by telephone date back from the nineteen-forties. In 1946, AT&T was the first provider of a mobile telephone system. At that time, they used a single, centrally located six-channel FM receiver/transmitter. The experiment was carried out in St. Louis, Missouri. The capacity of this network was, obviously, extremely limited because each FM channel allowed only one call to be handled. An exchange operator was in charge of the connections, and it was not possible to dial a telephone number directly. Based on this concept, a total of about 25 networks were eventually installed. The main disadvantage of this system

was the limited capacity, and that, eventually, caused it to stagnate. A new concept was devised, however.

MORE CAPACITY

The increasing demand for mobile communication services simply forced the operators to think of ways to boost the capacity of their networks. Several techniques were proposed for this. Improvements in FM technology enabled the bandwidth required for a link to be reduced from 120 kHz to about 25 kHz. Furthermore, *trunking*, or multi-channel allocation (the use of several channels in a transmitter service area) was introduced, a system which allowed each free, available, radio channel to be used for communications. Trunking in particular resulted in vast improvements over the older system in which one and the same channel was used all the time. The electronics necessary to implement trunking become more and more complex, however.

In 1947, Bell Laboratories patented a system which was to become the basis of one of the most important developments in mobile telephony: the *cellular* structure of a network of radio repeaters. It was not until 1983, however, that this technology saw its practical and commercial implementations. In a cellular radio system, the total service area is divided into small segments, or *cells*. Within each cell, which has a radius of a couple of miles, only the allocated frequencies (radio channels) are used. Because the area to be

serviced is relatively small, low transmit powers may be used, while available frequencies may be used on more than one repeater. The smaller the cells, the higher the number of calls that may be made per unit of area. Unfortunately, the cost of the infrastructure rises rapidly with a growing number of cells, simply because a fully equipped transmitter/receiver is required for each cell.

The cellular structure of a telephone network is sketched in Figure 1. As illustrated in Figure 1b, adjacent repeaters never use the same frequency groups. Not shown, but essential to the elementary operation of the cellular radio system, are the data links between the repeaters, those between the repeaters and a computer network, and those between the computer network and the PSTN (Public Switched Telephone Network). As an aside, it is not so much high-frequency (UHF/SHF) technology, but the combination of computer technology, large databases, and digitizing of analogue signals which allowed the 1947 Bell patent for cellular radio to become a reality. The data links between the cellular radio repeaters allow these stations to maintain a continuous information exchange, invisibly and inaudibly, which is necessary when a mobile user enters and leaves several cell service areas while travelling (by car, boat, train, you name it) and conducting a call. Today, the cellular structure is the only way to ensure that precious bandwidth is allocated and distributed in an efficient manner.

NMT, THE ANALOGUE APPROACH

In Europe, the Scandinavian countries in particular played an important role in the development of mobile telephony. In fact, the Swedish company Ericsson was the driving

force behind many of the early mobile telephone networks in Europe. NMT, Nordic Mobile Telephone, is the standard which has dominated analogue mobile telephony for years. NMT networks have been in use in several countries, using different frequency bands such as 450 MHz (NMT-450) and, more recently, 900 MHz (NMT-900). With NMT-450, the transmitter operates at 450 MHz, and the receiver, at 460 MHz. This results in an available bandwidth of two times 4.5 MHz. The channel bandwidth is then 25 kHz. The cells used for NMT have diameter of 2 to 50 km.

NMT-900 is based on transmit frequencies at 890 MHz and receive frequencies at 935 MHz. The cells are smaller, having diameters between 0.5 and 30 km (see Figure 2). NMT-900 for the first time allowed pocket-size telephones to be used. The transmit power of these units is about 1 watt, while carphones use a power of about 6 watts. Most of today's analogue mobile telephone networks are based on the NMT-900 standard. Services offered by this system are usually limited to speech. Data services are not supported, although the available audio bandwidth of about 3 kHz does allow the use of a low-speed modem.

THE GSM NETWORK

In Europe, the wide diversity in telephone systems was a stumbling block as far as the development of mobile telephony was concerned. Aware of this fact, the CEPT (Conférence Européenne des Postes et des Télécommunications) came up with two decisions. One of these was that it should be possible to use the

Figure 2. Cell size depends on path loss and transmitter power. The first carphone systems used large cells. By contrast, GSM uses small cells, while cordless telephones for home and office (for example, DECT), use micro-cells.

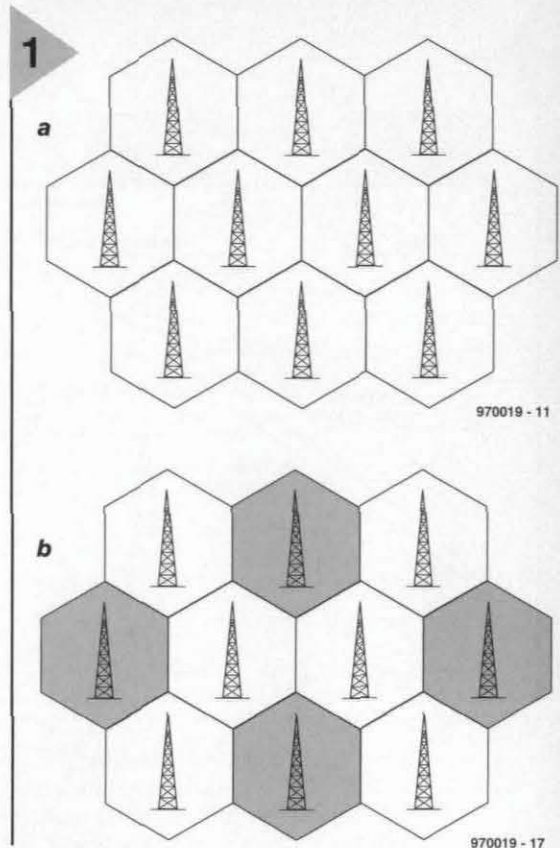


Figure 1. The capacity of a radio-based telephone network is considerably increased by applying the cellular structure (a). Adjacent cell repeaters may however not use the same frequency sets (b).

same mobile telephone in all participating countries. This is based on roaming agreements, in which telephone companies agree to support each other's clients in their respective service

areas. This CEPT decision in fact created a single European market for mobile telephones. The obvious results were mass production (mostly in the far East!) and cost reductions. Moreover, the mobile telephone user may travel across any CEPT country, placing and receiving calls, and be obtainable all the time.

The second decision asked for two frequency ranges in the 900-MHz band to be reserved. In 1986, the actual allocation of these ranges of 25 MHz each marked the birth of GSM, a single system and market for digital mobile telephony in Europe. The practical use of the two bands is illustrated in Figure 3.

Two phases have been defined for GSM. Phase-one comprises the most essential services, while phase-two is all about two extensions, including the possibility to reduce the bandwidth by a factor of two, thereby increasing the capacity of the network. Today's networks employ phase-one definitions, and thus offer speech and data transmission, tele-services for short messages of up to 160 characters (SMS, short-message service), fax and, for instance, short-dialling for emergency

2

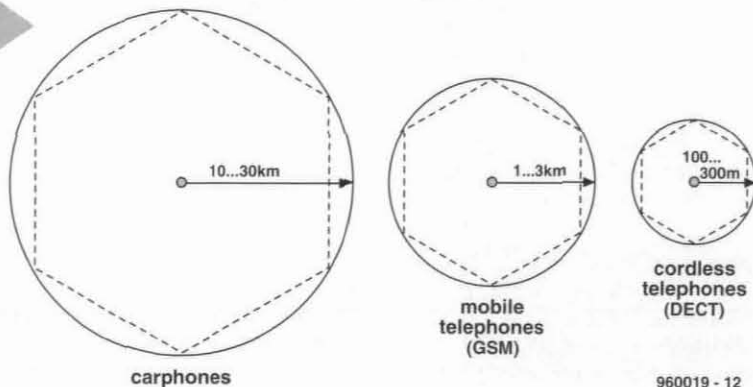
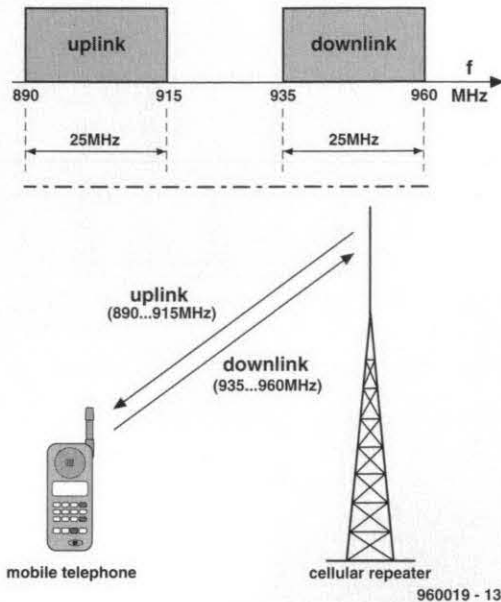


Figure 3. In the GSM system, the communication between the telephone and the local repeater station makes use of two bands, the uplink (890-915 MHz) and the downlink (935-960 MHz).



services. Additional functions are included in the package, providing call inhibiting to certain number groups, and the transferring of calls. The total GSM package (or 'deal' as some providers like to call it) turns this type of telephone into a versatile communication medium. The actually available services are determined by what is offered by the network operator (Cellnet, Vodaphone, Orange, One-

Two-One and others) as well as by features supported by the telephone you use. The cheapest of these are only suitable for speech. More advanced models usually feature SMS and a computer interface which enables you to participate in data communication. That allows users to surf the Internet or transmit fax messages via their GSM phone, provided, of course, the computer connected to the phone has a special type of modem.

Many GSM telephones offer SMS support, enabling short text messages like 'dinner burnt :(' or 'call office a.s.a.p.' to be exchanged with other mobile GSM phones. SMS texts are received in the background by a GSM phone. They may be processed and displayed as long as the phone is in contact with the cellular network. In some cases, it is possible to make a computer work with a GSM phone without the need of a special modem. In that case, the computer is only used to squeeze more efficiency from the SMS functions. The computer then communicates with the GSM set at the ASCII level (much like a dumb terminal). The messages to be sent are, however, still subject to the restrictions imposed by SMS.

Apart from standard SMS services, many network operators have a so-called GIN server at their disposal. This server offers information services based on SMS, such as traffic, weather and stock exchange information. Moreover, it is possible to transmit and receive fax and e-mail messages via this server, without having a computer connected to the telephone. The messages appear on the display, and are limited in length to 160 characters. Text entry is by means of the keyboard on the phone.

SYSTEM ARCHITECTURE

The development of GSM was steered by a number of important system

requirements:

- * a uniform system for all countries
- * system should allow the use of pocket-size phones
- * many users per network
- * high speech quality
- * protection against bugging
- * frequency band: 850-915 MHz and 935-960 MHz

Only a modern, all-digital system proved capable of complying with all of these requirements. In an analogue system, the transmit/receive link has to be kept alive all the time, while that is not necessary with digital systems thanks to the use of time multiplexing (TDMA, Time Division Multiple Access). With GSM, the available frequency band is divided into 124 channels, each having a bandwidth of 200 kHz. Next, these channels are chopped to give eight time slots, creating a combination of time and frequency multiplexing (TDMA/FDMA). **Figure 4** shows how the available bandwidth is divided into 124 channels, while the drawing in **Figure 5** illustrates the chopping up of the signal into eight slots of 0.577 ms. This system allows eight calls to be made simultaneously using one channel. For each eight calls it handles, only one receiver/transmitter is required at the cellular repeater. By using GMSK (Gaussian Minimum Shift Keying), the time available in each slot allows 148 bits to be transmitted. Because there are eight successive slots, each frame of 4.616 ms is transmitted as a packet of 1184 bits. After digitizing, the speech signal is encoded using adaptive PCM. This operation results in a datastream with a speed of 13 kBit/s which represents the speech information. To this datastream is added 9.8 kBit/s of channel encoding (including error correction, error detection and synchronization). The final data rate is 22.8 kBit/s.

