

ELEKTOR ELECTRONICS

THE INTERNATIONAL
ELECTRONICS MAGAZINE

February 1995
£ 2.45

RS.

Focus on:
Computer-aided design

SURROUND SOUND PROCESSOR

MOSFET inverter

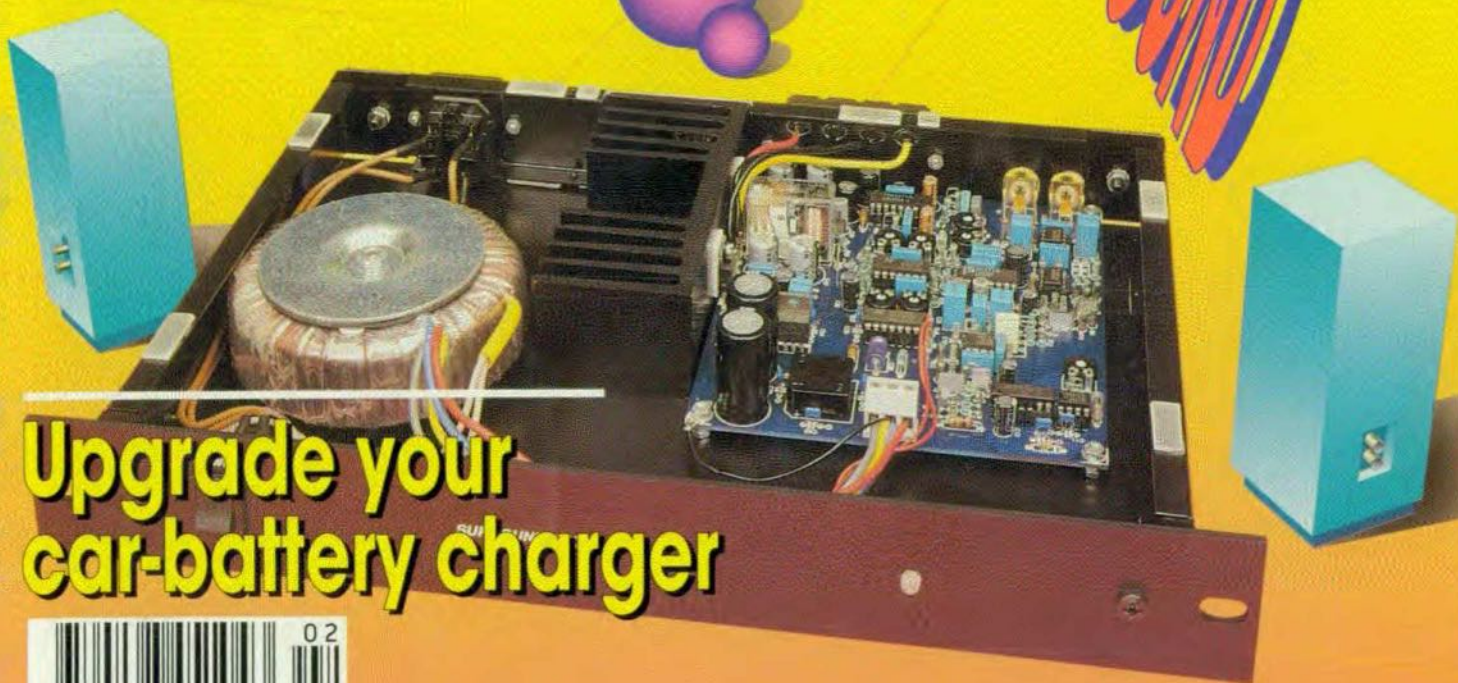
Parameters of
RF amplifiers

The op amp
revisited

Upgrade your
car-battery charger



SURROUND SOUND



AUDIO & HI-FI • COMPUTERS & MICROPROCESSORS • DESIGN IDEAS • RADIO, TELEVISION & COMMUNICATIONS • SCIENCE & TECHNOLOGY • TEST & MEASUREMENT

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- Wideband active loop antenna
- Telephone-controlled mains switch
- DSP function generator
- TDA1560Q: a 30 W audio amplifier for cars
- Stepper motor IC
- Long-life night light
- and others for your continued interest.

Front cover

Following last month's description of the Dolby Surround system, this month we present a practical application of it in the form of a Surround Sound Processor (see page 26) as illustrated. However, this does not use special Dolby ICs. The design described also includes the additional output amplifiers required for the centre channel and surround channels.

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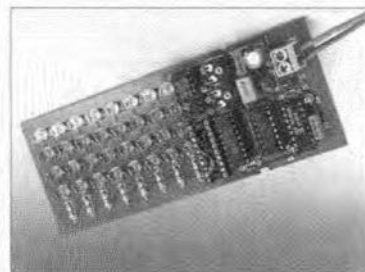
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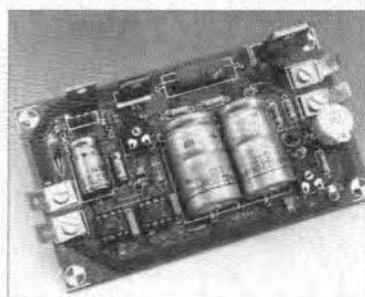
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Upgrade your car battery charger
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From the World of Electronics

BT to start trial interactive TV

BT is to start consumer trials of BT interactive TV – which includes video on demand – this summer with 2500 households in Colchester and Ipswich. This follows the success of its technical trials held near Ipswich with 60 BT employees.

The world-leading new service promises to create a revolution in the home. BT Interactive TV brings together the telephone and the television to enable customers to choose a range of services from a menu on an ordinary television set. The material is then transmitted from a central database over the telephone network to the television, while not affecting the normal telephone line.

BT aims to offer, during the period of the trial, shopping on demand, a range of educational programming for homes and schools, movies and television programming (video on demand), a home banking service, a magazine service and a community link (a local information service). Additional services will be introduced during the course of the trial.

Shopping on demand will be offered under individual brands by Thomas Cook for holidays and travel, Sears (Olympus, Adams and Freemans) for a wide range of fashion and sporting goods, and W.H. Smith for books, CDs and videos. A grocery service is being developed by Safeway Stores PLC and will be offered during the course of the trial as capacity on the system grows.

The television service will be developed with the consortium of BBC, Carlton, Granada, Kingfisher and Pearson with programmes supplied by the member companies and their subsidiaries. Movies will be offered from the major Hollywood studios and leading UK and European sources.

Additional sports programming will be supplied by BSkyB and music programming will be supplied by BMG Video (UK), Picture Music International (the video subsidiary of EMI), Polygram, Sony Music and Warner Music.

Customers will be able to choose from 600 hours of television programming, 400 hours of movies and 200 hours of music programming, all of which will be regularly updated.

There will also be 350 hours of educational programming ranging from children's to adult learning. This service will be offered free of charge to eight schools in the Ipswich and Colchester area as well as being available in the trial homes.

Educational programming will be supplied by Abbey Home Entertainment, Academy TV, Adult Literacy and Basic Skills Unit, Anglia TV, BBC, Channel 4, Dorling

Kindersley Vision, the Industrial Society, Open University, Video School and Yorkshire TV.

The trial homes will have access to a magazine service supplied by IPC Magazines Ltd which displays video, audio, text and graphics.

Customers will be able to access a TV programme guide with features about TV programming plus leadings sport and lifestyle titles such as *Golf Monthly* and *Family Circle*.

National Westminster Bank will offer a home banking service which will provide account management services, such as balances, statement information and transfers between accounts, as well as product information on a wide range of personal financial services.

Technology contracts

The technology used in BT's trials has been undergoing technical evaluation since March last year. Following its success, BT has awarded a number of contracts for the marketing trial.

Oracle will provide the multimedia database and navigational software and nCUBE will provide the media server. The customer management system comes from Sequent and Apple Computers are supplying the set-top boxes.

Technical notes

The set-top box (STB) was based on an Apple Macintosh LC475 computer, running Mac O/S modified to support MPEG and a 2 Mb/s network interface. At startup it downloads the operating system and Oracle Media Objects (OMO), the run time version of the authorware tool in which the services are created.

The network connected to the STB was a 2 Mb/s stream delivered over either copper using asymmetric digital subscriber loop (ADSL) or fibre. ADSL technology delivers over an ordinary telephone loop 2 Mb/s in one direction, a 9.6 kbp/s bidirectional control channel and the ordinary analogue telephone service.

The variety of ADSL used at the trial was DMT (discrete multitone) which divides the spectrum into a number of bands and spreads the video transmission over them in such a way as to minimize interference and noise. For the fibre delivery a passive optical network was used.

Users were connected directly to the server system without any concentration or switching stage. The server system consisted of an nCUBE massively parallel computer and the system ran on Oracle database software with the video content compressed to MPEG-1 standards.

In the marketing trial BT will be using ADSL along with fibre in the ratio of about

4 copper to 1 fibre. Instead of DMT, CAP (carrier-less amplitude and phase modulation) ADSL will be used in the marketing trial.

In the marketing trial, BT will be staying with the same combination of server and set-top box technologies supplied by nCUBE, Oracle and Apple Computers. However, there will be a switching/concentration stage which will be ATM based. Users will be connected to an ATM switch with a concentration ratio of roughly two to one. This means that there are about twice as many users as there are server ports and about half of them can be on line to the system at any one time.

Intelligent agents for communications networks of the future

With the burgeoning of communications systems to include new facilities, many and varied networks are coming into use such as those involving fixed optical fibre links, radio cells, optical wireless and satellite microwave – and these in turn use a variety of transport mechanisms.

The customers of the future will find themselves connected simultaneously to several different networks each of which may present limitations as well as advantages.

In the early days of telephony when human operators held sway, a caller asking for a number would perhaps be told by the operator: "Mr Jones has left home, and is now at his office. I've just put a call through to him, Shall I connect you to him there?" The advent of automatic telephone exchanges, however, soon put paid to this type of on-line intelligence.

BT (British Telecommunications) currently invests upwards of 2% of its annual turnover in Research and Development (R&D). Its major research facility, BTL (BT Laboratories) at Martlesham Heath is acknowledged as the leading telecommunications R&D establishment in Europe.

The main activity of BTL is in systems and software development and its prime purpose is to provide world-class expertise via its well-directed R&D programmes in advance of customer needs. The demise of the helpful operator has not escaped BTL's attention.

A major research project at BTL is directed to effectively restoring a service equivalent to that provided by the human operator but geared to the 21st century. The objective of this service would be negotiation in finding the best deal for the customer in terms of facilities and cost in the plethora of network types and services that confront him.

Mimic human

The devices that will provide this service are known as intelligent agents, special software processed which mimic human behaviour in providing a simple and elegant method of managing network complexity and providing an intelligent interface to the customer or his own intelligent agent.

It may be postulated that this aspect of network control should be centralized. However, this would involve a large database, high traffic density and low resilience. The simple comparison shown makes it evident that a simple distributed modular system has much in its favour.

The distributed agents form a single layered system using the underlying fixed network for inter-agent communication and can be grouped in three generic categories:

- * Interface Agents – Customer Agent (CA), Gateway Agent (GA);
- * Service Provider Agents (SPAs);
- * Network Management Agents – Fixed Network Agent (FNA), Cell Agent (CLA).

The Interface Agent, CA₁, mediates between the system and the customer (C₁) while GA links the agent system with another intelligent or non-intelligent management system, owned perhaps by another telecom operator. Between them they facilitate the transfer of information or requests between the agent system and the external world.

The Service Provision Agents are each responsible for a specific service. They manage provider service information and negotiate with those wishing to sell their resources: a customer may require specific data which comes from a variety of

sources.

Security issues

In principle, each agent is permitted to communicate with any other agent except SPAs which have communication channels only with CAs. This measure takes account of security issues in that it does not allow SPAs responsible for special services provisioned through the resources of an external company to have access to network management or customer information.

The CA relays the customer request to the SPA which then decides which customer agent (responsible for the resource required) should be contacted at the other end. Subsequently, the CAs contact the network management agents that set up the service.

The Network Management Agents are mainly responsible for managing resources in the fixed network or in the mobile (cell) network (CLAs). Cell agents can be of various types and relate to the cell managed: Macro Cell Agent (CLA-M), Micro Cell Agent (CLA-m), or Pico Cell Agent (CLA-p). They work cooperatively to integrate their available local resources (in the form of link capacities or cell bandwidth) in a complete configuration required for a particular service.

Constant updating

They are also continuously updating that resource configuration to cope with changes in the environment and service delivery point changes the customer moves around. The agents communicate by passing fixed format messages. On receipt of a message an agent will make its own decisions, triggering an internal task or deciding to

communicate with other agents sending or requesting information.

An example of the role of agents may be considered in the context of third generation mobile phones that use macro cells of 10 km, micro cells of 500 m, and pico cells a few metres across. The capacity of each cell is the same but because the customers-to-cell size will differ, the capacity to customer will differ. The customer does not know which cell he is in, simply the services available – so the following happens.

When the phone registers the customer's presence in the radio cell or the phone is plugged into the fixed network, the agent managing that network calculates the capacity and current cost and sends this information to a customer-facing agent representing the customer. This second agent intelligently compares the price and capacity available against the services the user is subscribed to and selects those that are acceptable. Relayed back to the customer the services are shown on the phone's LCD (liquid-crystal display) as a series of icons with the prices below. So, as the customer moves around he can see at a glance all the services available and the price, if appropriate.

Maintain service

When the customer selects a service and moves to a new cell, the agent will negotiate to maintain service. This may be at an increased price if the service is not normally available in that cell, or it might involve downgrading the quality of, say, the video picture. On a data service, the agent may store the information until the user is again in a position to receive it.

Produced and published by ELEKTOR ELECTRONICS (Publishing)	Unit 4, Gibbs Reed Farm Pashley Road TICEHURST TN5 7HE Telephone: (01580) 200 657 (National) or +44 1580 200 657 (International) Fax: (01580) 200 616 (National) or +44 1580 200 616 (International)	Overseas editions: FRANCE Elektor sarl Les Trois Tilleuls B.P. 59: 59850 NIEPPE Editor: G.C.P. Raedersdorf	NETHERLANDS Elektuur BV Peter Treckpoelstraat 2-4 6191 VK BEEK Editor: P.H.M. Baggen
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Editorial & Administrative Offices: P.O. Box 1414 DORCHESTER DT2 8YH England Telephone: (01305) 250 995 (National) or +44 1305 250 995 (International) Fax: (01305) 250 996 (National) or +44 1305 250 996 (International)	Deputy Managing Director: Menno M.J. Landman	GREECE Elektor EPE Karaiskaki 14 16673 Voula—ATHENA Editor: E. Xanthoulis	PORTUGAL Ferreira & Bento Lda. R.D. Estefani, 32-1° 1000 LISBOA Editor: F. Ferreira de Almeida
U.K. Advertising Office: 3 Crescent Terrace CHELTENHAM GL50 3PE Telephone: (01242) 510 760 Fax: (01242) 226 626	Editor-in-Chief/Publisher: Pierre E.L. Kersemakers	INDIA Elektor Electronics PVT Ltd Chhotani Building 52C, Proctor Road, Grant Road (E) BOMBAY 400 007 Editor: C.R. Chandarana	SPAIN Resistor Electronica Aplicada SA P. de la Castellana, 212-4° Izda 28046 MADRID Editor: Agustin Gonzales Buelta
International Advertising Office: Elektuur BV P.O. Box 75 6190 AB BEEK The Netherlands Telephone: +31 46 38 94 44 Fax: +31 46 37 01 61	Commercial Manager: Karel van Noordenne	ISRAEL Elektorcal P O Box 41096 TEL AVIV 61410 Publisher: M. Avraham	SWEDEN Electronic Press AB Box 5505 14105 HUDDINGE Editor: Bill Cedrum
Subscriptions: World Wide Subscription Service Ltd.	Distribution: SEYMOUR 1270 London Road LONDON SW16 4DH		
	Printed in the Netherlands by NDB, Zoeterwoude		

Intelligent agents using advance AI techniques to communicate and cooperate with each other are ideally suited to maintain network integrity and optimization. When a fault occurs, they can work together to heal the network and, in the worst case, they can ensure that the network degrades in a controlled fashion without catastrophic results.

BT believes that intelligent agents provide the ideal means to supply customers and businesses with fast, transparent access to the global information which will soon become the norm – anywhere, at any time, and in any format.

More computer aid for the dumb

New computer software that lets dumb people participate in real communications has been released for commercial use after 10 years research and development. The TALK:ABOUT programme, developed at the MicroCentre of Dundee University, allows the disabled to tell stories about themselves at the single touch of a button. Software developer Mr Don Johnston, whose eponymous company is putting the research into the hands of the consumer believes "we are standing on the threshold of a new era for users of augmentative and alternative communication – an era of near-real-time communication".

Professor Alan Newell, director of the Dundee MicroCentre, adds: "What makes TALK:ABOUT special is the way it can be used to communicate not just wants and needs, but thought, ideas and the more personal elements of everyday conversation such as anecdotes. Conversations encompass several components: fast social interactions, beginning small talk, novel sentences, extended reusable talk, wrap ups and farewells. TALK:ABOUT is the result of at least four distinct projects that have been developed in parallel to address different components of human interaction. It offers high-quality text-to-speech output or digitized voices and also works with external speech synthesizers".

The Dundee team is also working on another development: ALADIN (Advanced Language Device for Interaction) project which speeds up computer assisted conversations and adds synthesized voice for people unable to speak.

Further information from University of Dundee, Dundee, Scotland DD1 4HN. Telephone +44 (0)1382 23181. Fax +44 (0)1382 23117.

Faster introduction of digital-quality broadcasting?

The prospect of near-CD-quality audio

broadcast reception in the home and car may be brought closer by a plan to develop consumer radio equipment to a new Digital Audio Broadcasting (DAB) standard. The DAB Receiver Development Club set up jointly by the Roke Manor Research and Enigma companies will enable radio and audio manufacturers to join forces to turn low-cost DAB receivers into reality.

The club will focus on the early availability of low-cost DAB receiver chips and multi-band radio designs in the light of the allocation of different frequencies across Europe. The aim is to develop a DAB chip and a multi-band radio receiver board containing this chip by the end of the year.

The formation of the club has been welcomed as a timely complement to the BBC's plan to launch network radio service using DAB in September this year.

Roke Manor Research is involved in relevant radio technologies as an acknowledged European centre of excellence in the field of mobile radio and personal communications.