The mobile telephone transmits at a frequency between 890 and 915 MHz (uplink), while the cellular radio repeater station uses a frequency between 935 MHz and 960 MHz (downlink). As already noted, the frequency range is split into sub-bands of 200 kHz. Theoretically, this makes 124 channels available for each direction (transmitting/receiving).

The use of these frequency bands is, however, tied to a restriction. In practice, more than 200 kHz is used, so that is not possible to use two adjacent channels within a single cell. For the same reason, channels 1 and 124 are not available for use because interference by out-of-band components has to be avoided in frequency ranges not allocated to GSM. Another restriction is caused by the fact that the available frequency spectrum has to be divided

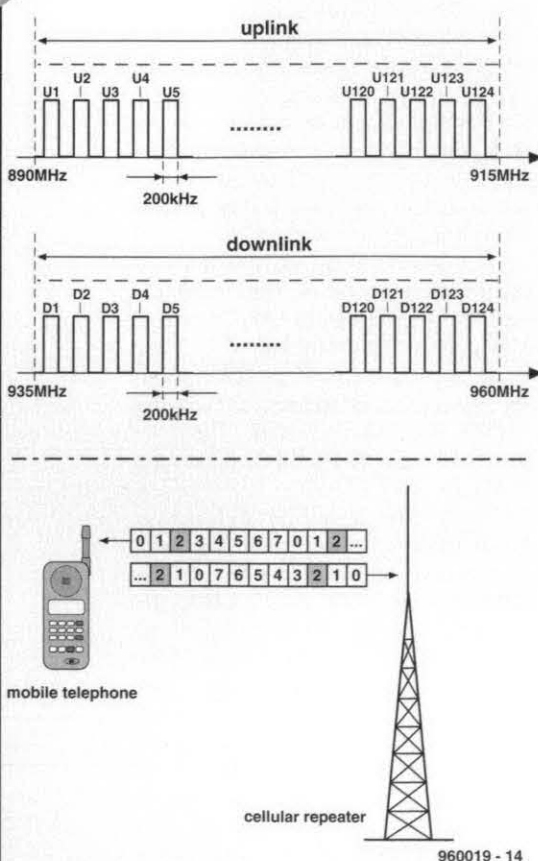


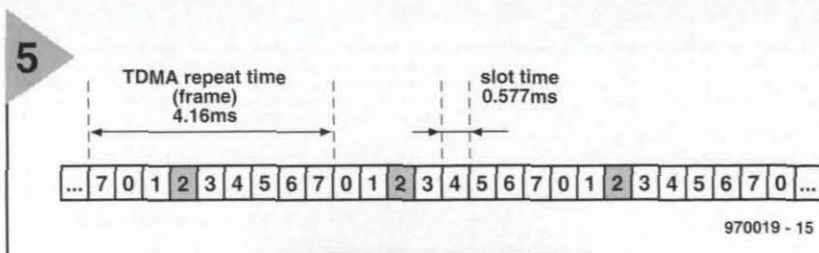
Figure 4. Each of the frequency bands allocated to GSM is divided into 124 channels with a width of 200 kHz.

or shared between network operators (they used to be called telephone companies) active in a certain area.

As already noted, GMSK is used as the modulation system. The main advantage of this standard is that nothing is being transmitted when there is no speech information. As a matter of course, this approach reduces the energy consumption of the phone, extending battery life considerably. Because radio silence can create confusion in a receiver, a little noise is purposely added to the speech signal. This is done to fool the receiver, which finds that the RF link is continuous rather than chopped.

The RF transmit power of a GSM phone is defined by classes. The ordinary pocket phone (class 4) has a transmit power of 2 watts, while a car phone belongs in class 2, having a power of about 8 watts. The other classes are rarely used at present. If desired, the RF output power may be reduced in 15 steps of 2 dB.

The maximum cell size is also determined by the maximum propagation delay allowed between transmitter and receiver. In practice, a maximum cell radius of 35 km is observed. Many network providers will not make use of this maximum, however, because the transmit power of pocket telephones is insufficient. Phase and frequency synchronization of the GSM telephone is possible at speeds of up to 250 km



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Figure 5. Thanks to the all-digital properties of GSM, each channel may be divided into eight time slots with a length of 0.577 ms each.

per hour (156 mph). So, a Formula-1 driver racing Silverstone, or a passenger on a high-speed train may expect problems when making a GSM call under these circumstances.

DCS-1800

Because of the explosive growth of mobile communication by telephone, the relevant infra-structures will soon reach their limits. Not surprisingly, thought has been given to successor systems, in other words, the next generation. A term frequently heard in this context is DCS-1800. DCS means *Digital Cellular System*, and represents a complementary digital telephone network. In the UK, Mercury first introduced its *One-Two-One* DCS-1800 network in September 1993. The main difference between DCS and GSM is the higher carrier frequency used. DCS-1800 uses a frequency between 1710 and 1785 MHz for the uplink, and

1805 to 1880 MHz for the downlink. All other system properties such as the network structure, encoding and encryption are identical to those of GSM.

With DCS-1800, two bands of 75 MHz are used. These bands offer 372 channels instead of 124 in the 900-MHz range. DCS-1800 also uses time multiplexing, resulting in a capacity of up to 2976 channels. The path loss on 1800 MHz is, however, much higher than on 900 MHz: the extra attenuation of the RF signals amounts to 6 to 8 dB. Consequently, 1800-MHz transmitters with RF powers equal to those used on 900 MHz have a smaller range, so that the size of the cells decreases. This property is, however, exploited in a clever way. The fact that the transmit power of the telephones is limited to 0.25 to 1 watt allows allocated frequencies to be used many times over in other cells. In practice, the largest cell diameter is only 8 km or so. The channel capacity of a DCS network is about three times that of a GSM network. In Germany, the so-called *E-Net* has capacity for 30 million users, which is more than sufficient to meet the market demand.

SURFING BY TELEPHONE

In contrast with analogue mobile telephones, a digital GSM phone is suitable for data traffic. Examples of such traffic include establishing links to a computer network, transmitting fax messages, transmitting and receiving e-mail, or, indeed, surfing the Internet.

To be able to use these services, the owner of the GSM phone has to inform the network provider that he/she wishes to use the phone for data services. A second phone number is then made available. Using the special connector on the phone, the computer may be connected to the GSM

Figure 7. Advanced GSM phones may be hooked up to a computer. This facility creates new, interesting, possibilities.



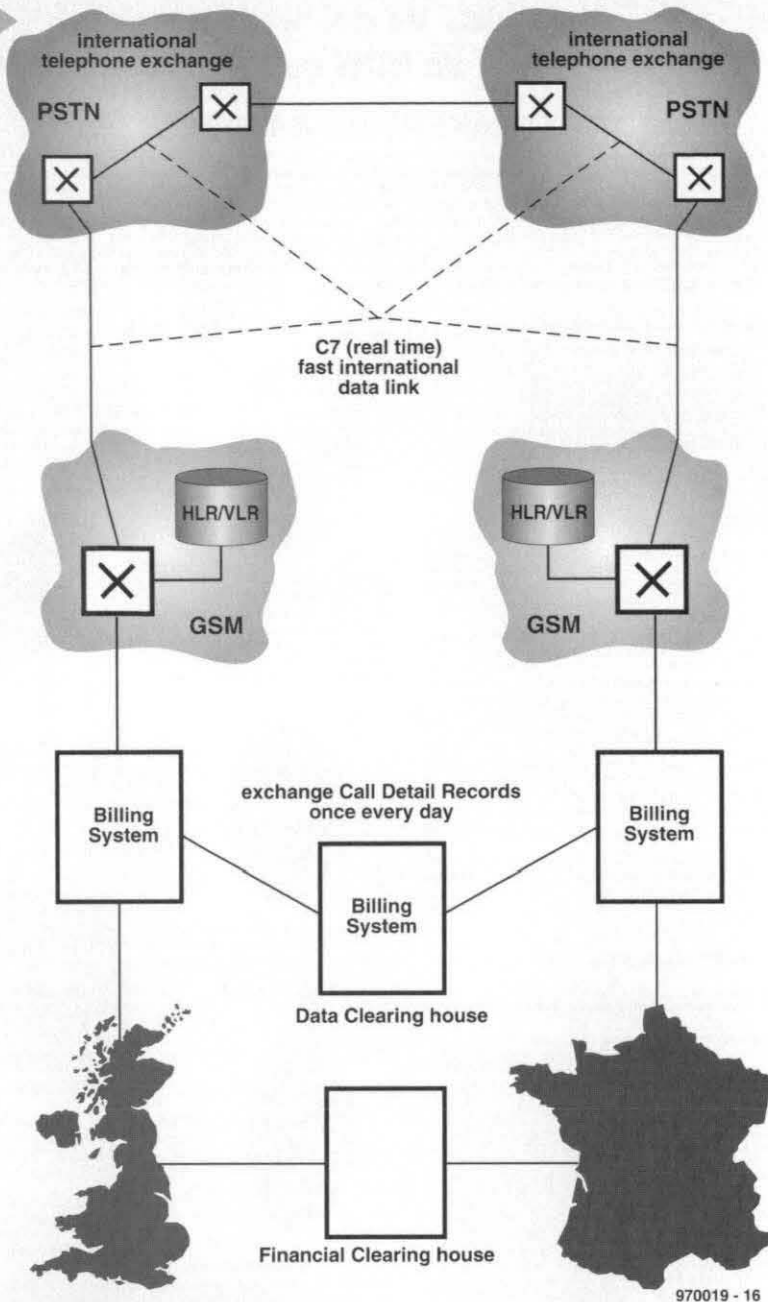


Figure 6. This sketch shows how an overseas call is made. At the highest level, the public switched telephone networks (PSTNs) communicate with each other, just as with ordinary international calls. Within the GSM network, all foreign-user registration is accomplished via the VLR (Visitor Location Register) and HLR (Home Location Register)

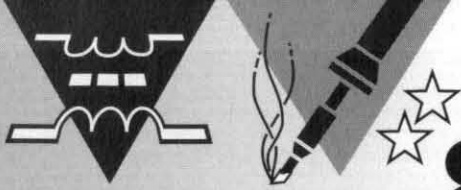
net via a GSM modem. In principle, such a GSM modem makes use of the standard Hayes commands, so that it may be used in combination with all popular communication software. In principle, a bandwidth of 22.8 kBit/s is

available per channel. Two methods are available for transmitting data: a transparent and a non-transparent one. If the first method is used, the modem itself has to add checksums and error correction to the signal. The better the error correction, the lower the effective transmission rate. In non-transparent mode, the GSM network is called upon to coordinate the error correction. This setting employs the Radio Link Protocol (RLP), and guarantees error-free transmission of information. Data packets of 60 bits are given a block of 24 bits for error correction. If the error is beyond correction, the relevant packet is recalled. Because 10% of the channel capacity is reserved for this type of activity, it is often possible to have a packet repeated without additional reduction of the channel

capacity. The price to be paid for this fault-tolerant system is a relatively low effective transmission rate. In practice, the effective transmission rate is between 2400 and 9600 baud, depending on the selected mode and the reception conditions.