Enigma, a specialist in real-time digital signal processing, designed the Texas Instruments decoder chip now used in 80 per cent of Japanese-manufactured NICAM video recorders.

Further information from Roke Manor Research Ltd, Romsey, Hants, England SO51 0ZN. Phone +44 (0)1794 833 658. Fax +44 (0)1794 833 589.

New Cirkuit catalogue

Cirkuit's Winter 1994/95 edition of the Electronic Constructors' Catalogue is now available. This enlarged, 280-page edition includes for the first time a new section with feature articles, news and two especially commissioned projects: infrared cordless headphones and a PC-controlled logic IC tester. These are published in full detail with complete kits available for both.

Many other new products have been added throughout the catalogue; the test equipment section, for instance, includes a wide range of new test gear from Kenwood, Hameg and TTI plus an RS232 multimeter with interface and comprehensive Windows software along with a new range of affordable thermometers and timers.

With 26 product sections, 280 pages and some 4000 lines, the catalogue also includes £21 worth of discount vouchers and is available from most larger newsagents or directly from Cirkuit Distribution, Park Lane, Broxbourne, England EN10 7NQ.

Serial EEPROM Handbook from Microchip

Microchip's new Serial EEPROM Handbook provides essential information and

valuable advice on Microchip's range of serial EEPROM memories. The 480-page handbook is the first comprehensive reference tool for Microchip's Serial EEPROMs. Including 25 product specifications, 12 application notes and nine qualification reports, the handbook covers all of the company's memory products and development tools.

The handbook, which is available through any Microchip sales office, distributor or representative, is an integral part of the company's newly announced Serial EEPROM Designer's Kit.

Arizona Microchip Technology, Unit 3, The Courtyard Meadowbank, Furlong Road, Bourne End, England SL8 5AJ. Phone (01628) 850 303; fax (01628) 850 178.

Sub note-book professional programmer

Stag Programmers have announced a new, battery powered programmer, the Orbit 48. This is a portable programmer with all the facilities found in a desktop unit. It is, therefore, easily carried in a briefcase or tool-box for use in the field, but equally suited to general engineering applications in the laboratory.

The Orbit 48 offers an extensive range of device support which includes popular devices from the world's major manufacturers in the following categories: CMOS PROMs, EPROMs, EEPROMs, FLASH and Intel style (87C51 family) Micros as standard and EPLDs via a low-cost docking module.

With a 48-pin WideBlade ZIF socket and 4 Mbit of RAM, expandable up to 16 Mbit, Orbit 48 can program 16-bit EPROMs, MROM pinout EPROMs and 8-pin serial EEPROMs – all as standard and all from one socket. Eight, 16 and 32 bit mode programming is made simple by the use of 'Interlace 2', pioneered by Stag which is easier and faster than the cumbersome 'split' and 'shuffle' technique.

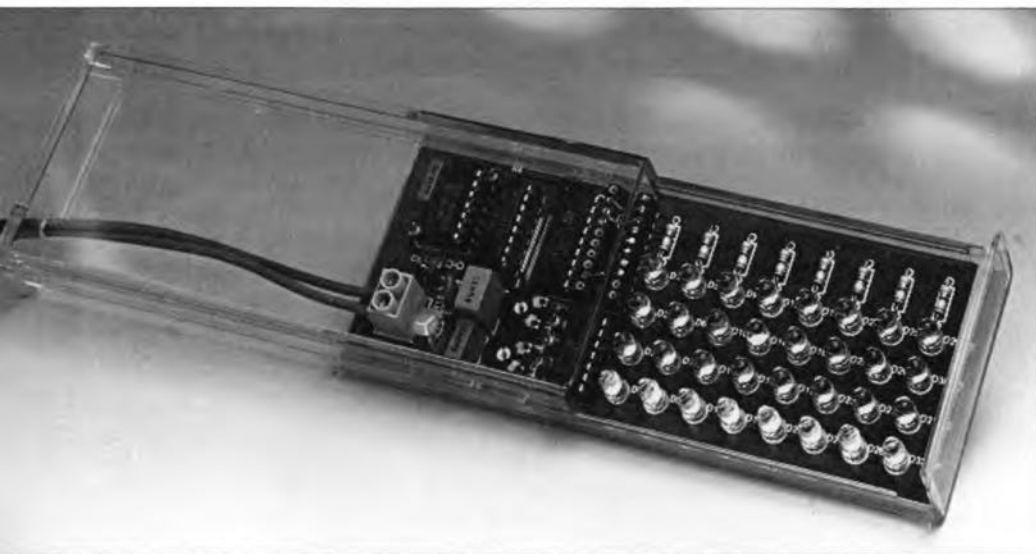
In keeping with Stag's quality engineering philosophy, all the data required to program this vast array of devices is held in FLASH (non-volatile) memory. This has two distinct advantages over other systems: (1) the data can not be corrupted in the way certain RAM-based systems do, and (2) updating the information can be performed without opening up the programmer – data transfer occurs via an I/O port or the programming ZIF socket.

The Orbit 48 contains a high-speed EPROM emulator which enables code to be run in a target system without first having to commit time and resource to programming and erasing devices.

Further information from Stag Programmers – see advertisement on page 39.

LIGHT-EFFECTS GENERATOR

This running light circuit drives a matrix consisting of 8 up to 32 LEDs, and is primarily intended for playful and decorative applications. A wide variety of display patterns can be programmed with the aid of a simple plug-in adaptor.



Design by G. Kleine

ALTHOUGH the present circuit contains most ingredients found in a typical running-lights generator, it is marked by one fairly special feature: the display pattern can be programmed with a plug-in adaptor. This adaptor sits between the driver IC and the LEDs. It determines three functions of the generator: the order in which the LEDs light; whether one or several LEDs light at a time; and whether or not a repeating pattern is shown. If you have had enough of a certain pattern, simply select a new one by plugging in the appropriate adaptor.

Circuit description

As shown by the circuit diagram in Fig. 1, the light-effects generator is a simple design by almost any standard. Even beginners should be able to build the circuit successfully because relatively few components are involved, and a ready-made circuit board is available. Building, programming and, most of all, using the circuit should be fun.

The display consists of eight rows of LEDs. Each row consists of a minimum of one LED (in which case it is not really a row), and a maximum of four LEDs connected in series. Series

resistors R_5 - R_{12} allow an LED current of about 15 mA. The exact value depends on the number of LEDs connected in series.

The display is connected to LED driver IC₃ via adaptor K₁. The latter is nothing but a good-quality 20-pin IC socket into which another 20-pin IC socket is plugged. The wires fitted on the latter determine the display pattern as will be discussed further on. IC₃ is an octal LED driver with open collector outputs. The device is capable of switching a total load of 500 mA to ground. The LED driver obtains its input signals from two cascaded shift registers, IC_{2a} and IC_{2b}. The first seven outputs of this double shift register (QA-QD of IC_{2a}, and QA, QB and QC of IC_{2b}) are connected to the LED driver inputs as well as to the inputs of NOR gate IC₄. This is done to ensure that a new logic one is formed when the shift register is completely filled with zeroes, which would otherwise remain so as long as the circuit is left on. This can be exploited by interconnecting pins 11 and 12 on adaptor K₁, in which case the output of the NOR gate is linked to the D input of shift register IC_{2a}. To make sure that a pre-defined state exists in the shift register at power-on, the reset input of IC₂ receives a reset pulse from network R₂-

C₂. This pulse causes all shift register outputs to go low on reset.

Both clock oscillators in the circuit consist of a Schmitt trigger NAND gate of which there are four in a the 4093 integrated circuit. The oscillators are identical except for the value of the capacitor used. The oscillator around IC_{1a} supplies the clock proper for the shift register, while IC_{1b} functions as a kind of data generator to provide the flash function of the circuit. The flash pulse is available on pin 1 of K₁, and causes the LEDs to flash at a rate adjusted with preset P₂. The other preset P₁, allows the speed of the shift register to be adjusted within fairly wide limits.

The circuit may be powered by a mains adaptor (with d.c. output) or directly from a car battery. The supply voltage is cleaned by a filter consisting of L₁, C₄ and R₁₃. The latter is a varistor or VDR (voltage dependent resistor) which is capable of suppressing fast voltage surges. The varistor and choke L₁ may be omitted if the circuit is not used in a car. L₁ is then replaced by a wire link.

Programming the light effects

Pins 2 through 8 of the adaptor socket, K₁, are connected to the LED driver outputs, while the data clock is available on pin 1. Pins 9 and 10 are connected to ground. At the other side of the socket, pin 11 is connected to the data input of the shift register. Pin 12 is linked to the output of the NOR gate, and pins 13 through 20 to the LED rows.

There are, in principle, three ways of programming the adaptor. If one of the LED row connections (pins 13-20) is wired to ground (pin 9 or 10), the relevant LED row will be on all time. Since that is not very appealing, it will be a rarely used option. By connecting one of the pins 13-20 to pin 1, the LEDs in the relevant row will flash at a rate set with P₂. Finally, if one or more LED row pins are connected to pins 2 through 8, the relevant LED rows will light in the rhythm of the shift register, whose shift speed is set with preset P₁.

The latter option has three further possibilities.

- (1). Adaptor pin 11 is not connected. The data input of IC₂ is then held high all the time via resistor R₄. At the first clock pulse which appears after the circuit is switched on, the first output of IC₂ will go high, and remain high 'forever'. At the next

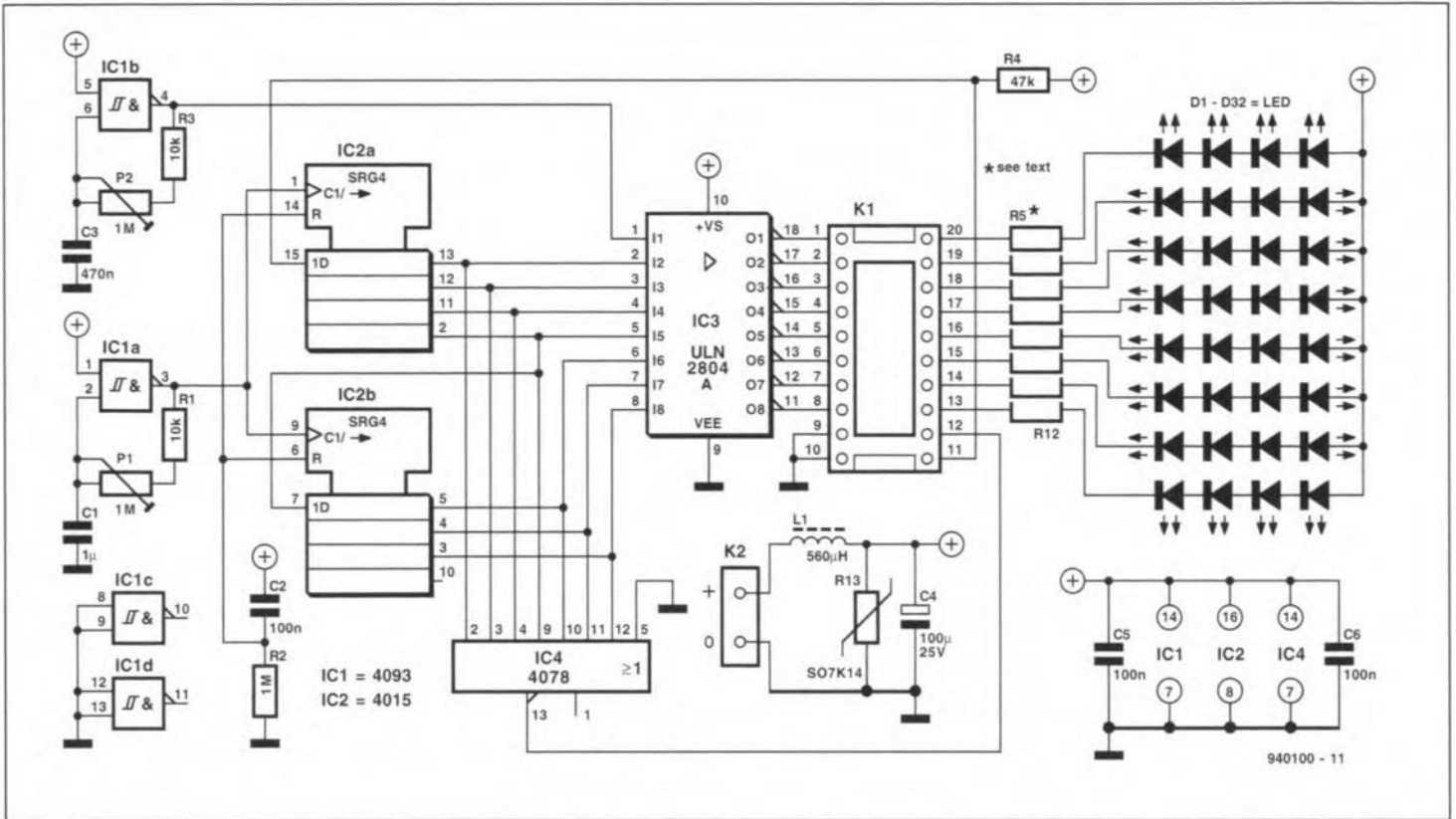


Fig. 1. The light effects generator consists mainly of two oscillators (IC_{1a} and IC_{1b}), a dual shift register (IC₂), an octal LED driver (IC₃) and a display which consists of 8, 16, 24 or 32 LEDs. The value of resistors R₅ through R₁₂ depends on the number and type of LEDs fitted.

clock pulse, the second shift register output goes high, etc. Therefore, when pins 14 through 20 of K₁ are linked to 8 through 2, respectively, LEDs D₁-D₄ light at the first clock pulse, followed by D₁-D₈, D₁-D₁₂, etc., until all LEDs light except those in the eighth row, which are not used.

- (2). Pin 11 is linked to pin 12. The data input of IC₂ is then connected to the output of NOR gate IC₄. Consequently, a '1' is clocked only if all outputs of IC₂ are at '0'. In other words, only one output of IC₂ is active at a time. Assuming that pins 14-20 are again linked to pins 8-2, the LED rows will light alternately. This pattern is repeated at the end of the cycle.

- (3). Pin 11 is linked to pin 1, so that the data input of the shift register is connected to the output of the data generator, IC_{1b}. The data clocked is random, and so is the light pattern produced by this option.

A number of programming examples are shown in Fig. 2. The most obvious one is given in Fig. 2a. This results in a running light, with one LED row moving from the left to the right across the display. If you want the row to move in the other direction, use the adaptor shown in Fig. 2b.

The configuration shown in Fig. 2c

causes a 'point' consisting of two LEDs to grow into a bar. If all 32 LEDs are fitted in the matrix, the effect is a vertical bar which widens from the centre of the display until the entire display

area lights. This variant is particularly suited to creating a third brake light in a car or on a motor cycle (note that the use of such a light may be restricted by laws).

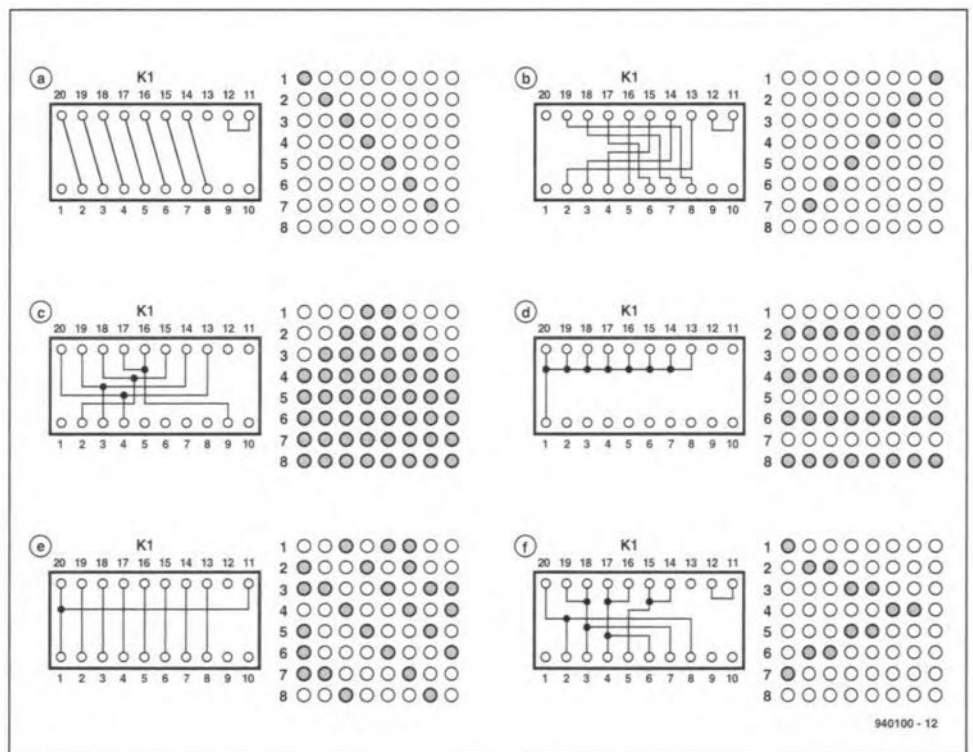


Fig. 2. Six examples of wire configurations on adaptor K₁, along with the resulting display patterns.

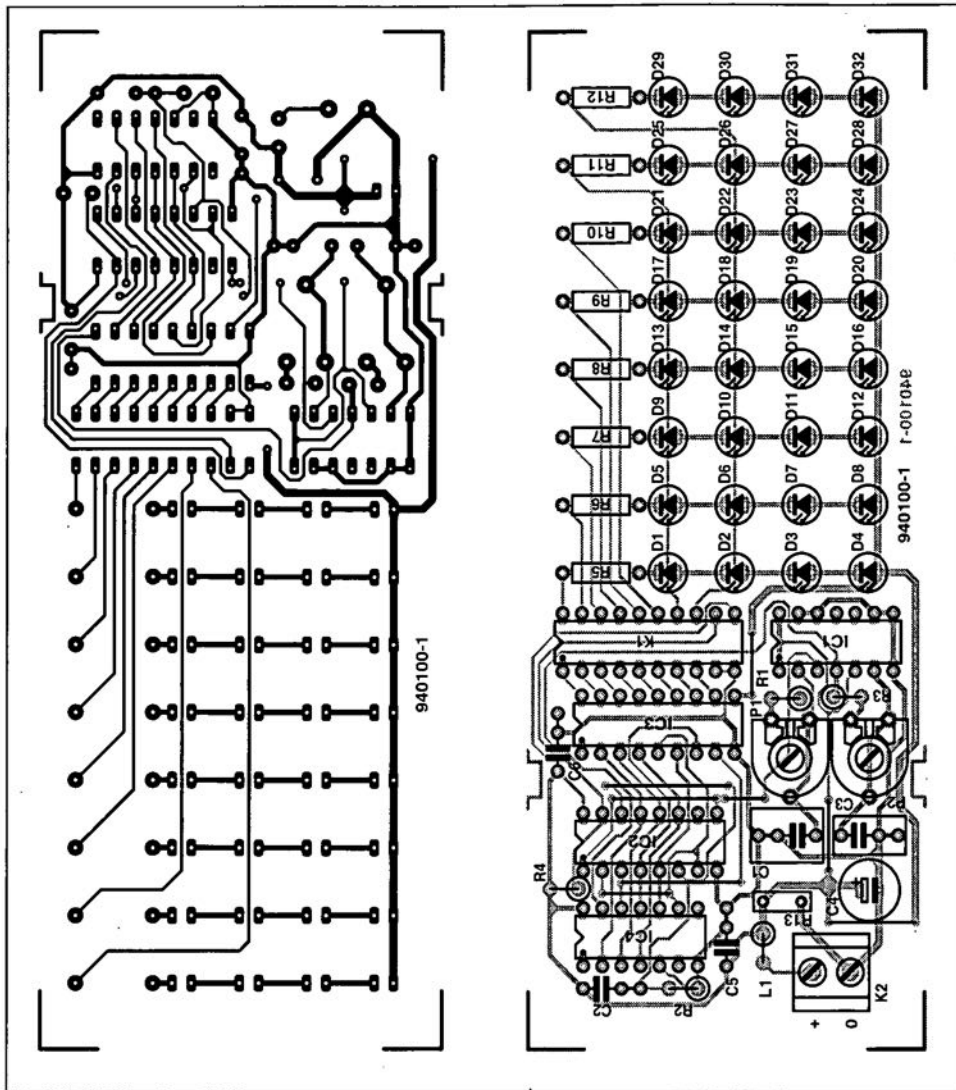


Fig. 3. Track layout and component mounting plan of the PCB designed for the light effects generator (board available ready-made through the Readers Services, see page 78).

The adaptor shown in Fig. 2d causes the entire display to flash at a rate set by P_2 .

Figure 2e shows an adaptor configuration which causes a random display pattern as with basic option (3) above.

Figure 2f, finally, results in a kind of combination of effect 2a and 2b: a running light which moves continuously from the left to the right, and vice versa. Evidently, there are many more possibilities to wire the adaptor, and these are left for you to discover and try out.

Construction

The printed circuit board designed for the light effects generator is shown in Fig. 3. Construction should not present problems if you stick to the component overlay and the components list.

So-called super luminosity LEDs are preferred if you want to make sure that the light effect is visible from a distance. These 5-mm diameter LEDs produce their highest light intensity at a

continuous current of 30 mA. However, to prevent damage to the LEDs at relatively high ambient temperatures, the value of resistors R_5 - R_{12} is such that about half the maximum current flows. The resistor value is, of course, dependent on the number of LEDs connected in series. Obviously, LEDs not fitted must be replaced by a wire link.

A disadvantage of super luminosity LEDs is their fairly high price. If you want to try the circuit with ordinary LEDs first, that is, of course, possible. Since ordinary 5-mm dia. LEDs are satisfied with a current of about 10 mA, the value, R , of R_5 - R_{12} has to be calculated from

$$R = (14 - 2n) / I \quad [\text{k}\Omega]$$

where n is the number of LEDs connected in series, and I , the LED current in mA.

If economy as regards current consumption is an issue, you may consider using high-efficiency LEDs. Since these can make do with 2 to 3 mA, R_5 - R_{12} can be given even higher values

COMPONENTS LIST

Resistors:

$R_1, R_3 = 10\text{k}\Omega$
 $R_2 = 1\text{M}\Omega$
 $R_4 = 47\text{k}\Omega$
 R_5 - $R_{12} = 390\Omega$ to 820Ω (see text)
 $R_{13} = \text{S07K14}$ or equivalent 14V VDR
 $P_1, P_2 = 1\text{M}\Omega$ preset H

Capacitors:

$C_1 = 1\mu\text{F}$ MKT
 $C_2 = 100\text{nF}$ MKT
 $C_3 = 470\text{nF}$ MKT
 $C_4 = 100\mu\text{F}$ 25V radial
 $C_5, C_6 = 100\text{nF}$ Sibatit or ceramic

Semiconductors:

D_1 - $D_{32} =$ super-luminosity LED, e.g., Sharp type GL5UR3K1
 $IC_1 = 4093$
 $IC_2 = 4015$
 $IC_3 = \text{ULN2804A}$
 $IC_4 = 4078$

Inductors:

$L_1 = 560\mu\text{H}$, 160mA

Miscellaneous:

$K_1 =$ two 20-pin turned pin IC sockets.
 $K_2 =$ 2-way PCB terminal block, raster 5mm.
 Enclosure: Heddic 222.
 Printed circuit board, order code 940100-1 (see page 78).

based on the above formula.

The sockets used for the adaptor and the one on the board (position K1) should be a good quality types, preferably one with turned contacts. The wire links should be soldered quickly to the adaptor socket pins to prevent deformation owing to overheating. Thin enamelled copper wire is fine to make the links. Check for the correct connections before inserting the adaptor into the socket on the board.

The completed board can be slid into a transparent plastic case type 222 from Heddic. No screws are required to secure the board in the case, while the LEDs are clearly visible.

Finally, if you plan to power the light-effects generator from a mains adaptor, make sure enough supply current is available. The current drawn by the circuit depends almost entirely on the type and number of LEDs fitted. The full-blown version, with 32 super luminosity LEDs fitted, requires a mains adaptor with a capacity of at least 150 mA at 12 Vdc.

(940100)

PCB PRODUCTION: THE DIRECT TONER METHOD

Transferring a PCB layout from paper on to a circuit board is either costly (photographic method) or cumbersome (using sprays and the like). Moreover, the second method is known to give rather unpredictable results, but that can be changed radically by the use of a new transfer foil called TEC200.

By Dr. R. Milker

A widely used method for making printed circuit boards is based on a photographic process. A transparent foil with the copper track layout is put on a printed circuit board which has a photosensitive layer covering a copper layer. After exposing the film and the board to ultra-violet light, the track layout is developed in a sodium-hydroxide solution. Next, the copper which needs to be removed is etched away in a special solution. That leaves the copper tracks as an exact copy of the original artwork.

Although several variants exist, the above process is always marked by the use of a photosensitive layer on a piece of circuit board. This layer may be applied with the aid of a liquid, a spray ('photolacquer') or a damping process (photo-resist film). In any case, the work then involves these steps: (1) affixing the artwork on to the board; (2) exposing to UV light; (3) developing; (4) fixing; (5) rinsing with water; (6) dry-

ing. The whole operation is cumbersome, fraught with pitfalls, and not easily accomplished by the unexperienced. To make it even worse, the photographic method is expensive, considering that, starting from a certain size, a board with a photo-resistive layer on it costs about the same as three equally sized ordinary boards.

The direct-toner method

The crux is that toner as used in photocopiers and laser printers has excellent etching resist properties. That in itself is not surprising, because toner consists mainly of inert carbon powder and a highly acid resistant compounding substance (resin or polyethylene). A further advantage is the fact that most laser printers (with a resolution of 300 dpi or more) are capable of producing PCB layouts at a scale of 1:1 at quite acceptable quality. Some PCB design programs also allow the art-

work to be printed at a scale of 2:1 or 4:1, all without the need of any photographic work whatsoever.

The aim is, of course, to copy the image formed by the toner on to the copper side of the circuit board. That can be achieved wonderfully well by the use of a special type of foil called TEC200, a transparent film which does not deform at temperatures up to 150 °C. Thanks to its chemical preparation, the film is capable of absorbing as well as reproducing toner. Thus, the foil is capable of 'transferring' the toner from the PCB layout to the circuit board. With the aid of TEC200, the production process of a printed circuit board is reduced to the following steps:

- printing (laser printer) or photocopying (normal copier) 'reflected' PCB artwork on to a piece of TEC200 foil, at a scale of 1:1;
- transferring the toner image on the TEC200 foil to the PCB surface, using some pressure, and heat;
- etching the board in the usual manner.

These steps are explained in greater detail below, using artwork found in *Elektor Electronics* as an example.

Step 1: copying

The copper track layout (reflected or non-direct reading) is copied directly from the magazine page on to the TEC200 foil (DIN A4 size). The TEC200 sheet is simply inserted into the (external) paper tray of the photocopier. Since there is no emulsion side, the sheet can be inserted either way. The copier should be set to give a quite dark copy, but not so dark as to cause smearing. This is best tested beforehand with plain paper. If necessary, the artwork can be made 'reflected' (i.e., not direct-reading) by first making a direct-reading copy on ordinary transparent film, flipping the film on the copier, and making a second copy on TEC200. Note that as of the September 1993 issue of *Elektor Electronics*, PCB track layouts are printed direct-reading, positive. That can be verified by looking at the PCB order number, which is legible.

TEC200 foil is capable of withstanding temperatures up to 150 °C without noticeable shrinking. Provided you use a modern photocopier with high reproduction accuracy, there should be no difficulty in maintaining the original

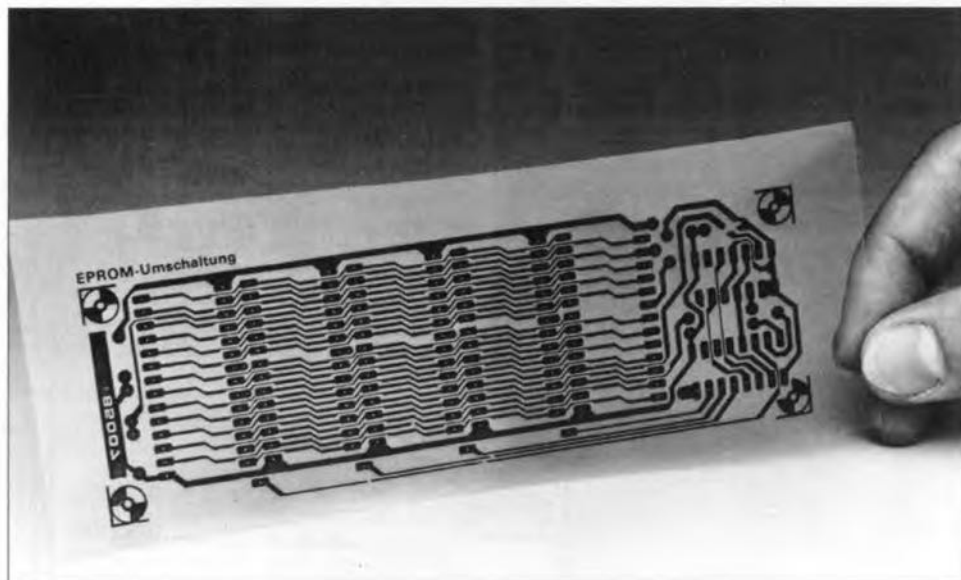


Fig. 1. TEC200 foil with the track layout copied on it.

size of larger components such as integrated circuits or pin headers.

Transferring the image

Having copied the reflected layout on to the TEC200 foil, it is cut out of the A4 sheet (see Fig. 1). The piece of foil is turned 'image down' on to the surface of a piece of copper-clad board. At one side, it is fixed to the board with a piece of sellotape. Next, the layout is transferred on to the copper, as follows:

- using an electric heater plate or a flat-iron turned upside down, the PCB is heated to about 140 °C;
- transfer the layout, exerting pressure with the aid of a roller (obtainable from most photographic tools shops), see Fig. 2;
- leave the board and the foil to cool off to room temperature, then carefully peel off the foil (Fig. 3).

In this way, even very narrow tracks are copied reliably on to the board.

In practice, it is recommended to put the PCB into the refrigerator for a while before peeling off the foil. Alternatively, good results are also obtained by immersing the board with the foil on it into the etching liquid. The foil will then come off automatically.

The layout copied on to the foil need not be totally opaque, because when transferred on to the board, the toner is melted again to form a lacquer-like, acid-resistant layer.

Figure 3 shows how the foil is carefully peeled off from the track image consisting of toner on copper, after the heating phase. Next, the board is ready for etching. The layout transferred on to the board is 'scratch-and-wipe' resistant to a certain extent, and best protected by the still weakly attached foil. That is why the foil should not be removed until just before etching.

3. Etching the board

The board may be etched directly after transferring the layout. There are no restrictions as regards normally used etching solutions or methods. On finishing the etching process, the board is rinsed with water. Next, the toner on the copper tracks is removed with acetone or similar. The direct-toner method described here enables you to produce a printed circuit board from 'reflected' artwork in just a couple of minutes, offering the electronics hobbyist as well as the professional circuit developer an interesting alternative to traditional production methods. Why not give it a try — you'll be amazed!

(940096)

Note: TEC200 foil is supplied by PS Services, 217 Prestbury Road, Cheltenham GL52 3ES, England. Phone/fax (01242) 254108. See advert on p. 57.



Fig. 2. Transferring the toner from the TEC200 foil to the copper-clad side of a piece of circuit board requires some pressure and a board temperature of about 140 °C. Here, a simple thermostatically controlled hotplate is used.

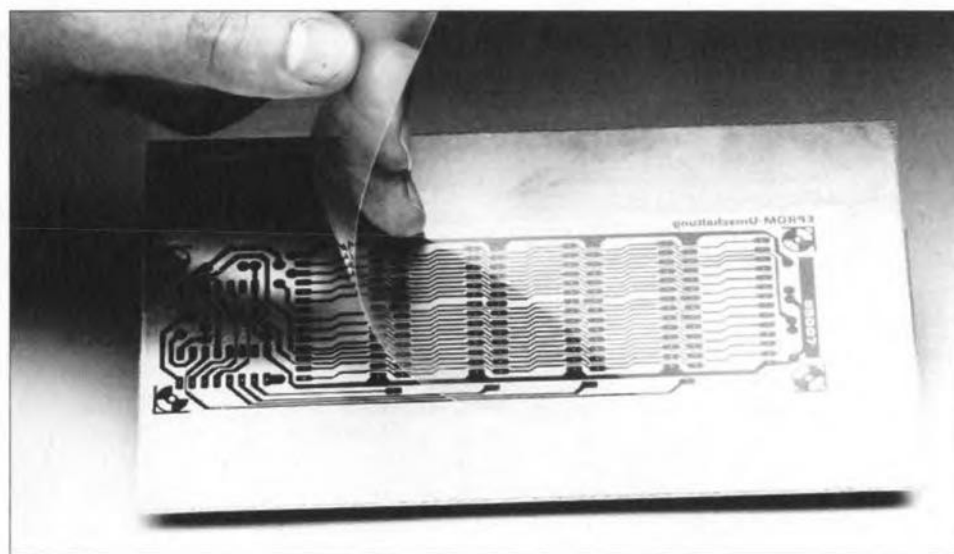


Fig. 3. The PCB after the copper track layout has been transferred from the foil to the copper surface.

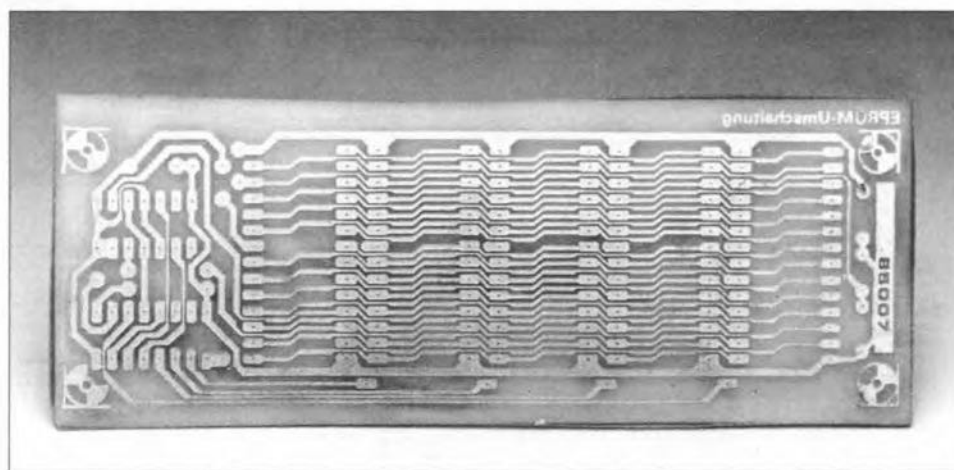


Fig. 4. Ready etched board, cut to size.

MIDI MULTIPLEXOR

Design by P. Rigail

Musicians appear to have a predilection for connections, as witness the myriads of cables that can be found around and on the stage when a pop concert is taking place. The multiplexor described in this article enables interconnecting of a number of MIDI instruments quickly and tidily.



Modern music groups make full use of instruments that generate electrical signals or need such signals to generate sound. Organs, synthesizers, sequencers, amplifiers and what have you all operate with electrical signals.

Fortunately, nowadays there is a standard, MIDI (Musical Instrument Digital Interface), with associated protocol, of which many musical instruments make use. Computer manufacturers have also taken the MIDI route, with the result that computers are eminently suitable for controlling musical instruments. The only damper on all this is that these new instruments need many cables to interact. Loose lying cables form a danger since they can be tripped over and are easily damaged. The multiplexor enables straightforward connections to be made between musical instruments that are to be linked via a MIDI.

The multiplexor may also prove of use on the domestic scene. Computer users whose computers have a sound card with MIDI connection can use the interface to bring about electrical isolation in the system, which obviates the likelihood of

damage to the computer when experiments are carried out at the MIDI output.

How it works

The circuit diagram of the control panel is given in **Fig. 2**. The signals from the MIDI are applied to DIN buses K_1 – K_4 . This digital serial connection operates at a baud rate of 32 kbit/s. The interface uses current loops of a few milliamperes. This design enables distances of several metres (up to 10 ft) to be bridged.

The LED in optoisolators IC_1 , IC_2 , IC_3 and IC_4 lights in rhythm with the digital data stream applied to the MIDI input. It is protected by a diode in case a signal of wrong polarity or a direct voltage is applied to the input. However, this risk exists only if home-made MIDI cables are used. When proprietary equipment and cables are interconnected, in principle, nothing can go wrong.