OVERSEAS CALLS

The important advantage of GSM is the global character of this telephone system. Many network operators offer GSM support in dozens of countries around the world. As a result, a customer may use his GSM phone in many countries, while he remains obtainable under his own phone number. When a GSM phone is called, it makes no difference whether it is within the national borders or at the other side of the globe, say, in Hong Kong or Australia. An example may help to examine how the telephone connection is actually made. As soon as the user inserts his SIM (subscriber identification module) into a GSM phone, and switches the unit on, the telephone goes on the air, and performs an automatic check-in on the network. The network operator, for example, one in Hong Kong, detects a visitor, in this case, an English GSM user. The essential condition for the whole system to operate at this point is that the Hong Kong network operator has a so-called *roaming agreement* with the UK-based network operator the customer has a subscription with. If that is the case, the network computer will look for user data in a large database called Visitor Location Register (VLR). Using a data link, the relevant information is requested in the UK. The information is found in the Home Location Register (HLR) of the UK network operator (say, BT's Cellnet), and is available within a few seconds. The telephone company in Hong Kong is then aware of the user's privileges, and if the use of his number is authorized. If everything is all right so far, the telephone is enabled. From that moment, the location of the user is known in the UK, and calls may be placed. All calls are automatically routed to Hong Kong, while the user may phone to any destination from Hong Kong. Every day, the two network operators (actually, their computer systems) exchange information about the relevant billing, so that call costs can be charged to the user. A copy of the bill sent to the user is kept at the Data Clearing House in Denmark or Luxembourg. The cost balancing between the two network providers is arranged via a special bureau in Switzerland, the Financial Clearing House. In many cases, balancing the books means that mutually supplied services are simply crossed out against each other. (970019)

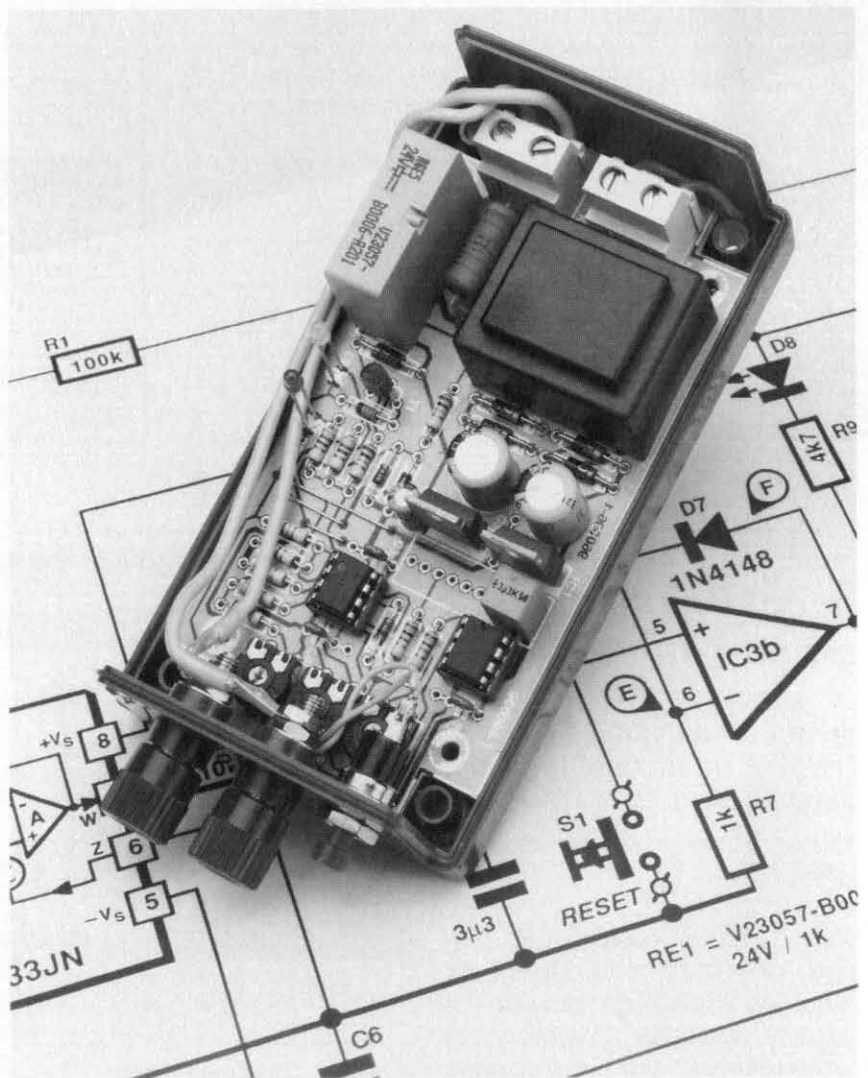


general-purpose electronic fuse

for direct and alternating current

A current detector and a threshold switch are not sufficient when it comes to building an electronic fuse. Such a circuit would be triggered each time the threshold value is exceeded, even by brief current surges. Normally, however, an electronic fuse should offer protection against excessive power consumption. Consequently, its triggering should be dependent on the product of the current (squared) and time, just like an ordinary cartridge fuse.

This means that the electronic fuse contains a squarer circuit and an integrator in addition to the current sensor and threshold switch. The advantage of the electronic fuse is not only that it is adjustable and totally free from wear and tear, but also its improved reaction behaviour as compared to an ordinary fuse.



Main specifications

<i>Application:</i>	Automatic fuse with adjustable trip current and response speed.
<i>Suitable for:</i>	direct and alternating current
<i>Trip-current range (I_N):</i>	50 mA to 1 A
<i>Time-delay setting (I^2t):</i>	TT to FF, see text
<i>Power supply:</i>	on-board PSU with mains transformer
<i>Special features:</i>	also suitable as a 240-V fuse provided relevant construction notes are observed

Design by H. Bonekamp

Assuming that the electronic fuse has to offer protection against damage caused by excessive current consumption, a current detector on its own is simply not sufficient. As you will probably know, the power caused by a current flowing through a load resistance equals

$$P = I^2 \cdot R$$

So, the amount of power is determined by the square of the current. The main selection criteria for the traditional cartridge fuse are discussed on a separate page. **Drawing A** shows the melting characteristic of a cartridge fuse. To make the fuse melt, a much higher current is required than the nominal current, I_N , printed on the device. At this minimum melting current, I_M , the actual melting still takes quite some time. Actually, the time needed to make the fuse wire melt is not shortened until the current becomes even higher. So, the fuse responds to the factors current and time, in other words, how long a certain power is consumed by the load. The fuse therefore limits the amount of energy, E , at the load side to

$$E = P \cdot t = I^2 \cdot R \cdot t$$

Assuming that the load resistance, R , is constant, you may also write

$$E = k \cdot I^2 \cdot t$$

This brings us to the I^2t parameter, which describes the electrical behaviour of the fuse.

I^2T PARAMETER

Studying the melting behaviour of a cartridge fuse, it is seen that the I_M curve rises exponentially before going flat. Given that logarithmic scales are used for x ($\log I$) and y ($\log t$), it follows that the product I^2t is constant in this range of the characteristic. This constant is the essential fuse characteristic which describes the melting behaviour (fast or slow). **Drawing B** in shows the characteristics of different types of fast fuses. The parallel-running curves are the result of different I^2t parameters.

The characteristic of the electronic fuse discussed here has a similar shape, see **Figure 1**. Note, however, that the nominal current, I_N , and the I^2t parameter are adjustable with a potentiometer. The I_N control allows values between 50 mA and 1 A to be set. Figure 1 indicates a setting of $I_N = 1$ A, which corresponds to a fuse actu-

ation level of 1.28 A (i.e. I_M for a cartridge fuse). The two current/time curves as shown are the result of the lowest and highest I^2t settings which correspond to that for a very fast acting cartridge fuse (FF, lower curve), and a very slow acting one (TT, upper curve) respectively. The actuation characteristic of the electronic fuse is continuously adjustable between these extremes using the I^2t potentiometer. In the diagram, imagine that the upper curve may be shifted down over a continuous range by turning the pot. Similarly, the lower curve, may be shifted upwards. At the indicated setting ($I_N = 1$ A), the electronic fuse is actuated within 0.02 s at a current of 2 A with the I^2t pot set to one extreme (FF characteristic). At the other extreme setting of the pot (TT characteristic) it then takes 20 s for the fuse to interrupt the current flow.

The dashed horizontal line is the minimum actuation time of the electronic fuse. This period is the result of the switching-off time of the relay used in the circuit.

Figure 2 shows that the I^2t parameter of the electronic fuse has a constant response, while it rises exponentially in the direction of I_N , just as with a traditional cartridge fuse.

BLOCK DIAGRAM

To be able to determine the I^2t parameter, the circuit has to measure the current, and subsequently square it (I^2). Next, the time factor, t , has to be realized. In the block diagram, **Figure 3**, these functions are implemented

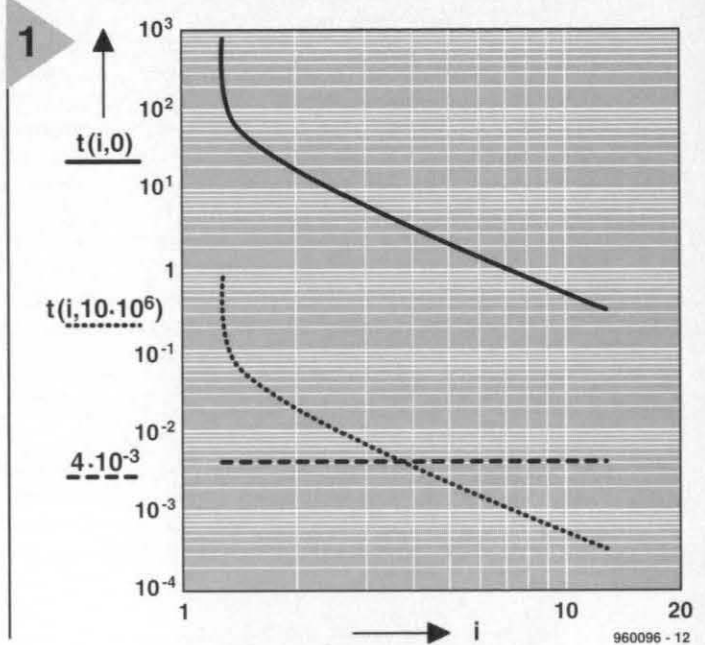


Figure 1. Actuation characteristic of the electronic fuse at its maximum and minimum I^2t settings.

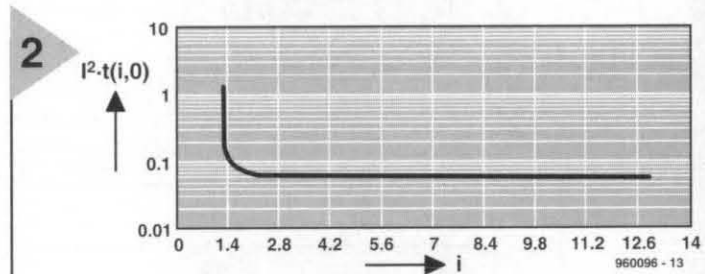
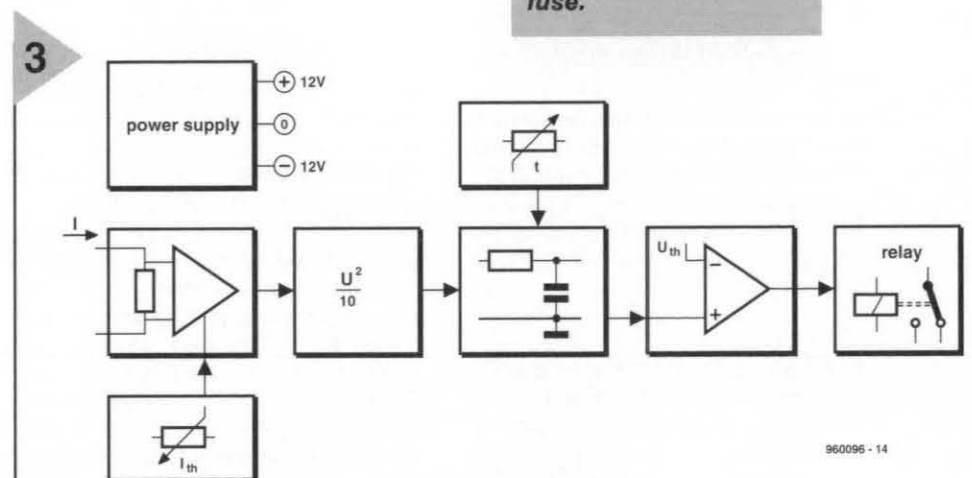


Figure 2. As with a cartridge fuse, the value of the I^2t parameter rises exponentially towards the minimum actuation current.

Figure 3. Block diagram of the general-purpose electronic fuse.



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as described below.