When the LED in the optoisolator lights, the associated phototransistor conducts in rhythm with the input signal. The output of the phototransistor is applied to one of four buffers in IC_2 . The buffered

digital MIDI signal is then available at the output of the relevant buffer.

Each output of IC_2 is applied to four multiplexing circuits, IC_6 – IC_9 . For instance, IC_{2a} is connected to pin 10, IC_{2b} to pin 11, IC_{2c} to pin 12 and IC_{2d} to pin 13 of these ICs. All four ICs are thus provided with the four MIDI signals applied to the inputs. It should be noted that only half of each IC is used in the present circuit. One half is disabled by a high level at pin 1; the other half is enabled by the signal at pin 15. The outputs (pin 9) of the ICs are linked to the associated MIDI output at all times. The four MIDI outputs are available at DIN buses K_5 – K_8 .

The output of HC devices can be used directly for generating the signal current in the MIDI. If standard TTL devices had been used, buffers would have been needed, since in these components the level of a logic low is not low enough, which would keep the currents in the MIDI connections below the required level.

Each multiplexing IC has two control inputs, A and B, that are driven by a 4-bit counter, IC_{14a} , IC_{14b} , IC_{15a} and IC_{15b} , of which only two bits, Q_0 and Q_1 , are used.

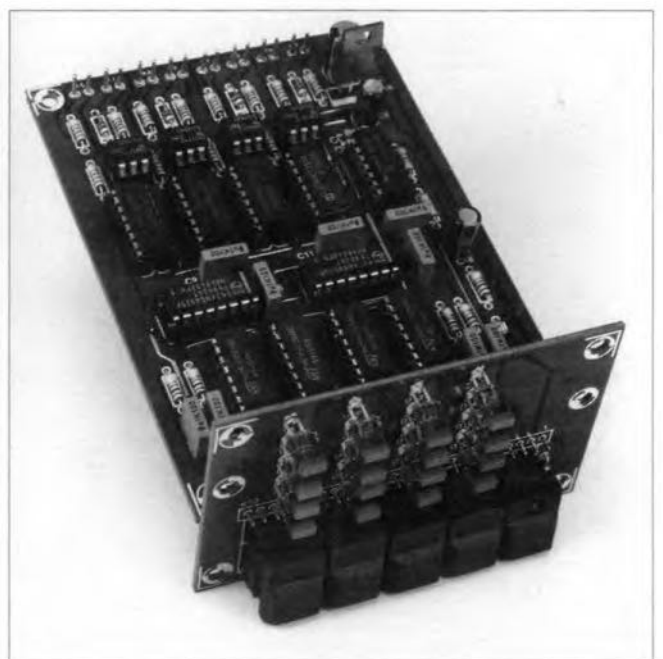
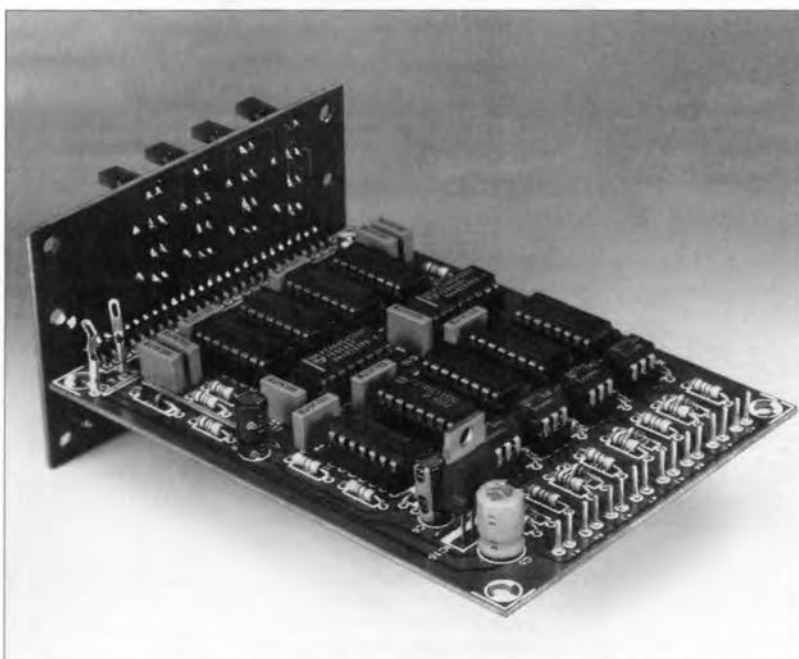


Fig. 1. Two views of the completed (prototype) boards; note the right-angle assembly of the boards.

the other switches is identical.

The control panel needs a supply voltage of +5 V. This is readily obtained from a 9–12 V mains adaptor which must be able to provide a current of not less than 100 mA. Supply on is indicated by an LED, D₂₁, in on/off switch S₅.

Construction

The circuit is intended to be built on the printed-circuit board shown in Fig. 3. Actually, it shows two board, which must be cut apart before construction is started. The smaller part is for the five push-button switches and associated 17 LEDs. The remainder of the circuit is housed on the larger part.

As usual, start by soldering the wire bridges, then the passive components and finally the active ones. The

soldering points for the MIDI connectors are neatly in a row at the rear of the board. It is advisable to fit soldering pins in these holes: the wires linking the points to the DIN buses are soldered to them later.

If a right-angle single-row pin-header is used for K₁, the two boards can be interconnected firmly as shown in the photographs of Fig. 1.

A suggested front panel for the enclosure into which the boards are fitted is shown in Fig. 4. Regrettably, the front panel foil is not available ready made.

When the supply voltage is switched on, the upper four LEDs indicate which interconnections have been made. The signal applied to K₁ is available at all four outputs. The various instruments are then interlinked by operating the relevant push-button

switches as appropriate.

Parts list

Resistors:

R₁, R₃, R₅, R₇, R₉–R₁₇ = 220 Ω
 R₂, R₄, R₆, R₈ = 4.7 kΩ
 R₁₈, R₁₉, R₂₁–R₂₃ = 10 kΩ
 R₂₀, R₂₄–R₂₆ = 330 Ω

Capacitors:

C₁–C₄, C₇–C₁₃ = 100 nF
 C₅ = 100 μF, 25 V
 C₆ = 10 μF, 25 V
 C₁₄ = 10 μF, 63 V

Semiconductors:

D₂–D₅ = 1N4148
 D₁, D₆–D₂₀ = LED, rectangular
 D₂₁ = LED, round, 3 mm (see text)
 D₂₂ = 1N4001

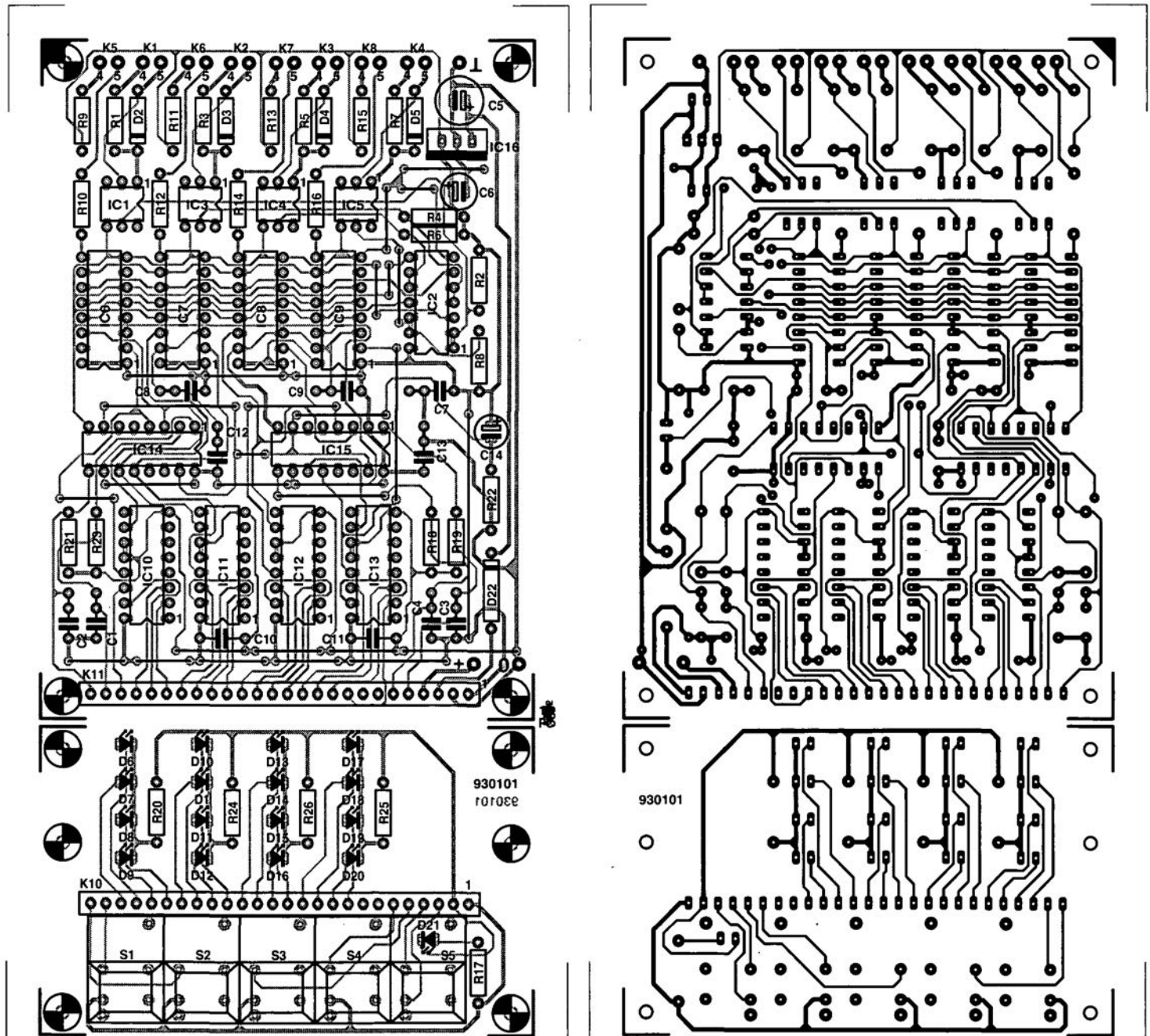
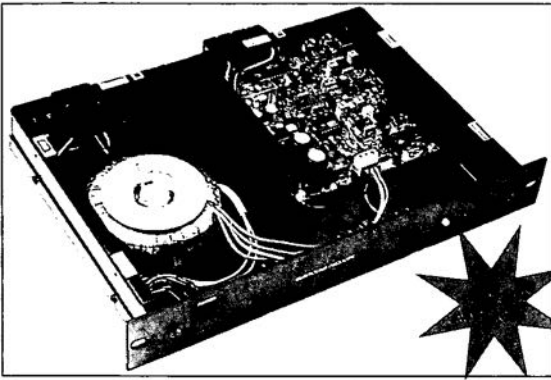


Fig. 3. Printed-circuit board for the midi multiplexor.

KITS AND COMPONENTS FOR ELEKTOR ELECTRONICS PROJECTS



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described in this issue.

Kit, incl. case and PCB, excl. mains transformer NLG 299.00, P&P 20.00

Individual parts also available:

2µF MKT 5mm	1.15	TL072CP	1.75
100pF polystyrene	2.45	NE571N	12.50
100nF ceramic	0.40	TL084CP	1.80
1µF MKT 5mm	0.95	TD1074A	15.00
4700µF 25V radial	3.75	TD2040	15.00
100µH choke	0.85	Phono socket, gold-plated	2.35
150µH choke	0.85	SB102	4.75
MV5491A	2.25	V23037-A2-A101 relay	9.75
NE5532N	1.90	SK57/37.5mm heatsink	29.50
MN3101	12.95	Ceramic washer AOS220	1.95
MN3008	65.00	Case ET32/04	54.00
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February 1994

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300µH 3A choke	5.50
B80C1500	4.00
TIC206D	1.80
SFH506-36	11.50
SAA3049	16.75
CNV65	4.65
SLB0587	9.75

MIDI multiplexer

Kit, incl. PCB and case 129.00
P&P 20.00

January 1994

1-to-3-phase converter

Kit, incl. case, PCB, GAL and EPROM 699.00
P&P 50.00

Mini audio DAC

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P&P 25.00

Polystyrene C's (1%)	2.45 each
2µF MKT 50V	1.95
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BAT85	0.85
B80C1500	4.00
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YM3623B	85.00
PCM1710U	90.00
74HC86	0.95
NE5532N	0.90
PCB terminal block	1.25
G2.3-FT12	4.75
VTR3209 transformer	27.50
16MHz crystal	4.10
11.2896 MHz crystal	9.75

V23042-A2005-B101 relay	12.50
Case ESM ET 24/04	39.00
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P&P 12.50

BAT85	0.85
HD11070	5.00
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80C31	21.50
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December 1994

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Many parts can be supplied. See our mini-catalogue for prices and availability

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T709G gold-plated socket	2.35
V23042-A2005-B101 relay	12.50
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July/August 1994

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SC80C451CCA68	39.50
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June 1994

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All parts also available separately.

B0C535 SBC KIT

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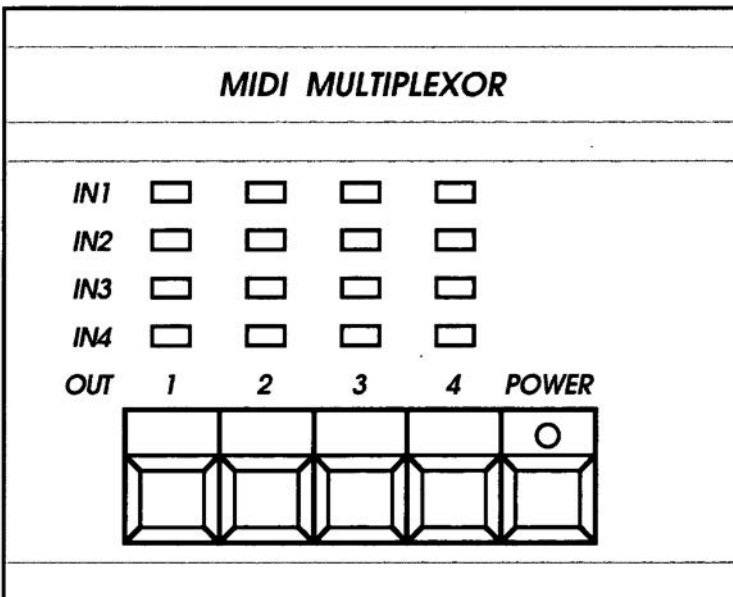
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Integrated circuits:

- IC₁, IC₃-IC₅ = CNY17-2
- IC₂ = 74HCT08
- IC₆-IC₉ = 74HC153
- IC₁₀-IC₁₃ = 4028
- IC₁₄, IC₁₅ = 4520
- IC₁₆ = 7805

Miscellaneous:

- K₁-K₈ = 5-way DIN socket for board mounting (180°)
- K₁₀ = 26-way, single-row pin header (90°)
- S₁-S₄ = Digitast switch
- S₅ = Digitast switch with hold contact and integral LED (D₂₁)
- Enclosure 80x100x130 mm (3¹/₈x4x5¹/₈ in)
- Plug to receive mains adaptor socket
- PCB Order No. 93010-1

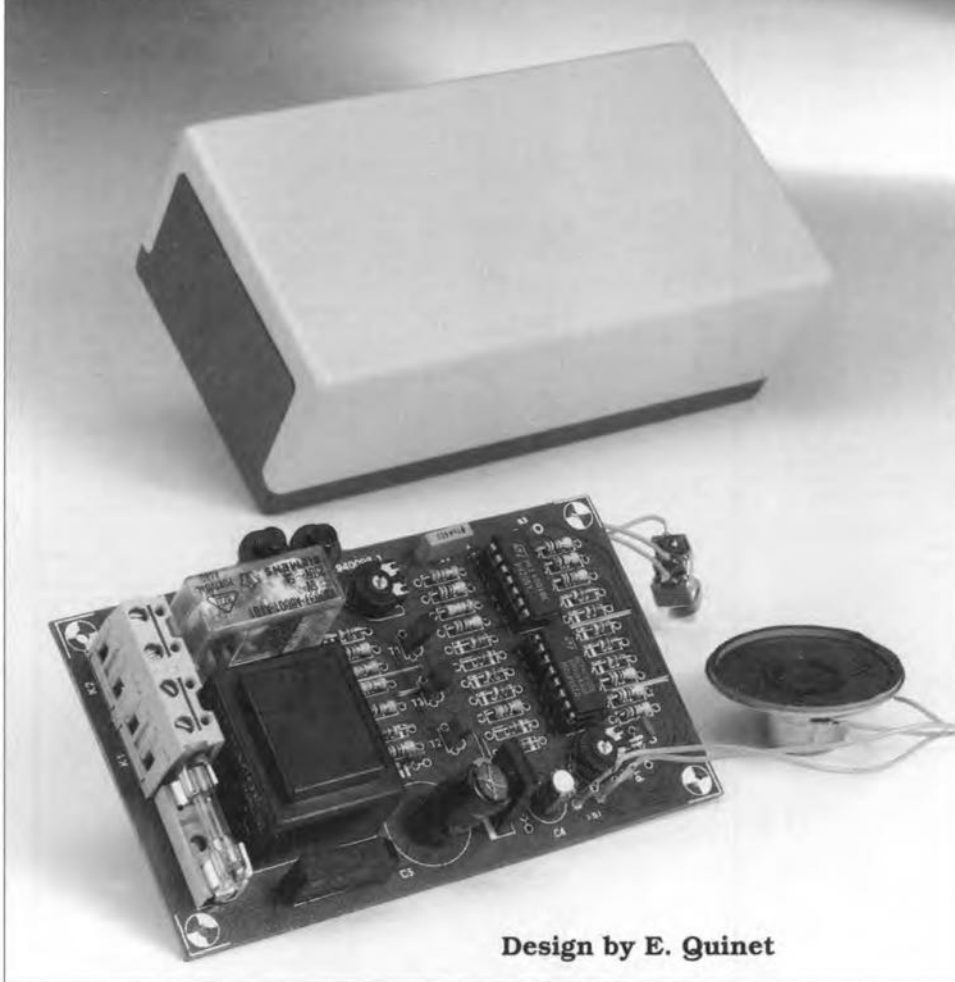
[930101]

930101-F

Fig. 4. Suggested front panel for the MIDI multiplexor.