The input forms a measurement resistor which acts as a current sensor. The voltage drop is processed by a difference amplifier whose gain is determined by the setting of the potentiometer. This setting actually determines the nominal current (and, consequently, the actuation threshold) of the electronic fuse. The output voltage is fed back to a squarer which is followed by a (non-ideal) integrator. The I^2t parameter which determines the fuse response characteristic (TT to FF) is fixed via the setting for the integration time, t (second pot). Next comes a threshold switch with a fixed setting. The output of this circuit controls a relay in such a way that the relay is de-energized the moment the

found back at terminal block K2. In the circuit, the current through the fuse flows through the relay contact and resistor R12, which may pass up to 7 A continuously. The resistor value of 0.1Ω causes a voltage drop gradient of 0.1 V/A , which arrives at the input amplifier opamp IC3a via resistor R1. Together with D5 and D6, R1 protects the input against excessive voltage levels. The amplification, A , of this stage is given by the equation

$$A = \frac{R3 + R4 + P2}{R3} \cdot R12$$

which shows that the gain may be adjusted with the aid of P2. Direct voltage offsets, if any, may be nulled using preset P1.

voltage may be written as

$$U_o = \frac{U_i^2}{10} [\text{V}]$$

where U_o is the output voltage of the squarer, whose drive margin extends up to 10 V. Figure 5 shows the output voltage as a function of the current measured via R12, at a fuse setting which equals that of Figure 1 ($I_N = 1 \text{ A}$, threshold (actuation) current $I_{th} = 1.28 \text{ A}$). The drive margin limit is then reached at 10 times the actuation current (12.8 A).

The integrator which follows the squarer consists of a simple RC low-pass filter, whose time constant $(R5+P3) \cdot C7$ provides the required delay, t . The preset, P3 (range: 0 to

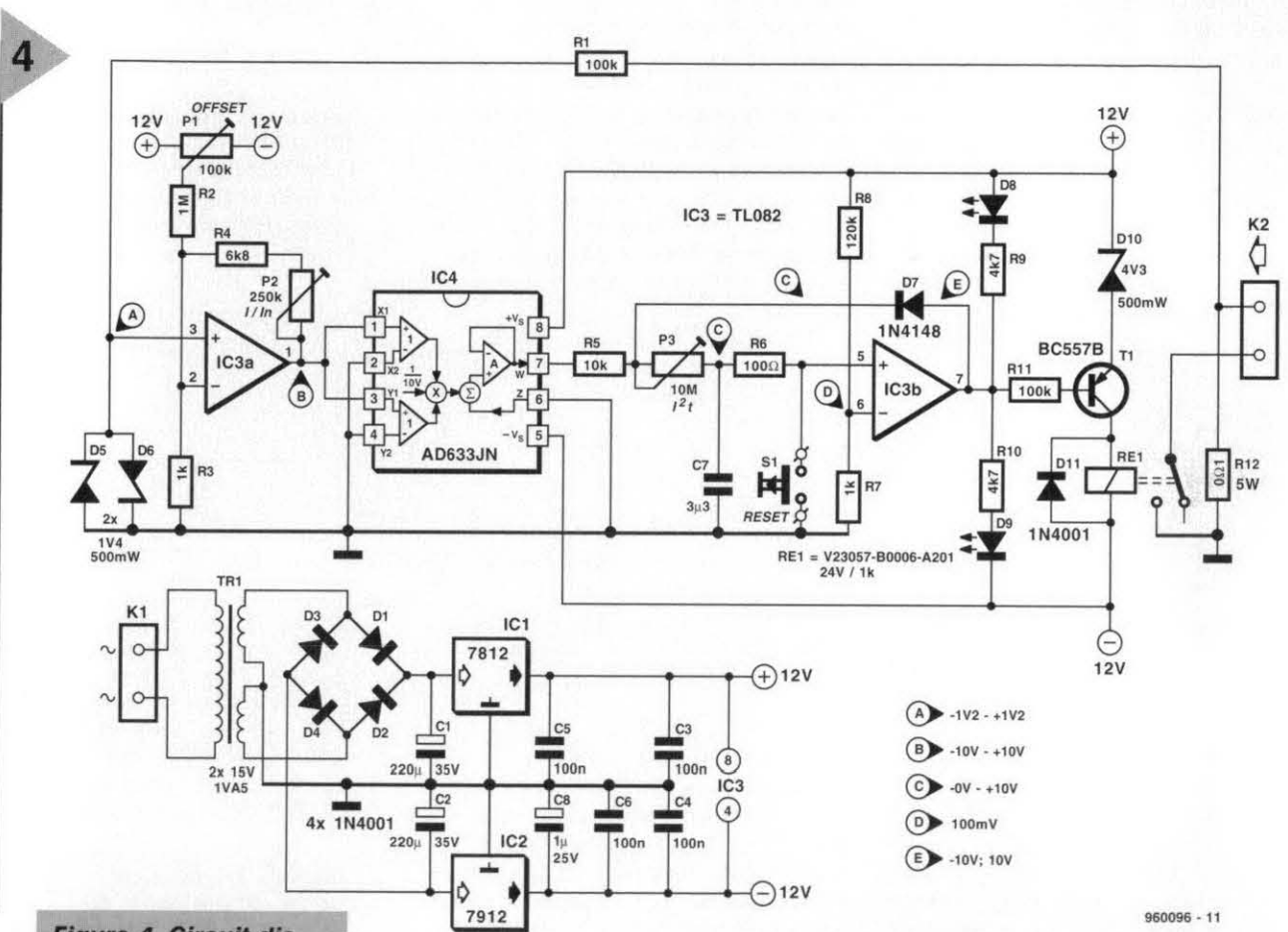


Figure 4. Circuit diagram of the electronic fuse for a.c. and d.c.

electronic fuse is actuated. Not shown in the block diagram is a push-button which allows the fuse to be reset.

As shown, the power supply provides a positive and a negative supply voltage for the opamps and the squarer.

DETAILED DESCRIPTION

The circuit diagram in Figure 4 allows the previously discussed sections to be recognized without problems. The two terminals of the electronic fuse are

The squaring function is performed by a special integrated circuit type AD633JN in position IC4. This is a four-quadrant multiplier which multiplies the signals applied to its inputs at considerable accuracy and stability. At 1 MHz bandwidth and $20 \text{ V}/\mu\text{s}$ slew rate, the AD633JN accepts direct as well as alternating voltages. In the present application, the inputs are connected in parallel, resulting in the signal being multiplied by itself, in other words, it is squared. Consequently, the output voltage is always positive, irrespective of positive or negative input voltages being applied. The output

(10 MΩ) allows a more or less slow actuation response to be set for the fuse. In Figure 1, the upper curve is obtained with P3 set to minimum resistance (0Ω), and the lower curve, by setting it to maximum resistance (10 MΩ). In Figure 2, too, the I^2t characteristic was recorded at P3 = 0Ω .

The integration network is followed by a peak detector using the second opamp (IC3b) as a comparator. To give the electronic fuse the largest possible actuation range, the reference level at the comparator has been fixed at 100 mV with the aid of R8/R7. The range is then $10 \text{ V}/100 \text{ mV} = 100$ -fold.

As soon as the integrator output voltage exceeds 100 mV, the comparator output swings from low to high. This condition is latched via D7. A reset is then only possible using reset switch S1. To avoid the use of a very rare and expensive diode in position D7, the diode is not connected directly to C7, but to junction R5/P3 which virtually eliminates the effect of the leakage current through the diode. In addition to the relay, the comparator also drives two LED indicators. The red LED lights when the circuit has been actuated, while the green LED, when on, indicates an 'intact' fuse. The relay is wired such that it is de-energized when the fuse is actuated, with greater certainty than in the case when it would have to be energized. Moreover, the contact disconnecting time is shorter than the pull-in time. Evidently, this is beneficial as far as the

reaction time of the fuse is concerned (dashed line at 4 ms in Figure 1).

A zener diode, D10, is connected in series with the emitter of transistor T1. The diode offers three advantages:

1. The transistor is also sure to be switched off when the opamp drive is just insufficient to reach the positive supply voltage (which is always the case in practice).
2. The current consumption of the relay is reduced, allowing a small (1.5 VA) mains transformer to be used.
3. At the reduced relay current, less energy has to be stored in the relay coil field. Consequently, the de-energizing time is reduced.

The power supply is traditional. A transformer with a central tap on the secondary allows full-wave rectification of the positive and negative supply voltage to be realized with just four diodes. Two three-pin voltage regulator ICs ensure sufficiently stable and accurate supply voltages at +12 V and -12 V.

Finally, a brief look at the calculation of the minimum actuation current and the I^2t parameter.

The lower threshold of the fuse actuation current is expressed as

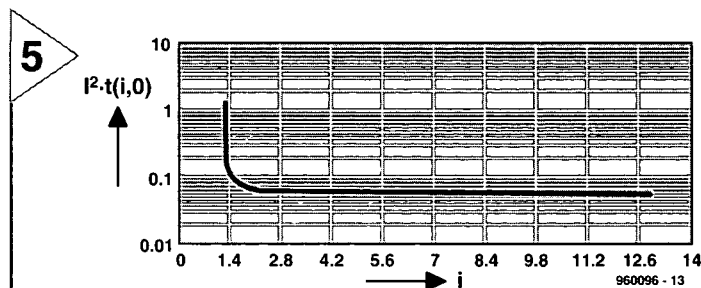


Figure 5. Output voltage of the squarer circuit as a function of the current carried by the fuse (assuming a nominal fuse current of 1 A).

$$I_{th} = \frac{\sqrt{U_{th} \cdot 10}}{A}$$

$$I_{th} = \frac{R3}{(R3 + R4 + P2) \cdot R12} [A]$$

Figure 6. The printed circuit board accommodates all parts of the electronic fuse, including the mains transformer and the power supply.

COMPONENTS LIST

Resistors:

R1, R11 = 100kΩ
 R2 = 1MΩ
 R3, R7 = 1kΩ
 R4 = 6kΩ8
 R5 = 10kΩ
 R6 = 100Ω
 R8 = 120kΩ
 R9, R10 = 4kΩ7
 R12 = 0.1Ω 5W
 P1 = 25kΩ preset H
 P2 = 250kΩ (preset or potentiometer with plastic shaft, see text)
 P3 = preset or potentiometer with plastic shaft, 10MΩ, 5MΩ or 4MΩ7, see text

Capacitors:

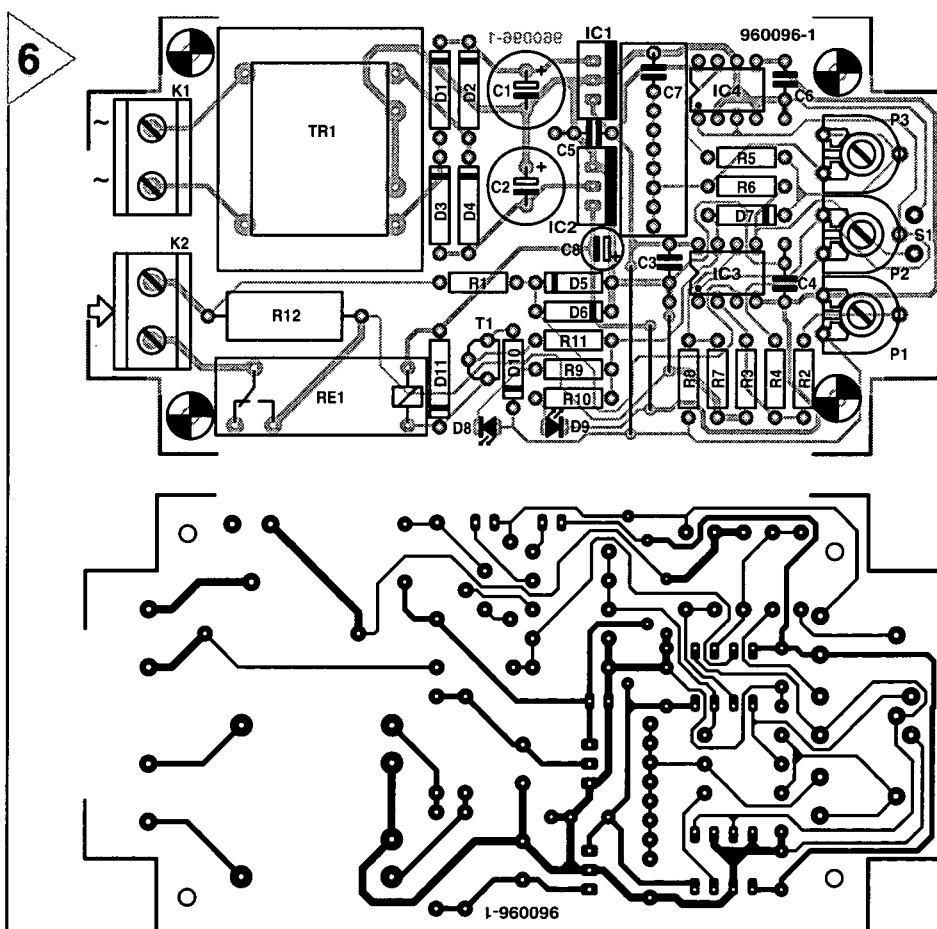
C1, C2 = 220μF 35 V radial
 C3-C6 = 100nF ceramic (Sibatit)
 C7 = 3μF3 or 6μF8, pitch 5-22.5mm, see text
 C8 = 1μF 25V radial

Semiconductors:

D1-D4, D11 = 1N4001
 D5, D6 = 1V4/0.5 W zener diode
 D7 = 1N4148
 D8 = LED green, high efficiency
 D9 = LED red, high efficiency
 D10 = 4V3/0.5 W zener diode
 T1 = BC557B
 IC1 = 7812
 IC2 = 7912
 IC3 = TL082CP
 IC4 = AD633JN (Analog Devices)

Miscellaneous:

TR1 = 2x15 V/1.5VA (e.g. Block VV 1215, Monacor VTR1215, Velleman 2150018M)
 S1 = push-button, make contact, see text
 K1, K2 = 2-pin PCB terminal block, pitch 7.5mm
 RE1 = relay V23057-B0006-A201 (Siemens)(24V/1kΩ2)
 Case, e.g. Bopla SE 430 (120x65x40mm)



where $U_{th} = 100 \text{ mV}$ as set by R8/R7, and A is the input amplifier gain as set by P2. From this,

$$I^2 t = \frac{(R5 + P3) \cdot C7 \cdot U_{th} \cdot 10}{A^2}$$

while for $I^2 t$ we may write

$$(I_{th})^2 = \frac{U_{th} \cdot 10}{A^2}$$

$$I^2 t = (R5 + P3) \cdot C7 \cdot I_{th}^2$$

CONSTRUCTION, ADJUSTMENT, APPLICATION

Building the circuit on the single-sided printed circuit board shown in Figure 6 should not present undue difficulties. As always, keep a close eye on the polarity (mounting orientation) of the electrolytic capacitors, diodes and voltage regulators, and do not forget the wire links (in this case, three). A large number of mounting holes are provided for foil capacitor C7 (MKT, MKS and similar) to allow physically larger versions of this component to be fitted also. If a $10 \text{ M}\Omega$ preset is difficult to obtain (P3), it is also possible to use a $4 \text{ M}\Omega$ or $5 \text{ M}\Omega$ type, and then increase the value of C7 to $6.8 \mu\text{F}$ (or use two $3.3 \mu\text{F}$ cap's in parallel).

The adjustment requires some care, and is best carried out in the following order:

1. Set P2 to maximum gain = maximum resistance (wiper fully counter-clockwise). For the offset adjustment, connect a digital multimeter between pin 1 of IC3a and ground, and adjust P1 for a meter reading of 0 V.
2. Set P3 to minimum (wiper fully clockwise), and connect a laboratory supply with adjustable current limiting to terminal block K2. If you only have a voltage-adjustable power supply, connect resistor between it and a DMM which is suitable for the DC current range, and adjust the current by means of the supply voltage. Set the current to a level of about 1.2 times the desired nominal fuse current, I_N . Carefully adjust P2 until the red LED just starts to light.

3. Using P3, the desired response of the electronic fuse may then be set to any value between very fast (wiper fully clockwise) and very slow (wiper fully counter-clockwise). If you want to record the fuse characteristic in a rather more exact way, use the equations for $I^2 t$ to compute the relevant resistance value for P3, or interpolate it from the Figure 1.

The adjustment carried out using direct current also applies to the case when the fuse is used to protect an alternating current (a.c.) current on K2. With alternating current, the squaring and subsequent averaging results in the square of the effective (rms) value being measured. Because of the limited drive margin of IC3a, the dynamic range is reduced with a sinusoidal alternating current flowing via K2, because the output voltage of the squarer circuit is then $\frac{1}{2} U^2$ rather than U^2 .

As regards applications for the electronic fuse, there are, in principle, two possibilities: use it as a fixed, internal, fuse, or as a 'portable', general-purpose unit for use in, say, an electronics laboratory.

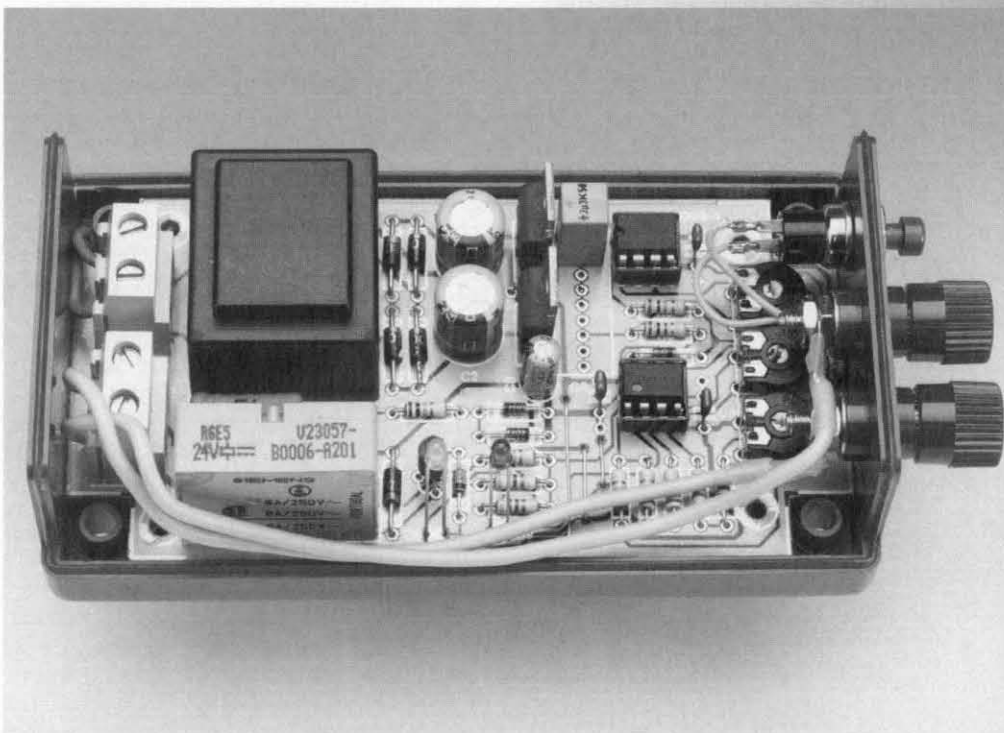
If the first application is chosen, P2 and P3 have to be set once only, as described, to fix the actuation (trip) current and the response time. The circuit

board is then fitted into the equipment case of the circuit or apparatus to be protected, with the LEDs and the reset switch migrating to the front panel to act as externally accessible controls.

When the unit is used as a stand-alone general-purpose fuse, the board is built into a suitably sized ABS enclosure. In addition to the LEDs and the reset switch, the front panel should then also have heavy-duty wander (banana) sockets for the current connection. If you want to be able to adjust the nominal current and the speed of the fuse, potentiometers have to be used instead of the two presets in positions P2 and P3. The pots are, obviously, also mounted on to the front panel, as well as given a label and a dial.

In principle, the fuse may be used to protect mains-powered (240 V a.c.) equipment. Note, however, that the circuit board is then connected to the mains, which means that **any part may be at mains potential**. When fitting the board into an ABS case, be sure to take precautions to ensure proper isolation of all voltage-carrying parts. This means that you have to use fully isolated LED holders and sockets for the current connection, as well as a mains rated switch for S1, and potentiometers with **plastic spindles** for P2 and P3.

(960096)



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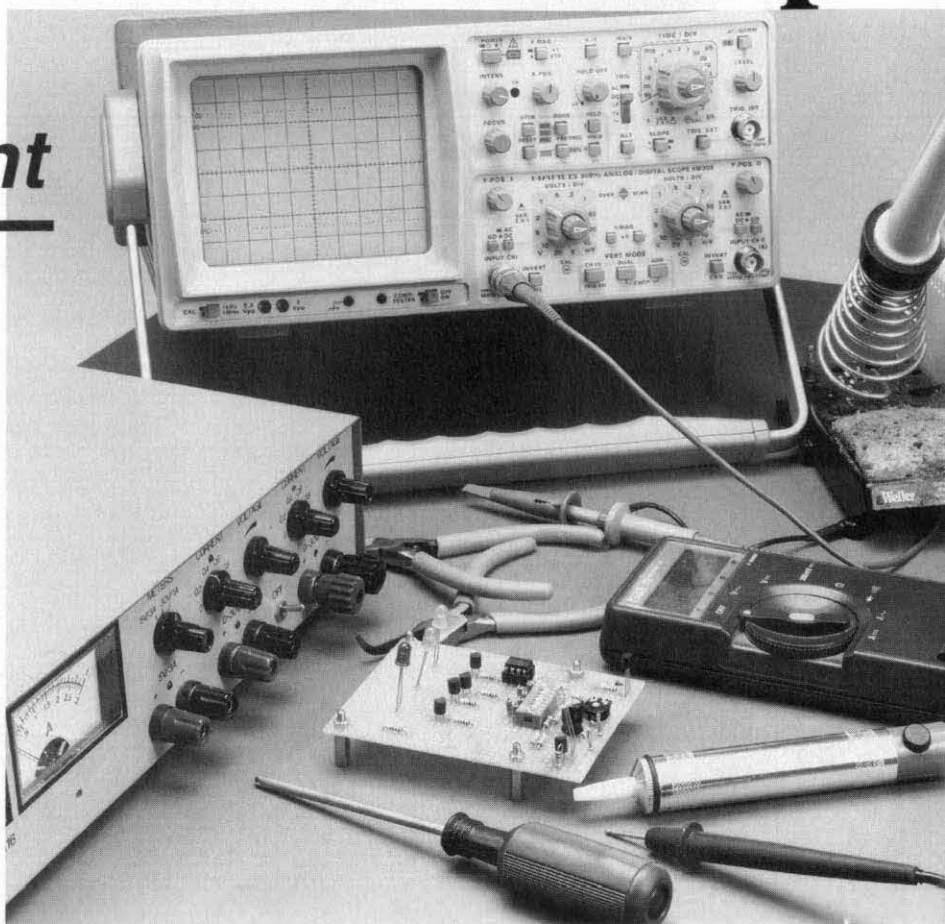
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the small workshop

part 2 test equipment

The article 'the small workshop' in our January 1997 issue was limited to basic requirements and tools for the small workshop. It also gave brief details of test equipment requirements. In this second part of the article, we take a closer look at the most frequently required test equipment and instruments. Such instruments can be added to the small workshop step by step. Every step requires some sort of outlay, of course, but as you will see, you don't have to be well-off to consider at least some of the instruments.



Only fairly simple work can be carried out with the basic tools and equipment described in the first part of this article. As soon as you start to work on rather more complex apparatus or construction, you will find that you need some more elaborate test instruments. These are also required when you want to fault-find and repair existing electronic equipment. A multimeter, a soldering iron and a mains adaptor are then no longer sufficient. At the same time, you may not want, or aren't able, to spend a lot of money on test equipment. Most good test instruments are expensive, but we will show how it is possible to get good results from less expensive alternatives.

POWER SUPPLY

As mentioned in Part 1, some sort of power supply is an absolute must. Such units come in many varieties and at many prices. It is perhaps fair to say that there is no other electronic equipment of which there are so many different models.