AUTOMATIC LIGHTING TIMER

Few of you will be impressed by the fact that this circuit turns on a light if you press a switch. The thing is, however, that the light goes out automatically after a predetermined time. A useful feature is also that a signal sounds to warn you when the 'lights on' time is nearly over.



Design by E. Guinet

CIRCUITS such as this one are often used in hotels and restaurants. They serve only one purpose: saving on the electricity bill by cutting off the light in hallways, toilets and staircases when there is nobody around. In most cases, the switch takes the form of a push-button, and is fitted with a weak neon light to help you find in the dark. After pressing the switch, the lamp is switched on for a certain period, which, hopefully, is long enough to find your key and open the door of your hotel room. In most cases, that will work just fine. A visit to the toilet, however, can become an embarrassing experience if the relevant room is fitted with such a timer.

Still, the idea behind a lighting timer is not bad. After all, it also happens that lights in and around the home (hallway, staircase, cellar, recep-

tion hall, garage) are left on longer than strictly necessary. Such negligence causes money and energy to go to waste, and there is a clear point in favour of installing a lighting timer as described here at several places in the home. The negative aspects hinted at above are easily overcome by using a slightly larger 'on' time than the miserly one or two minutes one gets in hotels and the like. Moreover, if the switch is extended with an early warning signal, frustration and awkward situations will seldom occur.

A flipflop and a timer

The block diagram in **Fig. 1** shows the essential ingredients of the lighting timer: a push-button, a flipflop (bistable), a timer and a relay. The push-button is the light switch. When

it is pressed, the flipflop is set, and the relay is energized. At the same time, the complementary flipflop output clears the reset input of the timer, causing it to start its countdown cycle.

Just before the set timer period elapses, an oscillator is started which supplies an acoustic warning signal. When the full time has elapsed, the flipflop is reset via the last timer output, so that its outputs toggle to their original state. The relay is de-energized, the lighting is switched off, and remains off until the push-button is pressed again.

Circuit description

Figure 2 shows how the block diagram has been translated into a practical circuit. A few things have been added to make the circuit even more versatile and easier to use. One of these extras is the possibility to reset the flipflop manually. Also, the acoustic warning has been extended, and an option is added to enable automatic or normal use.

The result of the design work is shown in **Fig. 2**. The mains voltage arrives in the circuit via the terminals of K_1 , and is output again via K_2 , to which the lamp is connected. The lamp voltage is switched by the contact of relay Re_1 , which is controlled by driver T_2 and an S/R (set/reset) flipflop consisting of IC_{2c} and IC_{2d} . This flipflop is set by pressing S_1 , and reset by either the timer or S_2 . Network C_2 - D_{12} - R_{10} serves to reset the flipflop at power-on. Diodes D_8 and D_9 form a kind of bypass around the flipflop, allowing the user to press S_1 and so reset the timer while the light is on. This may be done to start another 'on' period, giving you extra time.

The timer is formed by the well-known 4060 oscillator/ripple counter (IC_1). The oscillator works with external parts P_1 , R_1 , R_2 and C_1 . The preset, P_1 , allows the oscillator frequency to be adjusted between about 7 Hz and 45 Hz, which results in a 'lights on' period of between 2 and 10 minutes.

The oscillator/counter is disabled by keeping its reset input logic high. When S_1 is pressed, the oscillator is started, and the binary counter starts at state '0'. When a counter state with Q_3 , Q_6 - Q_9 and Q_{11} high is reached just before the counting operation is ended, an AND gate consisting of diodes D_1 - D_6 ensures that oscillator IC_{2a} - IC_{2b} is started via D_7 and T_1 . The oscillator frequency is adjustable around 1 kHz with the aid of preset P_2 . The acoustic warning signal is made

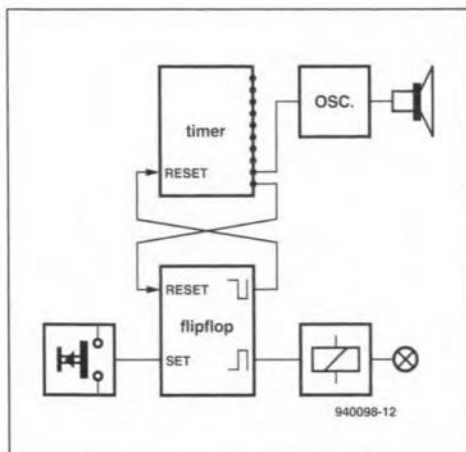


Fig. 1. The automatic lighting timer consists of only two functional blocks: an electronic switch and a timer. An acoustic signal is produced just before the 'on' time is over.

audible via transistor T_3 and loudspeaker LS_1 .

At the above mentioned counter state, four short beeps are produced in the rhythm of counter output Q_3 . These beeps indicate that the 'lights on' period is nearly over. They do, however, allow plenty of time to press the button again. If the button is not pressed, the remainder of the counter cycle is completed, and four beeps are produced again. After the last beep, Q_{12} goes high, causing the flipflop to be reset, and the relay to be de-energized.

Since it is desirable in some cases to be able to bypass the timer, switch S_3 has been added to the circuit. In position 'A', the relay driver transistor, T_2 , is driven all the time via R_{16} . Consequently, the light is on all the time, irrespective of the states of the flipflop and the counter. In position 'C', the base of T_2 is tied to ground, so that the light is always out. If you do not need the bypass function, simply omit switch S_3 .

The power supply has no surprises. It consists of a transformer, Tr_1 , a rectifier, B_1 , a smoothing capacitor, C_5 , a three-pin voltage regulator, IC_3 , and a pair of decoupling capacitors, C_3 - C_4 .

Diode AND gate

The operation of the diode AND gate which provides the early warning function of the circuit deserves a separate discussion. To begin with, however, let us have a look at the designations of the outputs of counter IC_1 , since these have given rise to a lot of confusion in the past.

This confusion is caused mainly by nomenclature differences between manufacturers of the 4060 (SGS, Motorola, Philips, National Semicon-

ductor, etc.). Surprisingly, the frequency at the counter output marked 'Q3' is the clock frequency divided by 16, and not, as one would expect, 8 (2^3). It is true, however, that the 'high' and 'low' periods of the Q3 output equal eight clock periods. That is a point to remember if a time interval is to be created with the aid of a diode-AND gate, as in the present case.

The output of the AND gate is formed by the anodes of the six diodes. Transistor T_1 starts to conduct if Q_{11} , Q_9 , Q_8 , Q_7 , Q_6 and Q_3 are all logic high at the same time. That happens after the following number of clock cycles:

$$2.048 + 512 + 256 + 128 + 64 + 8 = 3.016.$$

Since the counter has a total of 4,096 states, the early warning sounds at about three-quarters of the available time. The absence of Q_5 and Q_6 in the above 'AND' series causes the four beeps produced by the loudspeaker, while the absence of Q_{10} on the 4060 provides the division between the first and the second state of four beeps. The end of the 'light on' period is reached when counter output Q_{12} goes high. That happens after exactly 4,096 clock cycles.

Construction

The artwork of the printed circuit board used to build the lighting timer

is shown in Fig. 3. This PCB is available ready-made through the Readers Services. The board accommodates all components, except the switches and the loudspeaker.

Since the circuit is connected to the mains, special attention should be given to safety. Terminal blocks K_1 and K_2 should be mains-rated types. The mains and lamp wires connected to these blocks should be fitted with approved grommets and strain reliefs. The enclosure used may only be plastic type with the appropriate insulation specifications as regards mains-powered equipment. The loudspeaker and the control elements, S_1 , S_2 and (optionally) S_3 , may be fitted on the cover plate. The connections of these external parts are clearly marked on the printed circuit board overlay. Since only small currents are carried by these wires, ordinary light-duty insulated wire may be used.

Adjustments

The circuit has two adjustment points in the form of presets on the board. The most important of the two is P_1 , which determines the oscillator clock frequency, and thus the length of the 'light on' period. This preset is best adjusted empirically until the desired 'on' time is reached. The relevant component values shown in the circuit diagram and the parts list result in a period which is adjustable between 2

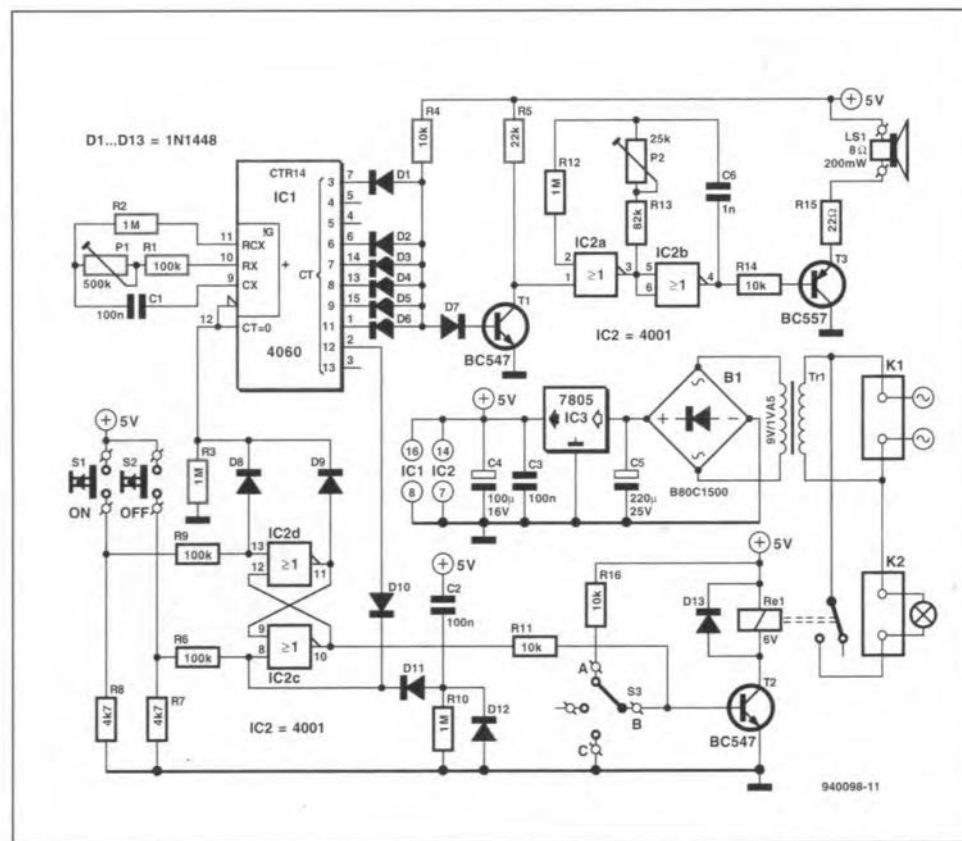


Fig. 2. Circuit diagram of the automatic lighting timer.

COMPONENTS LIST

Resistors:

R1;R6;R9 = 100k Ω
 R2;R3;R10;R12 = 1M Ω
 R4;R11;R14;R16 = 10k Ω
 R5 = 22k Ω
 R7;R8 = 4k Ω
 R13 = 82k Ω
 R15 = 22 Ω
 P1 = 500k Ω preset H
 P2 = 25k Ω preset H

Capacitors:

C1;C2;C3 = 100nF
 C4 = 100 μ F 16V radial
 C5 = 220 μ F 25V
 C6 = 1nF

Semiconductors:

D1-D13 = 1N4148
 B1 = B80C1500*
 T1;T2 = BC547
 T3 = BC557
 IC1 = 4060
 IC2 = 4001
 IC3 = 7805

Miscellaneous:

K1;K2 = 2-way PCB mount terminal block, raster 7.5mm.
 S1;S2 = push-to-make button.
 S3 = 1-pole 3-position switch.
 Tr1 = mains transformer, 9V, 1.5VA, short-circuit proof (e.g., Block VR1109 or Monacor VTR1109)*.
 Ls1 = loudspeaker, 8 Ω , 0.2W.
 Re1 = V23057-A1-A101 (coil voltage: 6V) (Siemens).
 Printed circuit board, order code 940098 (see page 78).

* C-I Electronics, P.O. Box 22089, NL-6360 AB, Nuth, Holland. Fax: (+31) 45 241877.

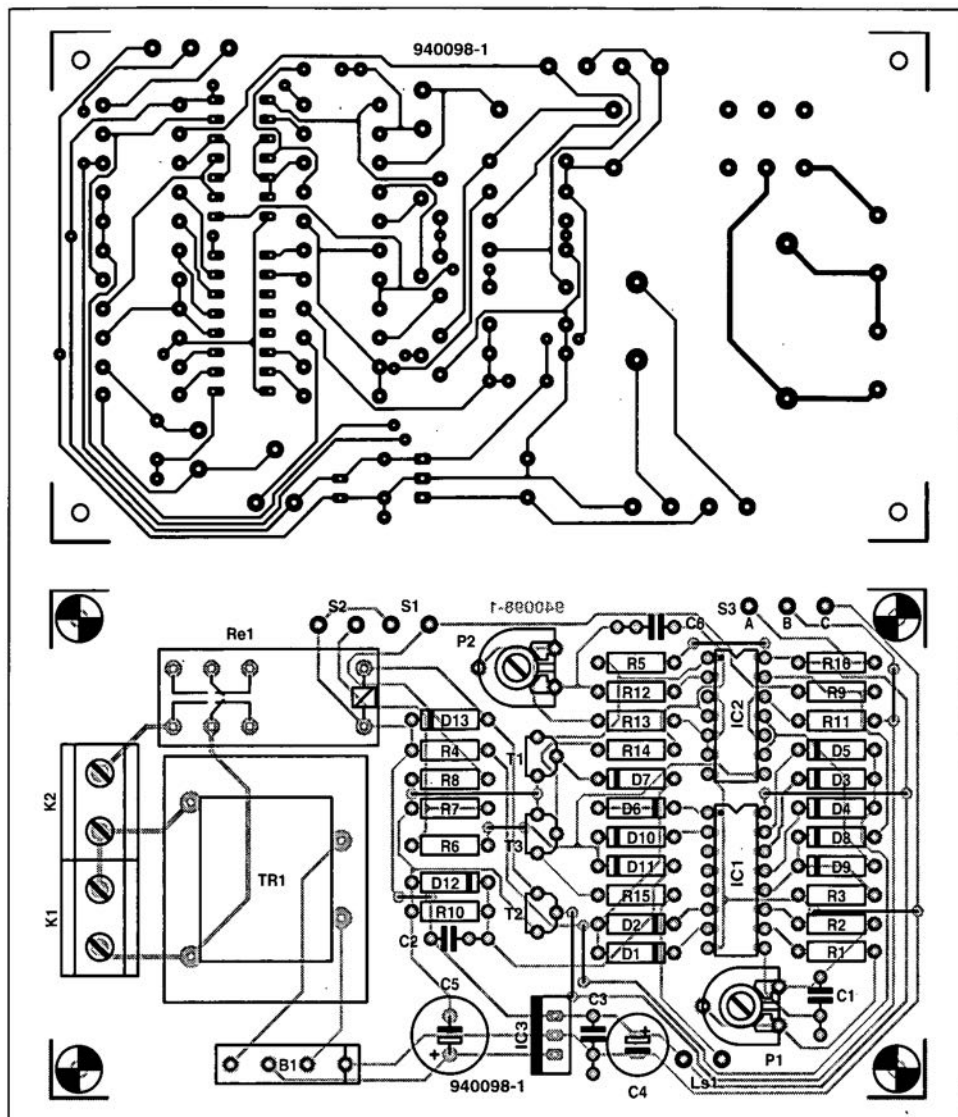
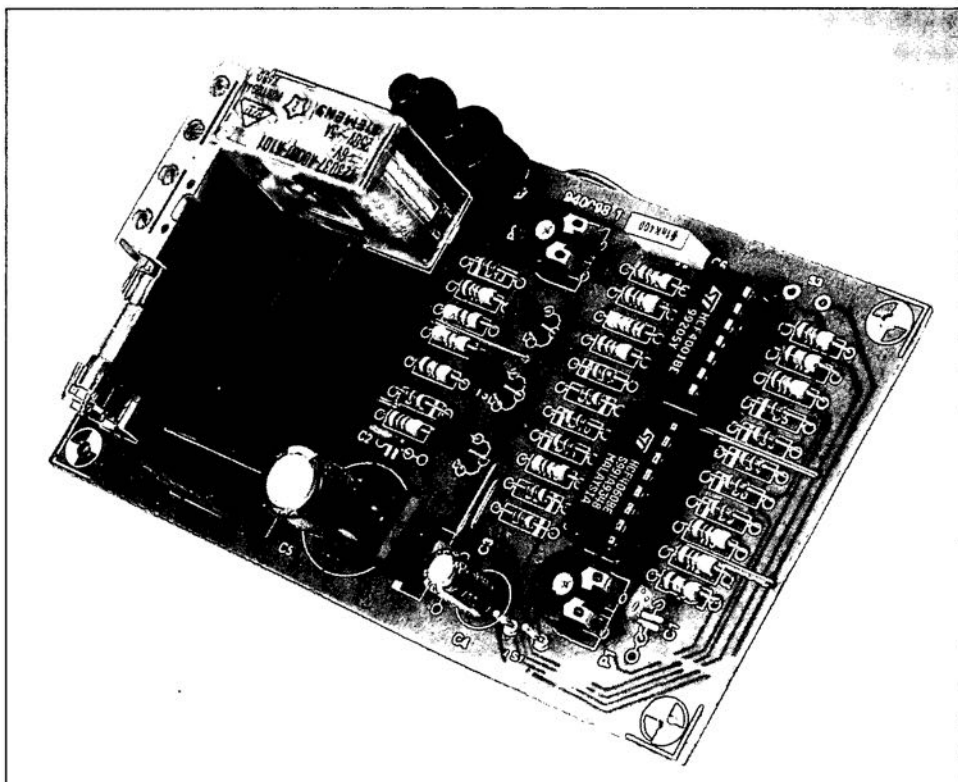


Fig. 3. Track layout and component mounting plan (overlay) of the PCB designed for the lighting timer (PCB available ready-made through the Readers Services).



and 10 minutes. If you find 10 minutes too short, C₁, R₁ and/or P₁ may be made a little larger. If you want a period of less than 2 minutes, give these components a smaller value.