Mains adaptors are easy to use, very handy and not expensive. Many can provide an output current of up to 300 or even 500 mA. Consider, however, that almost without exception mains adaptors are not regulated, so

that the actual output voltage can differ quite substantially from the nominal output voltage, depending on the load (that is, the current drawn from it). All this means that mains adaptors are generally not suitable for serious work.

There are, fortunately, inexpensive regulated power supplies on the market. These usually have a higher output current than mains adaptors and are normally provided with a switch to select voltages of 3 V, 4 V, 5 V, 6 V, 9 V and 12 V (some of these may be missing from a particular supply).

The best, but, of course, also the most expensive choice is a variable power supply with an output voltage of 0–30 V that can provide an output current of up to 2 A. Depending on the type work you regularly do, 5 A may be a better choice. Moreover, if you frequently test or construct circuits with op amps, it is more propitious to get a supply with a variable output voltage of ± 15 V – this can, of course, also be used to provide an asymmetrical output voltage of 30 V.

A power supply must have an accurate output voltage indicator and preferably also an output current monitor. Short-circuit protection and, for many occasions, variable current lim-

iting, are not essential but highly recommended. If, at the onset of a test, the variable current limiting is set to a low value, say 100 mA, a small error does not necessarily cause a disaster.

The final choice is yours and will depend on the kind of work you do, whether this is done now and then or fairly regularly, and, last but not least, on what you can afford.

MULTIMETER

A multimeter is the workhorse of electronics technicians and engineers and is available in many variations and prices.

The analogue multimeter is really obsolete and replaced in many workshops by a digital model. The digital multimeter has a number of important advantages over an analogue instrument: it is more accurate, the input impedance is much higher, so that the circuit on test is hardly loaded by it, and it is possible to extend it with a number of external functions. An advantage of analogue multimeters

used to be the rapid change of the meter pointer showing whether a measurand varies. Today, most digital multimeters have, in addition to the liquid-crystal display (LCD), an analogue scale or bar graph that also rapidly shows variations in the measurand.

When buying a multimeter make sure that it has an a.c. current range. Also, it should have provision for measuring a.c. currents and voltages at frequencies up to a few kilohertz at least. These facilities are not normally available on inexpensive instruments. Another facility that is very useful is autoranging, which means that the instrument sets itself to the correct range.

Today, many multimeters include functions such as a frequency meter and a capacitance meter. Whether you need these only you can decide. Bear in mind that a capacitance meter costs appreciably more than one integrated into a multimeter.

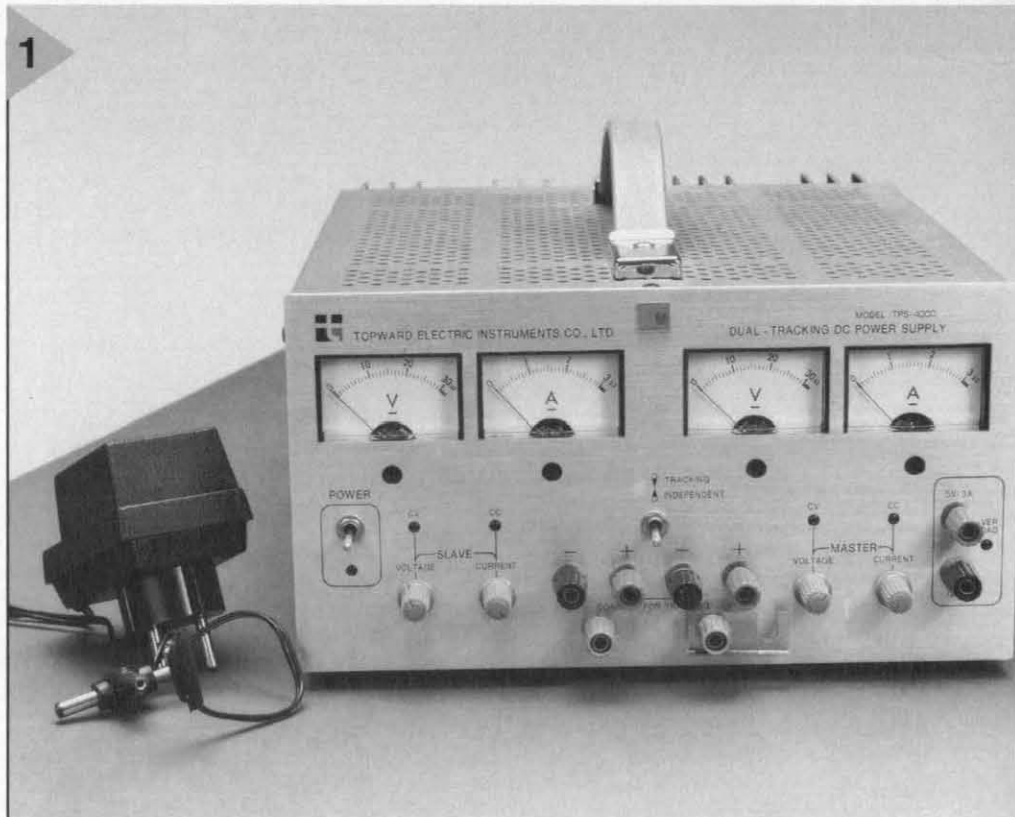


Figure 1. Power supplies come in all sorts and sizes and prices. One of the most useful in a small workshop, depending on requirements, is a variable 0–30 V, 2 A supply. Even better is a ± 15 V, 5 A supply.

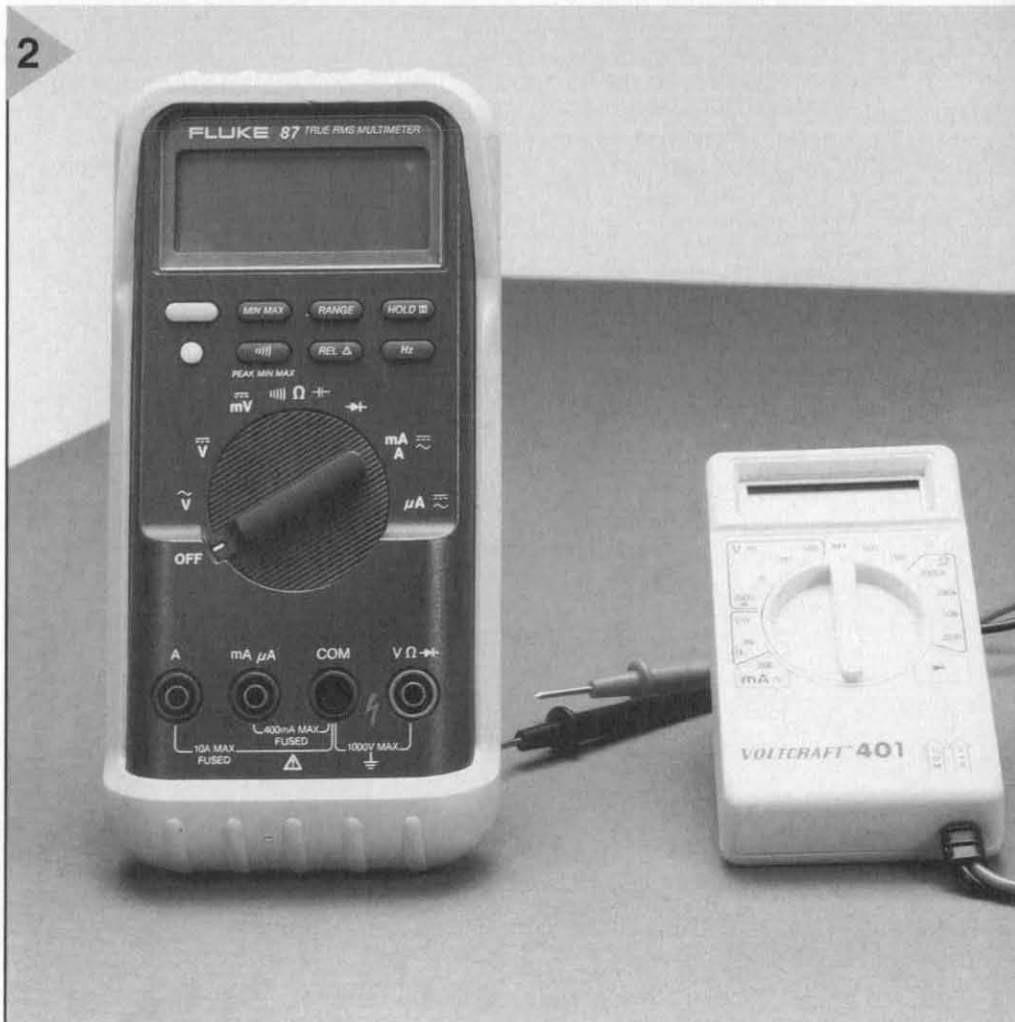


Figure 2. The price of multimeters varies with the quality between £10 (\$US15) and £50 (\$US75)

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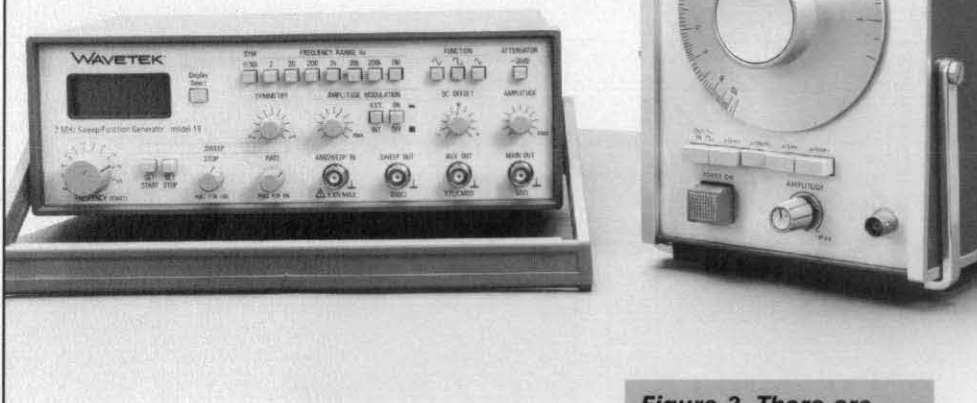


Figure 3. There are generators for any conceivable output signal.

SIGNAL GENERATOR

Certain tests are impossible without a test signal. This may be provided by a simple test oscillator cum buffer, designs of which are published in most electronics magazines from time to time. Strangely enough, it is almost impossible to buy one. Such a simple instrument consists of a simple oscillator that enables a 1 kHz signal to be injected into an audio circuit. This signal can be traced throughout the circuit with a small amplifier driving headphones.

Generally, however, a rather more sophisticated generator will be required. In case of audio circuits, a sine-wave generator or, preferably, a function generator is needed. A sine-

wave generator provides a sinusoidal output only, whereas a function generator additionally provides rectangular and triangular waveform outputs. For testing transmitters, receivers and associated equipment, an RF signal generator, whose output can be modulated, is required.

OSCILLOSCOPE

If signals are to be viewed, an oscilloscope is indispensable. Such an instrument shows at a glance whether a waveform is all right or not. Moreover, since the period of the signal can be

read fairly accurately on the screen, a good estimate may be obtained of the frequency of the signal. Most oscilloscopes are bench-type models, but portable models for travelling technicians are also available.

If you normally carry out tests on audio equipment only, a 20 MHz, 2-channel oscilloscope will suffice. However, testing r.f. equipment requires a 40/60 MHz, and possibly a 100 MHz, 3-channel instrument, costing, perhaps, £800 (\$US1,200).

Digital storage oscilloscopes provide facilities for freezing and continuously displaying fast, complex or non-repeatable events. They may also provide equivalent sampling for very high frequencies for digitising and observing high-speed repetitive signals. The price for such an instrument is about £900 (\$US1,400).

An attractive alternative to a bench-type scope for computer owners is the so-called PC-scope. This consists normally of a small box that is connected to the printer port of the computer. The monitor then becomes the screen of the oscilloscope; operation is via the computer mouse.

FREQUENCY METER

If you are regularly testing or servicing r.f. equipment, a frequency meter (often erroneously called frequency counter) becomes a must. This instrument enables the output frequency of oscillators and generators to be measured very accurately. Its price is comparable to an oscilloscope of equivalent quality.

If your wallet prevents you buying a frequency meter, bear in mind that much work can be done with a dip-meter, which is an absorption instrument used by radio and television amateurs since times immemorial.

SPECIAL EQUIPMENT

When it comes to testing digital circuits, a logic probe is very handy, since it enables the rapid measurement of logic levels.

Rather more sophisticated is a logic analyser, which can display several digital signals simultaneously. Unfortunately, this instrument is not cheap, but a design for one to be used in conjunction with a PC was described in the May 1996 issue of this magazine.

For analogue audio signals, an

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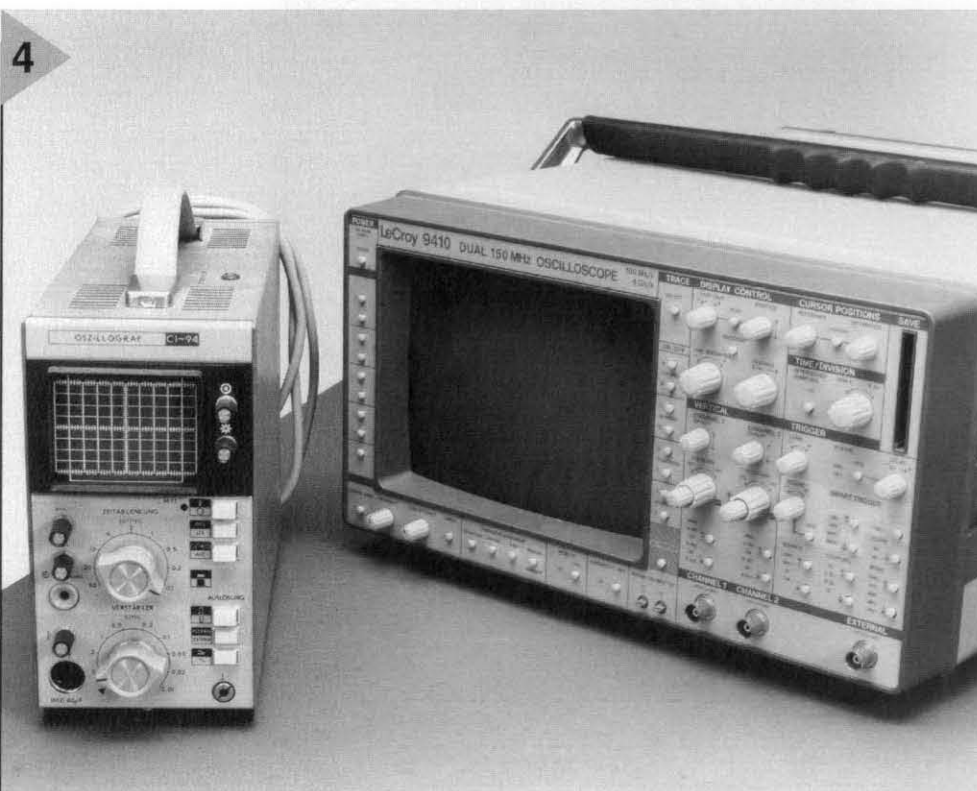


Figure 4. An oscilloscope is indispensable when it comes to testing generated signals. There is a wide range of such instruments at a wide range of prices.

audio analyser is needed. As its name implies, this instrument allows a detailed analysis of analogue audio signals. It is ideal for measuring frequency drift, signal-to-noise ratio, and distortion. Unfortunately, audio analysers are costly instruments and therefore hard to justify in the small workshop.

TEST LEADS

A good selection of test leads is vital in any workshop. Special leads and test probes are supplied with instruments like an oscilloscope, audio analyser and frequency meter. Many leads are terminated at one end into a BNC connector and at the other with a special probe tip or clip and earth clamp. For measuring high voltages, oscilloscopes are usually supplied with a probe with built-in 1:10 attenuator (which, because of its lower capacitance, affects the circuit on test less than a 1:1 probe).

The test leads for connecting a power supply, multimeter, and so on, must be of good quality. This means that they should be made of flexible, heavy-duty, stranded insulated wire. The insulation should be heat resistant. Their ends should be terminated into banana plugs on to which special test clips can be fitted. A BNC-to-banana-plug adaptor is very useful.

5



Figure 5. A frequency meter is a very useful instrument, but for many test purposes a dipmeter is a much cheaper alternative.

FINALLY

There are many more test instruments as already enumerated in Part 1 of this article. Whether any or all of these are ever needed in a small workshop only time can tell.

[970038]

A few tips

When testing equipment, it is often fairly difficult to make a good contact between the relevant plugs and sockets on the equipment and the test probes or clips. It is therefore advisable to keep a number of free, relevant plugs and sockets in the workshop: the rear of these normally affords far better contact for a test clip. Home-made adaptor leads of various sorts (headphone jack-to-audio socket; audio socket-to-DIN) are always useful.

We assume that you have a good selection of standard value resistors, capacitors and other frequently used parts available. If you do not already have a selection of fuses as well, we would advise you to rectify that situation, because fuses have a habit of blowing when it is least convenient.

A 50 Ω or 75 Ω dummy load is a must for testing RF equipment.

If you have to measure the output of a power amplifier, it is strongly recommended to disconnect the loudspeakers and replace them with an 8 Ω resistive load. This need not be rated at 50 W or 100 W: two 15 Ω , 10 W resistors in

parallel suffice in most cases.

Voltage should invariably be measured under load conditions since this can often throw light on the possible cause of a defect. The best example of this is a flat battery: since this retains its nominal e.m.f. for a long time after going flat, simply measuring its voltage at the terminals is totally inconclusive, whereas a light bulb connected to the same terminals shows immediately that it is flat. So, it's a good idea of having a few light bulbs of varying voltages in stock.

Repairs often include mechanical work and it is, therefore, advisable to keep some balls of cotton wool and a phial of pure alcohol in the workshop, which will prove useful for cleaning recording heads and slipping capstans. Contact spray is a well-known remedy for noisy potentiometers. A pinprick of light (sewing machine) oil may work wonders in a sluggish recorder drive. Discarded (and well-cleaned) toothbrushes are ideal for cleaning switch and relay contacts. A spray can with liquid air is often just the thing to remove an awkwardly seated piece of fluff or dust.



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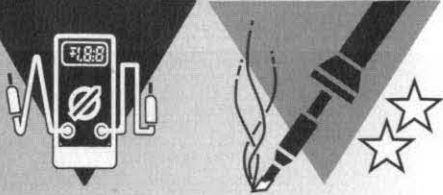
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battery simulator

active load for test purposes

To design a battery charger with switching regulators you need quite a few flat batteries and the patience of Job. When you come to calibrate the circuits for accuracy, control and efficiency you need a constant load. Unfortunately, the terminal voltage of a battery is never very stable. On top of that difficulty you have to be careful not to overload either the charger or the battery. The simulator described in this article provides a load that remains constant for long periods of time.



The battery simulator is in fact an active load for the battery charger and provides a constant voltage that is independent of the charging current. It can simulate a set of batteries that have a given state of charge. The load presented by the simulator is at all realistic frequencies of the charging current smaller than 0.5 ohm. The most useful property of it is, however, that it allows you to carry out lengthy tests and faultfinding on the charger without having to worry about overcharging (and damaging) one or more batteries.

CIRCUIT DESCRIPTION

The circuit diagram of the battery simulator is shown in **Figure 1**. Its operation depends largely on power dar-

lington transistor T_1 connected across the +ve and -ve output terminals. The transistor functions therefore as a shunt regulator which holds the terminal voltage constant: any overvoltage is instantly short-circuited. The base voltage of the p-n-p transistor is controlled by a fast op amp, IC_{1a} . This control amplifier is powered by an asymmetrical supply.

The amplifier compares the potential at the +ve terminal with the nominal voltage at its non-inverting input. The potential drop across the two zener diodes is about 2.5 V. The current through the diodes is prevented from exceeding a value determined by R_6 . Preset P_1 sets the voltage at the positive input of the op amp to a level

between 0 V and 2.5 V when switch S_1 is closed and between 2.5 V and 5.0 V when the switch is open.

Since the d.c. amplification of the amplifier is $\alpha = 1 + R_3/R_4 = 4$, the terminal voltage of the battery simulator can be set between roughly 3.5 V and 20 V. Operation at the lower voltage can be enhanced by using 1.2 V zener diodes and raising the amplification of the op amp by giving R_4 a value of 1.8 k Ω .

The supply for the op amp is derived from the charging voltage via diode D_1 . During the short periods that there is no charging current, the op amp is supplied by the potential across C_2 .

The remainder of the components form protection circuits.

Capacitors C_1 and C_3 decouple the input voltages to the op amp.

Resistors R_1 and R_2 ensure that the base current of T_1 cannot exceed a given value and also that the transistor switches on without any delay. At the same time, they suppress any r.f. oscillations.

Resistor R_5 , which determines the output impedance of the simulator, and fuse F_1 protect the transistor against high charging currents and D_2 against reverse polarity.

Buffer capacitor C_4 assists in keeping the terminal voltage constant.

CONSTRUCTION

The battery simulator is best built on the printed-circuit board shown in Figure 2. The work should be completed in

no time at all, particularly since housing the board in an enclosure is not really necessary.

For stability's sake it is advisable to mount the potentiometer on an aluminium angle piece.

Also, it is advisable, although not strictly necessary, to mount the transistor on a small heat sink.

The charger is to be connected to K_1 together, if felt necessary, with a voltmeter.

Tests with the prototype show that currents between 30 mA and 3 A can be drawn without any variation in the output voltage.

When a battery on charge is to be simulated, the voltage setting may be increased so that the charger behaves as if a fully charged battery is connected, whereupon the current

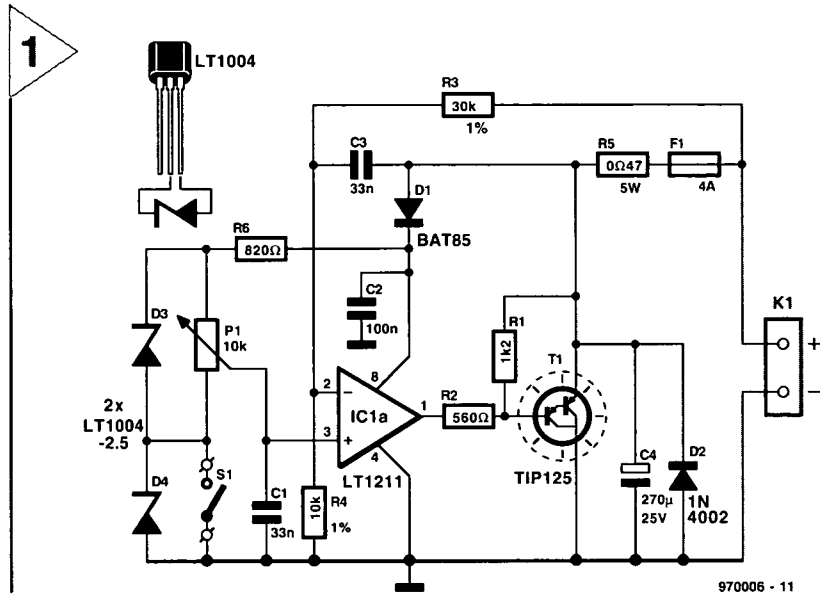


Figure 1. Circuit diagram of the battery simulator which is based on a shunt regulator.