The frequency of the acoustic warning signal is adjusted with the aid of preset P₂. Temporarily interconnect the collector and emitter terminals of T₁, so that the oscillator is permanently on. Then adjust P₂ until the desired tone frequency is obtained. Finally, a tip. If a certain application requires more 'on' and 'off' buttons at different locations, the appropriate number of switches may be connected in parallel with S₁ and S₂. (940098)

SURROUND SOUND PROCESSOR

Based on a design by D. Laues

The processor described in this article expands the sound of an existing stereo TV receiver or audio installation with a centre channel and a surround channel. It does not use special Dolby ICs. Additional output amplifiers are not needed, because they are provided in the processor.



Creating surround sound in a domestic room can be approached in two ways: by a processor that generates the four signals required: left-hand, right-hand, centre and surround, or by one that adds the two missing channels, that is, centre and surround, to the existing stereo sound. The first is the most elegant, but also the most complicated and most expensive. Moreover, it requires an additional line to return the left-hand and right-hand signals to the input of the TV/audio equipment. The second way is much more straightforward and has proved in practice to give an excellent spatial effect. Moreover, it can be accomplished in a compact and fairly inexpensive unit. The design in this article is of the second kind.

The basic setup in a domestic room is shown in Fig. 1. The left-hand and right-hand channels are reproduced as before, that is, via the loudspeakers in the TV receiver, as shown, or by those of the audio installation to which the TV receiver is connected. The extra items are the processor and three loudspeakers. The inputs of the processor are linked, possibly via the SCART connector, with the line out terminal of the TV receiver, or audio amplifier, while the extra loudspeakers are connected to the outputs of the processor. The processor contains two integral amplifiers each of which provides 20 W output into 4 Ω : quite sufficient for the centre and surround loudspeakers.

As briefly discussed in last month's article on Dolby surround sound, the additional loudspeakers need be no more than compact (bookcase type) hi-fi types that are not too expensive. If possible, however, choose types whose efficiency is about the same as that of the main loudspeakers: this affords rather more freedom when the system is set up as a whole.

Basic design

A block diagram of the basic design is given in Fig. 2. The design of the processor is similar to that of the active decoder discussed in last month's article on Dolby surround sound. There are some differences between the two, since the present processor not only functions as a decoder, but also provides the signals for the centre and surround channels and contains two output amplifiers.

As explained last month, the two additional channels are processed (whence the name of the unit) from the sum and difference of the two stereo channels. The centre channel is the simpler to produce, because it suffices to add the left-hand and right-hand channels together and apply the sum to a suitable output amplifier via a voltage-controlled amplifier (VCA).

To produce the surround signal, the right-hand signal is deducted from the left-

hand signal (or vice versa) and the resulting signal is applied to a delay network via a low-pass filter. The delay can be preset between 10 ms and 30 ms. The signal is then applied to an expander via a band-pass filter. The expander is essential because the surround signal is compressed during recording. The output of the expander is applied to a second output amplifier via a VCA.

The dynamic compensating network, in conjunction with the VCAs, reflects the difference between an active and a passive (matrix) design. In this network, the correlation between the two stereo channels is analysed continuously. The results of the analysis are converted into control signals for the VCAs which constantly adjust the levels of the centre and surround signals. This arrangement ensures a much larger channel separation than possible with a passive design.

Centre channel

From the inputs of the left-hand and right-hand channels, K_1 and K_2 in Fig. 5, the signals are taken via buffer amplifiers IC_{1a} and IC_{1b} to R_{51} and R_{52} , and then summed in preset P_6 . From there, the signal is applied to pin 5 of IC_9 . This IC contains four electronic potentiometer circuits (of which only two are used) which function as VCAs; their amplification is governed by a control voltage at pins 9 and 10. The output of one of the circuits is available at pin 7, from where it is applied to output amplifier IC_{10} . This circuit provides an output of up to 20 W into 4 Ω .

The output of IC_{10} is applied to the centre channel loudspeaker via relay contact Re_{1b} . The relay is controlled by a simple delay circuit, T_1 , and obviates any clicks and plops in the speaker caused by the switching on and off of the processor.

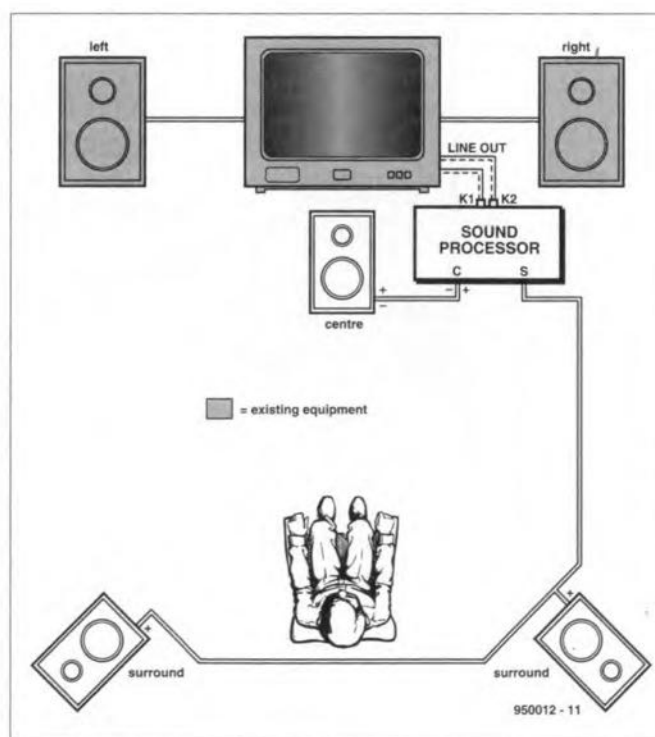


Fig. 1. Basic setup of a surround sound system in a living room.

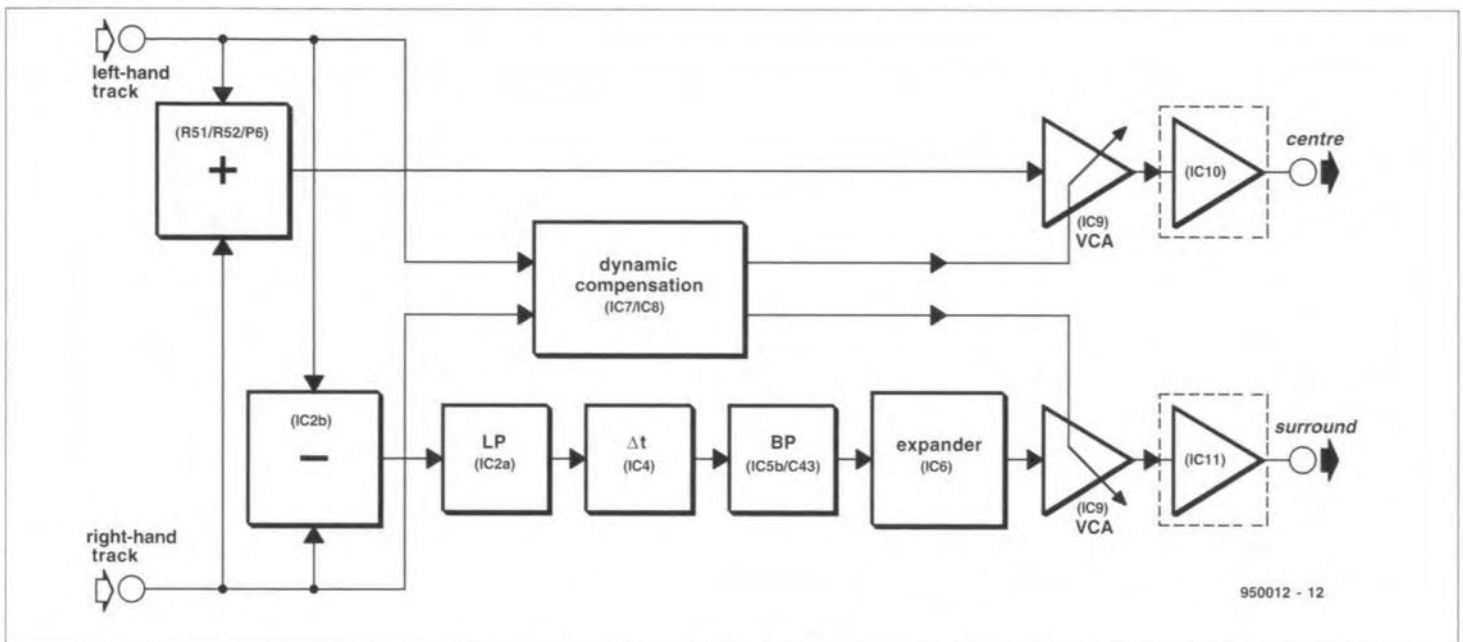


Fig. 2. Block diagram of the surround sound processor.

Surround channel

The signals at the outputs of IC_{1a} and IC_{1b} are also applied to the inverting and non-inverting inputs of IC_{2b} respectively, so that the output of the op amp is the difference of the two stereo signals (L-R). The difference signal is applied to a 4th-order low-pass filter based on IC_{2a} , which limits its upper bandwidth to 7 kHz. This anti-aliasing filtering serves to obviate the formation of spurious mixing products of the signal and the clock of the following delay line, which is based on IC_4 . This IC is a 2048-stage bucket brigade device. The rate at which the internal electronic switches are operated is determined by IC_3 . This CMOS-IC is designed especially to generate a low-impedance, double-phase clock. The specified values of its frequency-determining components, R_{15} , R_{16} , C_9 and P_1 allow a delay between 10 ms

and 30 ms to be set with P_1 .

The outputs of IC_4 are applied via buffer IC_{5a} to a low-pass filter based on IC_{5b} (identical to that based on IC_{2a}) which filters out any residue of the clock signal. The cut-off frequency is 7 kHz. The signal is subsequently fed to compander IC_6 , whose input network contains a high-pass filter, $R_{55}-C_{43}$, the specified values of which give a lower cut-off frequency of about 50 Hz. The overall effect of the low-pass and high-pass filters is, of course, that of a band-pass filter as shown in Fig. 2.

The compander IC contains two circuits each consisting of a rectifier, a variable gain cell and an op amp. In the present processor only one of these circuit is used and that as an expander. The values of external components $R_{27}-R_{32}$ and $C_{23}-C_{29}$ allow for an expansion factor of 1:1.3.

The surround signal is then applied to

the second electronic potentiometer circuit in IC_9 , whose output is available at pin 17. From there, the signal is fed to output amplifier IC_{11} , whose amplification is identical to that of IC_{10} . The output of IC_{11} is applied to the surround loudspeaker(s) via a second contact on Re_1 .

Dynamic compensation

The outputs of buffers IC_{1a} and IC_{1b} are also applied to twin comparators IC_{7b} and IC_{7c} via C_{31} and C_{32} . The output of each of these comparators is a rectangular voltage the frequency of which is a measure of the variation in the relevant input signal. Both outputs are applied to XOR gate IC_{8c} . (Remember that an XOR gate has an output only when its inputs are dissimilar). Integration of the output pulses of the gate by $R_{37}-C_{36}$ results in a direct voltage whose amplitude is a measure of

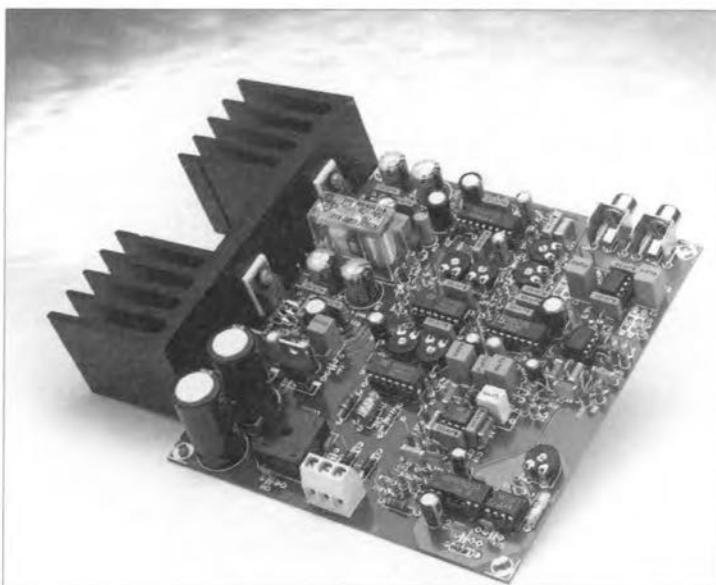


Fig. 3. Completed prototype board.

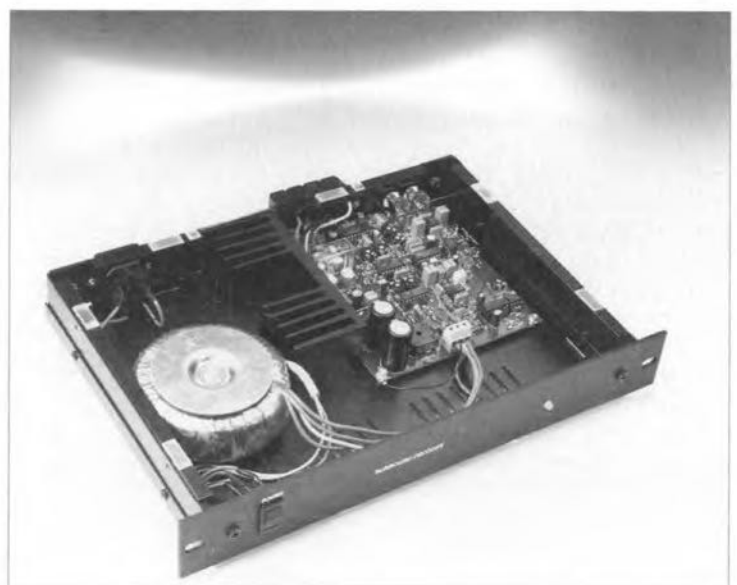


Fig. 4. Completed prototype processor.

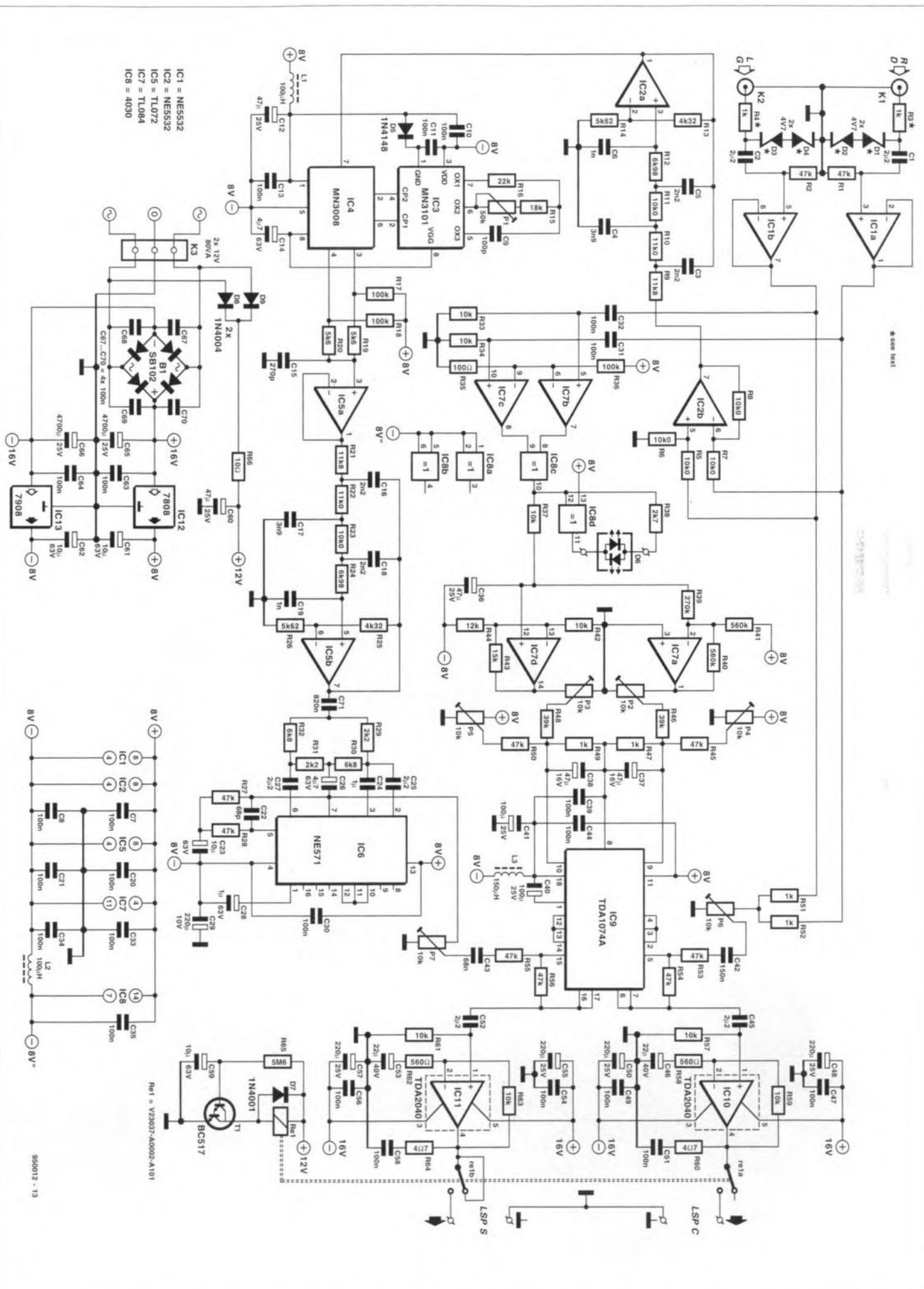


Fig. 5. Circuit diagram of the surround sound processor.