Parts list

Resistors:

- $R_1 = 1.2 \text{ k}\Omega$
- $R_2 = 560 \Omega$
- $R_3 = 30.1 \text{ k}\Omega, 1\%$
- $R_4 = 10 \text{ k}\Omega, 1\%$
- $R_5 = 0.47 \Omega, 5 \text{ W}$
- $R_6 = 820 \Omega$
- $P_1 = 10 \text{ k}\Omega$ linear potentiometer

Capacitors:

- $C_1, C_3 = 33 \text{ nF}$
- $C_2 = 100 \text{ nF}$
- $C_4 = 220 \mu\text{F}, 25 \text{ V}$, radial

Semiconductors:

- $D_1 = \text{BAT85}$
- $D_2 = 1\text{N}4002$
- $D_3, D_4 = \text{LT1004-2.5}$
- $T_1 = \text{TIP125}$

Integrated circuits:

- $\text{IC}_1 = \text{LT1211}$

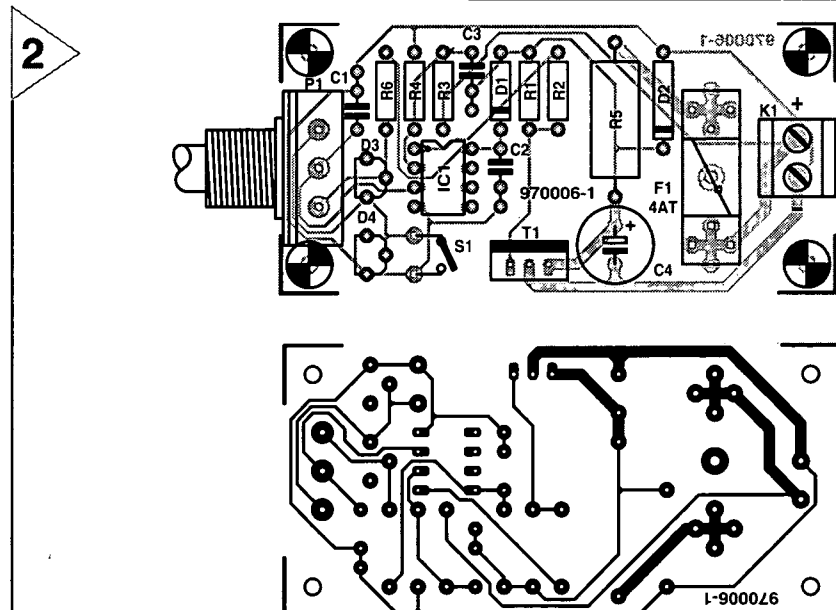
Miscellaneous:

- $K_1 = 2\text{-way}$ terminal board for PCB
- $S_1 = \text{SPST}$ switch
- $F_1 = 4 \text{ A}$ slow fuse with holder for PCB

through the simulator is increased. Conversely, if the reference voltage across P_1 or S_1 is reduced, the charger behaves as if the battery is flat, whereupon it raises the level of the charging current.

[970006]

Figure 2. Printed-circuit board for the battery simulator - there is no need for this to be housed in a case.



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Mike Tooley is the well-known author of many books, including the Newnes Computer Engineer's Pocket Book, now in its fourth edition.

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perienced communications professionals the book constitutes a handy reference source and a way of finding out about related technologies.

Geoff Lewis is an information technology and satellite television consultant. He is the author of *Communications Services via Satellite* and *Communications Systems*

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John Crisp is currently a senior lecturer in fiber optics, microprocessors, mathematics, and electronics at Lowestoft College. He has written several training manuals for use on the courses that he teaches.

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LETTERS

DECLINE IN CONSTRUCTION OF HOME ELECTRONICS PROJECTS (Editor's comments on page 13)

Dear Editor—Further to your request for your readers to point toward the decline in the construction of Home Electronics Projects despite the obvious increase in the use of electronics domestically, perhaps, I as a reader of the English edition since Issue 1 (which I still have along with the other 250-odd) might be allowed to contribute my ideas.

When *Elektronik* started all those years ago, the emphasis was on projects which were within the pocket of the 'average hobbyist', and the magazine filled a niche between the serious professional magazines like *Wireless World* and the 'comics'. *Elektronik's* projects usually worked first time, whereas those of other magazines seldom did, if ever. The possible exception being the much vaunted 'Texan' solid-state hi-fi audio amplifier which, even more than twenty years on is still capable of giving a good account of itself. In those days the average hobbyist had the choice of spending a week's salary on a project or buying ready-made equipment 'off the shelf' and paying about five times as much. As virtually everything seems to be made, cheaply, in China these days, most electronic equipment has become much more affordable in real terms. There's quite a wide choice of 'consumer electronics' available, 'ready made', at prices you couldn't buy the components for and, more importantly, in the UK at least, most of it is guaranteed to work for at least a year, so most of us opt for easy solutions rather than making units up from components.

So, where does *Elektronik* come in? Well, over the past few years, there's been a marked decrease in circuits I might have taken an interest in. If the January 1997 issue is anything to go by, I shall have to give serious thought as to whether I shall continue to buy the magazine on a regular basis. The 'Audio Amplifier' on page 14 may appeal to the alleged purist, but few of us live in an anechoic chamber, or have the unlimited funds to pursue perfection, so there's little point, apart from the engineering exercise, in building a unit which deviates from the norm by a certain portion of a

gnat. Likewise, the 'Model Railway Speed Regulator': I first built a pulse-width controller of this ilk over thirty years ago, and still use much the same circuit, which uses three of whatever small signal transistors I can lay hands on, four resistors, a pot, a power transistor and a couple of capacitors. The component count has decreased over the years, not increased, and whilst the circuit you describe on page 32 of the same issue is technically elegant, one might query if such elegance, and potential lack of reliability, is justified.

On the other hand, whoever writes the technical (descriptive) bulletins does a very good job, and usually manages to write articles which are informed, interesting and well researched: would that I could write such prose.

There is one particular niche which no magazine has ever (to the best of my knowledge) even started to explore, and that, put simply, is an explanation of what goes on under the cover of the average PC, and how you might, without parting with an arm and a leg, tweak hardware and software to best suit your own purposes, instead of making do with whatever way your computer left the factory. As most businesses these days seem to change computers every couple of years or so, there's a lot of equipment just dumped because few people know how to make use of it. That's what I'd like to see in the *Elektronik* of the future.

Harry Wellborne
Newcastle-upon-Tyne

Dear Editor—May I suggest some reasons why home construction is not so popular now as it once was.

As an ex-kit producer I explain below the problems of the business.

The time-consuming nightmare of trying to keep one hundred or so components needed in stock to produce even a modest range of kits. Fred Bloggs will not appreciate having to re-order with three component suppliers just for that last component to finish off his kit.

You try to cover everything in the instructions but how do you start to answer a letter which starts: 'What are the holes for in the PCB; is this a fault and can I supply one without any holes?' With all the trouble of writing

one-off personal letters for a kit with a £4 profit margin, can you blame the kit producers for finding better ways of making a living?

The home constructors can no longer built cutting-edge projects which need multilayer PCBs and custom-moulded cases or we will end up with amateur-looking LCD TV the size of a suitcase. The alternative technical hobby of computing is becoming more and more welcoming.

Virtually the only new component for home constructors since the '70s is the PC and that is what I would like my book on if I am lucky enough to get this letter printed!

Andrew Davies
Harlech

Dear Editor—The humble soldering iron, this age-old 'bonding agent' of the home constructor is facing redundancy, in cold storage, from the joysticks and the 'moulded-mouse' brigade. Is the phenomenal growth in consumer oriented electronics, the prime catalyst, fuelling the apparent down-turn in home construction?

The entertainment industry has excelled in producing special effects, utilizing ultra-fast computers. This has created a magnetic attraction, powerful enough to 'dislodge' the home constructor from his/her workshop seat, into a seat in some cinema.

Similar developments in the automotive electronics sector have made the microchip-controlled vehicle the favoured option to 'consume' a free Sunday afternoon. The thrill of exercising state-of-the-art gadgetry, ranging from electrically operated wing mirrors to microprocessor-controlled seat memory units. Who knows where the intrepid constructor may end up when guided by an automotive navigation aid. Truly, a case of temptation beyond endurance!

Advances in computer technology are etching away the thrill and excitement experienced during the execution of a home construction project. The element of surprise/delight is being nullified by the existence of a software package, capable of simulating circuit behaviour, thereby eliminating the need for home construction!

However, the fundamental reason for this decline could simple be the fact that many con-

structors have been left standing by the space-thrusting pace of technology. The thought of handling surface-mount devices, conjuring scenes of microscopic brain surgery; a quad flat pack being confused with a furniture pack from MFI or even a four-slice-bread toaster!
S S Lall
Derby

Dear Editor—It was not until after the Second World War that electronics started gaining ground. Seminars and conferences were jointly organized between nations. This gave rise to an upsurge of interest.

When silicon and germanium were made into transistors, most home constructors who are used to thermionic valves could not cope and lost interest: this was the beginning of the declining.

By the time integrated circuits were introduced and of late microcomputer components, electronics has been taken away from the hands of the home constructor and become more academic.

Electronics is now a major source of income, hence interested governments voted heavily into its research and development, warning who cares to listen that this is a serious business. Japan is such a country.

If an idea is conceived, the following day what one is thinking about is already on the market. What one thinks is new is no longer new, there are a lot of new things lying in the cooler in most laboratories.

There is too much stress and distraction in the world today. People now sit down by television sets and computers from morning till night. Watching, playing computer games or surfing the web.

The cost of updating the workshop environment in a world where economy is biting hard does not help matters
O. Sladele
Tananger, Norway

Dear Editor—In reply to your request here are some reasons in the decline of home constructing.

- New modern designs are becoming more complex and use new exotic devices. This can make it harder to produce a finished item.
- Making printed-circuit boards has become more or less impossible when designs demand double-sided, through-plated-hole

boards.

- The cost benefit is not worth the time and effort involved.
- Many items that are available in kit form are over-priced compared to a commercial item.
- It may be possible to put together a project and then impossible to obtain a good case for it at a price that can be afforded.

As far as radio is concerned, the problems that I have found are the lack of good designs available. The devices used are difficult to obtain or beyond my means.

Obtaining data for some of the integrated circuits can prove a major problem. Manufacturers do supply data sheets for many ICs but the cost can be quite high or the information quite obscure.

Many items are available to people from standard suppliers at a cost that it would be impossible to match even just buying the components.

The use of surface-mounted component has also restricted construction to those with more advanced facilities owing to the

very small sizes of many components now in use.

Many projects are rehashed designs, especially those for amplifiers, or the parts used are difficult to source.

Also, schools are promoting computers as the way forward and ignoring electronics because the teaching staff themselves are often ignorant as far as electronic construction is concerned. Ian Johnson
St. Albans

Dear Editor—I think the main reason for the decline in home construction is the increase in mass production and cheaper manufacturing methods by the industrial electronics producers. Because the price is low, many people don't want to have the trouble, and use the necessary time it takes to make a construction by themselves. Another problem is to make a case for your construction which has the same professional look as the one you buy (housing proprietary equipment). Jan Olesen

Ikast, Denmark

Information Technology

Dear Editor—'Electronics now and tomorrow' (January 1997) gives an interesting overview of Information Technology. What I'd like to know is how Europe is faring in this important industry. Can you give me some information?
B. Wylde
Leeds

The European market for Information Technology is currently valued at \$US 190 billion and is expected to grow to \$US 260 billion by the end of 2002. The market is dominated by the services sector (37%), with hardware second (33%) and software third (20%). The leading companies in terms of revenues are Compaq, IBM, Apple, NEC and Packard-Bell.

[Editor]

Image Technology

Dear Editor—The article on Image Technology (February 1997) only mentions the Agfa ePhoto307 digital camera.

Aren't there any others on the market as well?

F. Lucas
Newport, Gwent

The only other one we have reliable information on is the Fuji digital camera, which offers live LCD monitor as viewfinder, VGA resolution via 350,000 pixel CCD, instant playback, downloads pictures to a PC or a Mac, and comes with a free copy of Adobe Photo Deluxe, is now available in the UK at £499 excl. VAT.

[Editor]

New Item Tracer

In response to the many letters we receive asking questions like 'Have you ever published ...?', we would like to draw all our readers' attention to the Item Tracer 85-96, which is now available. This contains, in alpha-numeric order, the digital contents of all articles (except news columns) published in the magazine in the period 1985-1996 incl. For more details and price, see advert on page 6.

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