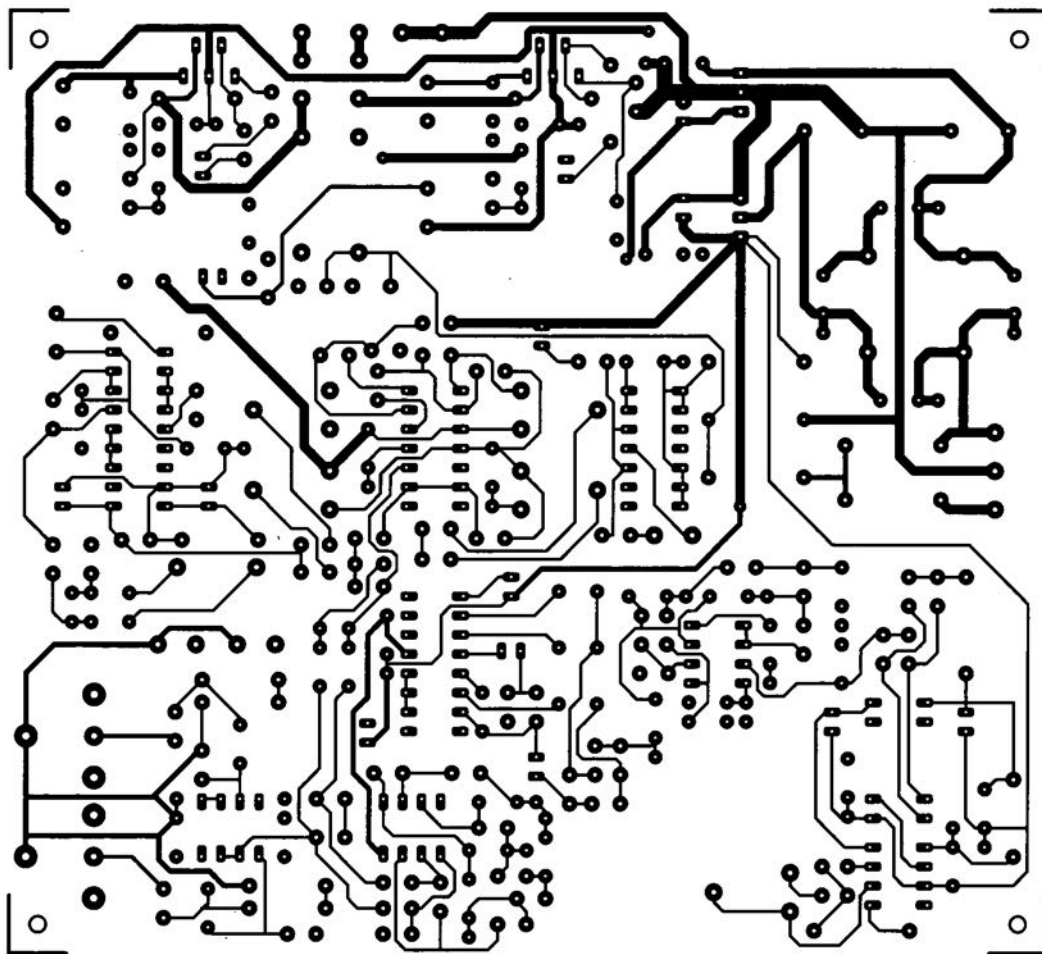
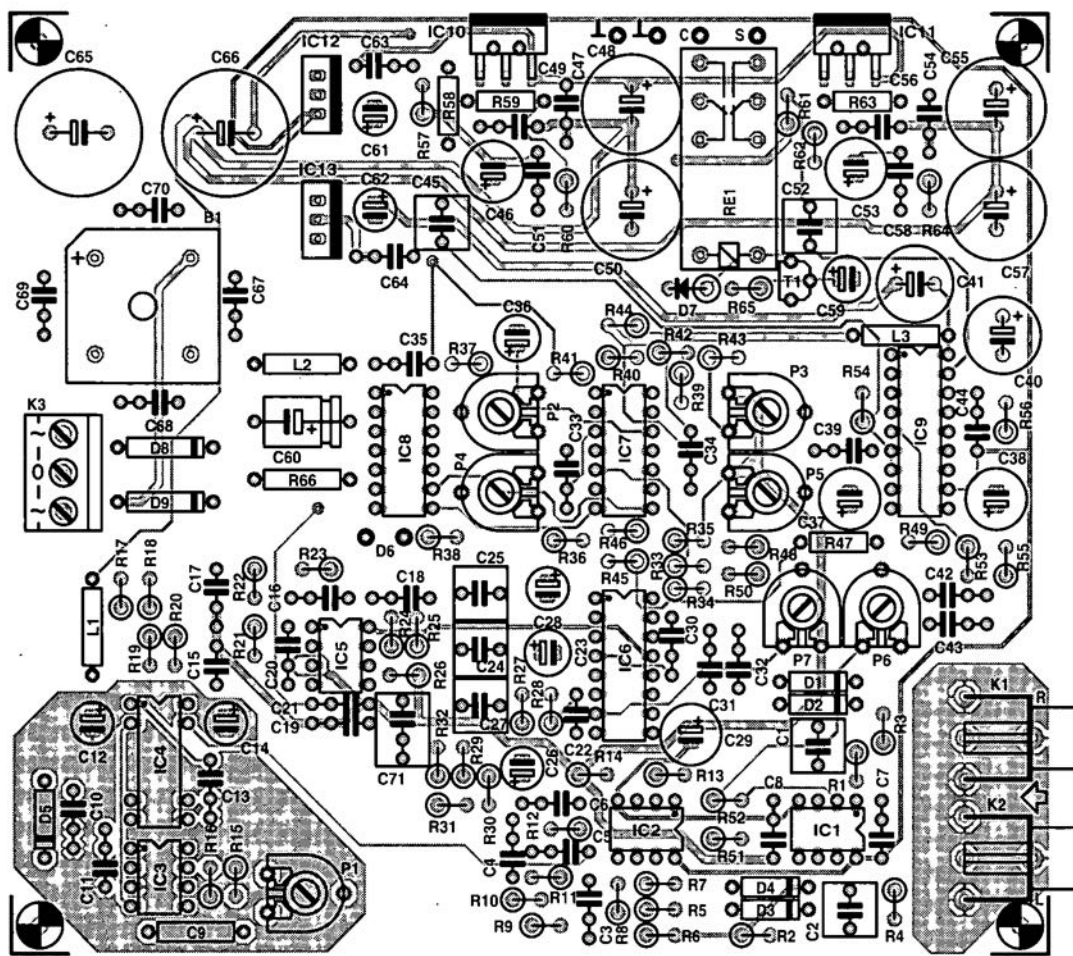


Fig. 6. Printed-circuit board for the surround sound processor. (See also next page)

the phase difference between the two stereo signals.

This direct voltage is applied via IC_{7a} (inverted) and IC_{7d} (non-inverted) to the control inputs (pins 9 and 10) of IC₉. This arrangement ensures that when a mono signal is present at the inputs (no or hardly any phase difference), the amplification of the VCA controlling the centre channel is raised. Conversely, when a surround signal is present (large phase difference), the amplification of the VCA controlling the surround channel is increased.

The degree to which the amplification of the VCAs is influenced by the control signals is preset by P₂ and P₃. When the wipers of these controls are at earth potential, the amplification is fixed; when they are at the opposite end of their travel, control is maximum.

Presets P₄ and P₅ serve to shift the operating point of the VCAs to some extent. They thus make the preset range wider and, in fact, support the operation of P₆ and P₇. If, for instance, P₇ has already set the surround level to maximum, P₅ enables this to be increased slightly. The same applies to P₄ insofar as the level of the centre channel preset with P₆ is concerned.

The currents through R₄₅ and R₄₆ and those through R₄₈ and R₅₀ are simply added together: there is, therefore, no interaction between P₂ and P₄ nor between P₃ and P₅.

Further circuit details

Resistors R₃ and R₄ and diodes D₁-D₄ limit the level of the input signal to a safe value and are imperative if the stereo signals are taken from the loudspeaker outputs of the TV receiver. Note that even line out terminals sometimes provide a signal at a level well above 1 V. If it is absolutely certain that the line output level is 1 V, and this is the only input, the resistors can be replaced by a wire bridge and the diodes may be omitted.

Bi-colour LED D₆ functions as a kind of signal monitor that shows the change from surround channel to centre channel and vice versa. In the case of a surround signal, the output of IC_{8c} is high. Since

one output of IC_{8d} is at +8 V, both inputs of this XOR are then high, so that its output is low. This results in the red segment of D₆ lighting. In the case of a centre signal, pin 12 of IC_{8d} is low, so that its output is high, resulting in the green segment of D₆ lighting. In practice, the changes between the signal are so rapid that the LED shows a fluent transition from red to green and back to red again.

The power supply provides three different voltages. The secondary of the mains transformer is connected to K₃. The 12 V input, after rectification and smoothing, results in a symmetrical supply of ± 16 V, which is used to power output amplifiers IC₁₀ and IC₁₁.

From the ± 16 V lines, voltage regulators IC₁₂ and IC₁₃ derive a supply of ± 8 V, which is used to power the remainder of the circuit.

The 12 V line for the relay is taken directly from K₃ and rectified by D₈-D₉.

Construction

The processor is best constructed on the PCB illustrated in Fig. 6. Since this board is double sided and through-plated, it is not possible to make it without special tools and equipment.

Populating the board is straightforward and should not present undue difficulties. Note that when the specified enclosure is used, capacitors C₆₅ and C₆₆ must be not higher than 38-40 mm.

Use gold-plated connectors for K₁ and K₂ to ensure good, lasting connections. The positions for these connectors are at the edge of the board so that all that is necessary when fitting the board into the enclosure is drilling a few holes in the back

panel through which these sockets can protrude. Note that they must not touch the enclosure.

Output amplifiers IC₁₀ and IC₁₁ are located at the edge of the board so that they can be fitted readily to a heat sink. The ICs must be electrically isolated from the heat sink by ceramic washers and heat conducting paste.

The photograph in Fig. 3 shows the completed prototype board.

The main requirements of the enclosure are that it is made of metal and that it provides adequate space for the finished board.

Apart from K₁ and K₂, fit suitable sockets or spring-loaded terminals at the back of the enclosure for connecting the centre and surround loudspeakers. Link these terminals with heavy-duty insulated wire to points 'C' and 'S' and the adjacent earthing points on the board. The specified mains entry with integral fuse holder should also be fitted at the back of the enclosure.

The mains on/off switch and D₆ should be fitted at the front panel (for which a ready-made foil is not available). The diode should be connected to the relevant points on the board via lengths of flexible

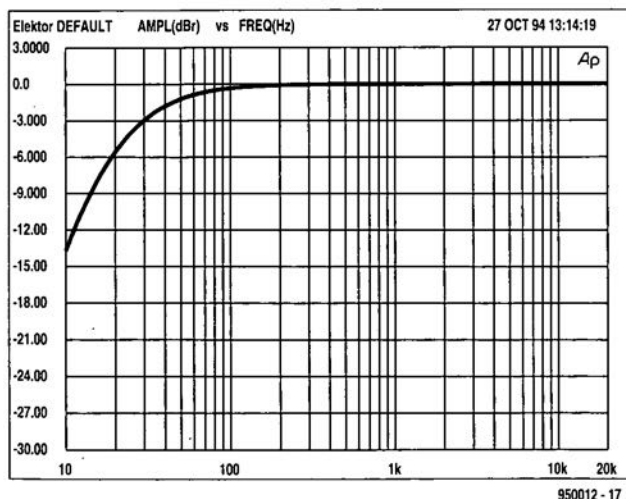
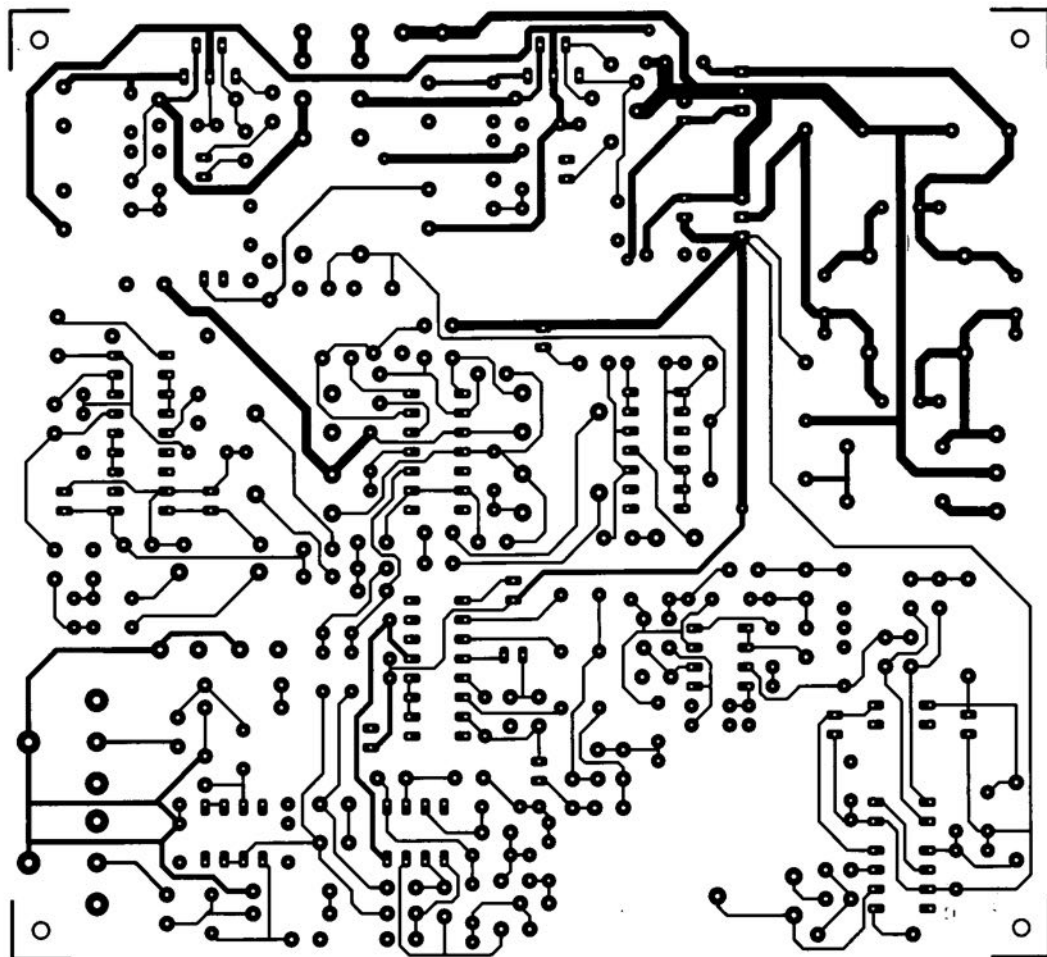


Fig. 7. Frequency response of the centre channel.

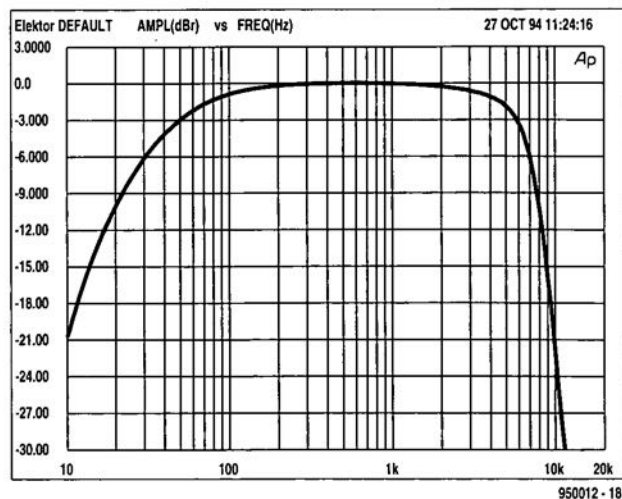


Fig. 8. Frequency response of the surround channel.

stranded wire.

Finally, link the centre pin of K_3 to the mass of the enclosure with the aid of a solder tag.

The completed prototype is shown in the photograph of **Fig. 4**.

The output amplifiers are suitable for operation with load impedances $\geq 4 \Omega$, but not lower ones. Thus, for the surround channel, two 8Ω loudspeakers may be connected in parallel only if it is absolutely certain that the impedance is 8Ω . If it is not, connect the speakers in series: this is safer. It is essential that the two speakers are in phase: the +terminals must go to the same terminal on the board; whether this is earth or 'S' does not matter.

The centre loudspeaker must be in phase with the main speakers. Since the relevant VCA functions as an inverter, the +terminal of this speaker must be connected to the earth point on the board; the -terminal to point 'C'.

Calibration

Start by setting presets P_2 - P_7 to the centre of their travel, and P_1 to maximum (fully clockwise).

Inject a (mono) speech signal and adjust P_6 until the sound appears to come from the centre speaker. Wait for a surround signal (indicated by the red segment of D_6 lighting) and turn P_7 till sound emanates from the surround speakers. Do not set the level too high, because this leads quickly to an exaggerated effect. If, however, it is felt that the desired level can not be obtained with P_6 or P_7 , as the case may be, adjust P_4 or P_5 , or both, as required.

Next, create a spatial effect by slowly turning P_2 and P_3 until the centre channel and the surround channel seem well 'separated'. It is more than likely that P_6 and/or P_7 must then be readjusted. Note that these controls give an instinctive 'wrong' feel: turning them clockwise reduces the level.

If the surround speakers give exaggerated reverberation, reduce the delay with P_1 . In the average living room, a delay of 25 ms appears correct: this corresponds to P_1 being almost at its maximum setting.

Do not be surprised if after watching and listening to a number of films, some readjustment of the controls are found desirable.

Characteristics

The curves in **Fig. 7** and **8** show the amplitude vs frequency characteristics of the centre channel and surround channel respectively. The curves were obtained with an audio analyser. It is evident that they correspond closely with the descriptions. The -3 dB point of the centre channel is at 30 Hz. The -3 dB points of the surround channel are at 50 Hz and

6 kHz; the -6 dB bandwidth is roughly 30 Hz to 7 kHz.

Figure 8 shows that it does not make sense to use tweeters with a linear characteristic up to 20 kHz for the surround channels.

Both curves make it clear that a subwoofer must be connected to the main channels and not to the centre channel or surround channel.

Parts list

Resistors:

$R_1, R_2, R_{27}, R_{28}, R_{45}, R_{50}, R_{53}$ - $R_{56} = 47 \text{ k}\Omega$
 $R_3, R_4 = 1 \text{ k}\Omega$ (see text)
 R_5 - $R_8, R_{11}, R_{23} = 10.0 \text{ k}\Omega, 1\%$
 $R_9, R_{21} = 11.8 \text{ k}\Omega, 1\%$
 $R_{10}, R_{22} = 11.0 \text{ k}\Omega, 1\%$
 $R_{12}, R_{24} = 6.98 \text{ k}\Omega, 1\%$
 $R_{13}, R_{25} = 4.32 \text{ k}\Omega, 1\%$
 $R_{14}, R_{26} = 5.62 \text{ k}\Omega, 1\%$
 $R_{15} = 18 \text{ k}\Omega$
 $R_{16} = 22 \text{ k}\Omega$
 $R_{17}, R_{18}, R_{36} = 100 \text{ k}\Omega$
 $R_{19}, R_{20} = 5.6 \text{ k}\Omega$
 $R_{29}, R_{31} = 2.2 \text{ k}\Omega$
 $R_{30}, R_{32} = 6.8 \text{ k}\Omega$
 $R_{33}, R_{34}, R_{37}, R_{42}, R_{57}, R_{59}, R_{61}, R_{63} = 10 \text{ k}\Omega$
 $R_{35} = 100 \Omega$
 $R_{38} = 2.7 \text{ k}\Omega$
 $R_{39} = 270 \text{ k}\Omega$
 $R_{40}, R_{41} = 560 \text{ k}\Omega$
 $R_{43} = 15 \text{ k}\Omega$
 $R_{44} = 12 \text{ k}\Omega$
 $R_{46}, R_{48} = 39 \text{ k}\Omega$
 $R_{47}, R_{49}, R_{51}, R_{52} = 1 \text{ k}\Omega$
 $R_{58}, R_{62} = 560 \Omega$
 $R_{60}, R_{64} = 4.7 \Omega$
 $R_{65} = 5.6 \text{ M}\Omega$
 $R_{66} = 10 \Omega$
 $P_1 = 50 \text{ k}\Omega$ preset
 P_2 - $P_7 = 10 \text{ k}\Omega$ preset

Capacitors:

$C_1, C_2, C_{25}, C_{27}, C_{45}, C_{52} = 2.2 \mu\text{F}$, polypropylene, pitch 5 mm
 $C_3, C_5, C_{16}, C_{18} = 2.2 \text{ nF}$
 $C_4, C_{17} = 3.9 \text{ nF}$
 $C_6, C_{19} = 1 \text{ nF}$
 $C_7, C_8, C_{20}, C_{21}, C_{30}$ - $C_{34}, C_{39}, C_{44}, C_{47}, C_{49}, C_{51}, C_{54}, C_{56}, C_{58} = 100 \text{ nF}$
 $C_9 = 100 \text{ pF}$ polystyrene, axial
 $C_{10}, C_{11}, C_{13}, C_{35}, C_{63}, C_{64}, C_{67}$ - $C_{70} = 100 \text{ nF}$, ceramic
 $C_{12}, C_{36}, C_{60} = 47 \mu\text{F}, 25 \text{ V}$, radial
 $C_{14}, C_{26} = 4.7 \mu\text{F}, 63 \text{ V}$, radial
 $C_{15} = 270 \text{ pF}$
 $C_{22} = 68 \text{ pF}$
 $C_{23}, C_{59}, C_{61}, C_{62} = 10 \mu\text{F}, 63 \text{ V}$, radial
 $C_{24} = 1 \mu\text{F}$, polypropylene, pitch 5 mm
 $C_{28} = 1 \mu\text{F}, 63 \text{ V}$, radial
 $C_{29} = 220 \mu\text{F}, 10 \text{ V}$, radial
 $C_{37}, C_{38} = 47 \mu\text{F}, 16 \text{ V}$, radial
 $C_{40}, C_{41} = 100 \mu\text{F}, 25 \text{ V}$, radial
 $C_{42} = 150 \text{ nF}$
 $C_{43} = 68 \text{ nF}$
 $C_{46}, C_{53} = 22 \mu\text{F}, 40 \text{ V}$, radial
 $C_{48}, C_{50}, C_{55}, C_{57} = 220 \mu\text{F}, 25 \text{ V}$, radial
 $C_{65}, C_{66} = 4700 \mu\text{F}, 25 \text{ V}$, radial
 $C_{71} = 820 \text{ nF}$

Inductors:

$L_1, L_2 = 100 \mu\text{H}$
 $L_3 = 150 \mu\text{H}$

Semiconductors:

D_1 - $D_4 =$ zener diode, 4.7 V
 $D_5 = 1\text{N}4148$
 $D_6 =$ bi-colour LED (green/red)
 $D_8, D_9 = 1\text{N}4004$
 $B_1 = \text{SB}102, 10 \text{ A}, 100 \text{ V}$, for PCB mounting
 $T_1 = \text{BC}517$

Integrated circuits:

$IC_1, IC_2 = \text{NE}5532$
 $IC_3 = \text{MN}3101$
 $IC_4 = \text{MN}3008$
 $IC_5 = \text{TL}072$
 $IC_6 = \text{NE}571$
 $IC_7 = \text{TL}084$
 $IC_8 = 4030$
 $IC_9 = \text{TDA}1074\text{A}$
 $IC_{10}, IC_{11} = \text{TDA}2040$
 $IC_{12} = 7808$
 $IC_{13} = 7908$

Miscellaneous:

$K_1, K_2 =$ audio socket for PCB mounting
 $K_3 = 3$ -way terminal block, pitch 5 mm
 $Re_1 =$ relay 12 V, 5 A, 270 Ω
 Heat sink SK57, 37.5 mm high*
 Ceramic washers Type AOS220*
 Enclosure 300x45x210 mm (WxHxD)
 ($11\frac{7}{8} \times 1\frac{3}{4} \times 8\frac{1}{4}$ in)
 Mains transformer with 2x12 V, 80 VA secondary
 Mains entry with integral fuse holder and 500 mA slow fuse
 Loudspeaker terminals (spring loaded) or suitable audio sockets
 Mains on/off switch
 PCB Order No. 950012-1

[950012]

* Available from Dau (UK) Ltd, 70-75 Barnham Road, Barnham PO22 0ES, telephone (01243) 553 031

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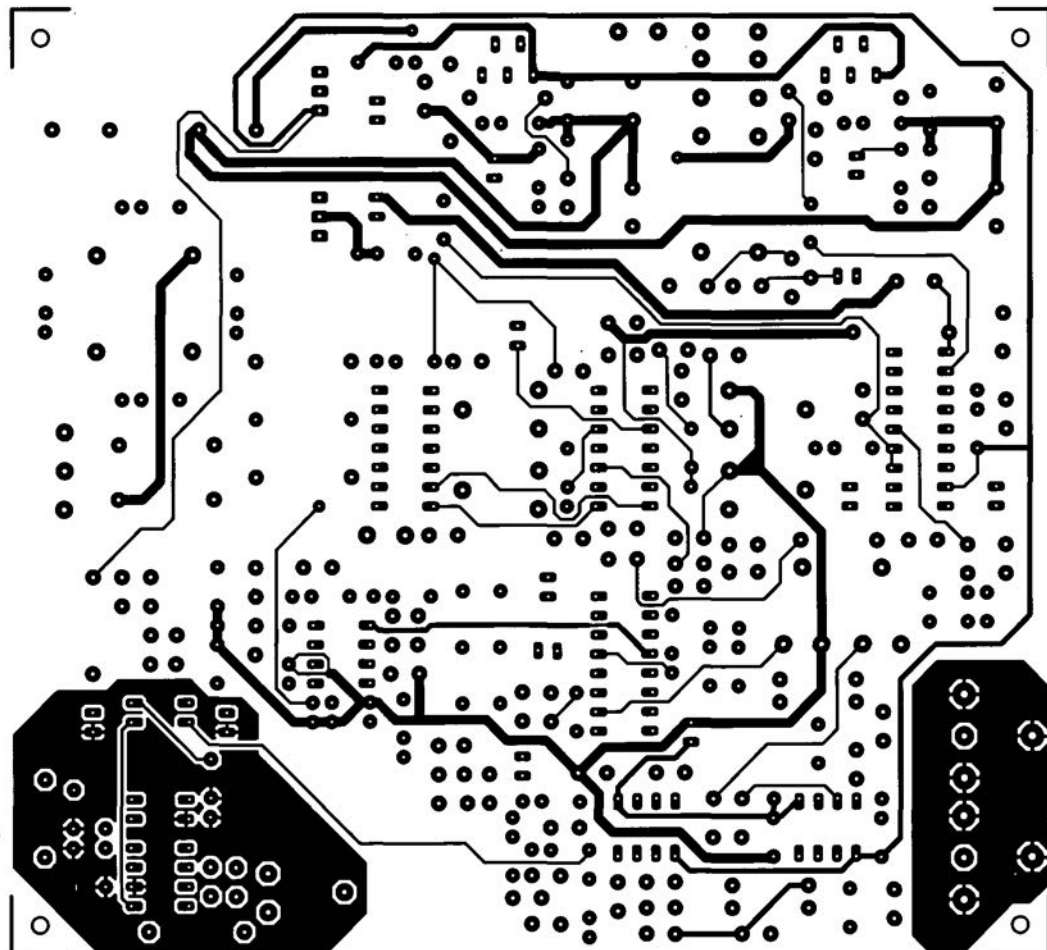


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Corrections

Surround Sound Processor (February 1995)

The overlay for the printed-circuit board was not shown on p. 30 as stated; instead, the track layout was repeated. We apologize for any inconvenience this may have caused. The correct illustration is shown adjacent.



Overlay for the PCB for the Surround Sound Processor (February 1995)

LETTERS

Sampling-rate converter settings

I have been a subscriber for nearly twenty years, having benefited from many circuit diagrams, privately as well as in my professional capacity.

The Sampling-Rate Converter published in your October 1996 issue caught my attention. If I understand the article correctly, this design may also be used as a copybit eliminator in conjunction with a MiniDisc player, without the need for internal modifications to the player. Digital copying could be accomplished via the optical inputs and outputs of the MiniDisc equipment and the sampling rate converter. I am, however, not quite sure how to set DIP switches S1 and S2. Do I have to make additional settings? I am convinced that many more readers will be interested in using the sampling rate converter as a copybit eliminator.

J.P. Demarsin

You are right! Unfortunately, the switch settings create so many possibilities that you can not see the wood for the trees. Admit-

tedly, it took us a while to figure out how S1 and S2 have to be set to achieve such a digital copying function.

Although we have little experience with MiniDisc equipment, it should be possible, in principle, to transfer signals digitally. The player then maintains a sampling rate of 44.1 kHz. The following switch settings turn the sampling rate converter into a copy unit:

S2:		all ON
S1:	1:	OFF
	2:	OFF
	3:	OFF
	4:	ON
	5:	OFF
	6:	OFF
	7:	OFF
	8:	ON

(ON = switch closed; OFF = switch opened). This setting applies to a converter output frequency of 44.1 kHz; the crystal frequency is then 33.8688 MHz. When a DAT tape has to be copied (48 kHz), switch 6 is set to ON, and switch 7 to OFF, while

a crystal frequency of 36.864 Mhz should be used.

Finally, be sure to respect the copyrights vested in any music material you are copying.

Noisy Surround-Sound processor

I have built your Surround-Sound Processor (January 1996), and it works great as far as TV surround sound is concerned. It does, however, have a flaw: the circuit produces rather a lot of noise. This noise is always present (even if the TV is switched off), but becomes much louder when surround sound is actually sent to the rear speakers: the volume of the relevant VCA in IC9 is then turned up. The latter fact suggests that the noise is generated at some location along the signal path starting at the inputs and ending at IC6. The noise level is actually so annoying in the living room that the volume setting on the surround channel has to be turned down to stop the annoying background noise with normal TV programmes.

Have you received similar com-

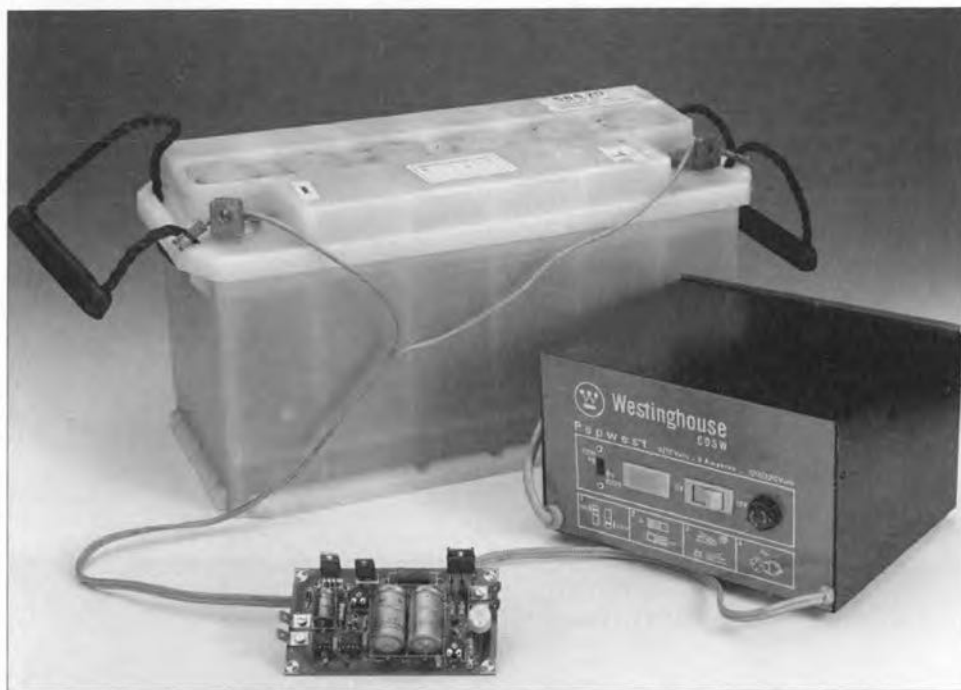


plaints from other readers bothered by this problem, and can you suggest ways of eliminating the noise, or at least reduce it?

L. Pattison

The noise produced by the decoder emanates mainly from the bucket-brigade memory, which is actually a long cascade of capacitors which are supposed to pass the signal. This noise may be lessened by increasing the input signal level, and attenuating the output level. That is easily accomplished by replacing resistors R5 and R7 by 4.99-k Ω types (1%) and changing R56 to 10 k Ω .

UPGRADE YOUR CAR BATTERY CHARGER



Many car battery chargers costing not more than £12-£15 are pretty spartan devices. Car owners should beware of using such chargers which offer no protection whatsoever. This article describes a simple upgrade circuit that adds voltage and current limiting, and polarity reversal protection, to such inexpensive chargers.

Design by L. Lemmens

IN spite of their low price, many cheap battery chargers look, well, impressive because of their smartly finished case, heavy-duty switches, solid connecting cables and robust clamps. Considering that the case contains a powerful mains transformer, such a charger is certainly not too dear at a price between £5 and £15. A pity, though, that these chargers lack any form of voltage or current regulation. Chargers which offer these features are, of course, more expensive, typically between £25 and £30.

So why not design an upgrade circuit for all those cheap chargers, and make them competitive with their regulated, but much more expensive, counterparts? As illustrated by **Fig. 1**, most cheap chargers have plenty of space inside to fit a printed circuit board and some warning devices to signal overload or error conditions.

The board described here does not

require complex modifications to the low-cost charger. In fact, it is simply connected in series with the output.

How it works

The circuit diagram of the battery charger upgrade is shown in **Fig. 2**. The circuit is intended for 12-V chargers with a maximum capacity of about 7 A. The essential ingredients are a voltage regulator, IC₁, a current limiter, IC₂, and a 'big' output transistor, T₂. The latter functions as the power stage for both the voltage and the current limiter, and performs the actual regulation. Two potentiometers are available to set the maximum battery voltage and the maximum charge current. If the set values are exceeded, the charging current is interrupted, and a LED lights to tell you that something is amiss. Similarly, a buzzer sounds when the battery is accidentally con-

nected the wrong way around.

The connections shown at the left-hand side of the circuit diagram are connected to the output of the battery charger, while those at the right-hand side go to the battery terminals.

A high-power diode, D₅, is inserted into the positive line to make sure that no damage can be caused by connecting the charger outputs the wrong way around to the inputs of the circuit. Interestingly, the diode also allows the existing bridge rectifier in the charger to be skipped, and the inputs of the upgrade circuit to be connected directly to the secondary of the mains transformer. The diode is followed by two large reservoir capacitors, C₇ and C₈, which smooth the direct voltage.

The charging current drawn from the mains transformer is fed to the battery via power resistor R₁₁ and transistor T₂. As already mentioned, the transistor is part and parcel of the voltage limiter and the current limiter. Since voltage limiting is the most important function for a battery charger, it will be discussed first.

Voltage divider R₈-P₁-R₉ is connected in parallel with the battery. The scaled-down battery voltage is compared to a fixed reference level of 4.7 V by comparator IC₁. The reference voltage is obtained from a zener diode, D₂. As long as the voltage at the -input of IC₁ is lower than the reference level at the +input, the comparator output will be high. Transistor T₁ is then switched on and consequently supplies base current to T₂. The result is that the charging current is allowed to flow from the mains transformer to the bat-

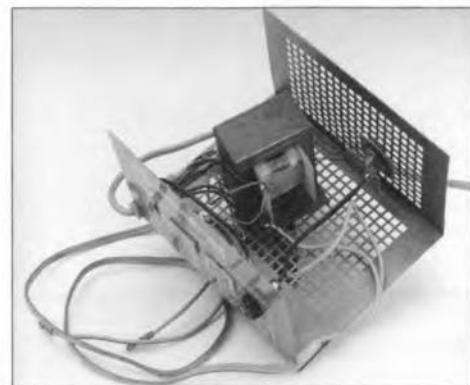


Fig. 1. Bleak House! Although they represent good value for money, most off-the-shelf car battery chargers have a pretty barren interior.

tery. If, after some time, the battery voltage rises above the threshold set with P_1 , the comparator output swings low, causing T_1 and T_2 to be switched off. Since the cathode of diode D_1 is then pulled to ground, this LED draws just enough current (via R_4) to light.

Transistor T_2 remains off until the battery voltage drops below the set threshold again. That happens as a result of self-discharging, or because a load starts to draw current. The divide ratio of the voltage divider is adjustable between 2.2 and 3.25 with the aid of potentiometer P_1 . Multiplying these values with the reference voltage (4.7 V), a voltage limiter span of 10.4 V to 15.2 V is obtained. A fully charged battery normally supplies 13.8 V.

The current limiter function is provided by comparator IC_2 and current sensing resistor R_{11} . The inputs of IC_2 are connected to voltage dividers whose divide ratios are nearly equal. One, however, has a potentiometer (P_2), and is connected behind series resistor R_{11} instead of ahead of it. When the charging current rises to an abnormal level, for instance, because of a faulty cell in the battery, the voltage at junction R_1 - R_{10} drops below that at junction R_2 - R_3 . Consequently, the output of comparator IC_2 drops low, drawing away the base current of T_1 . This causes the series regulator to be switched off and LED D_4 to light that and the current limiter has been actuated. In other words, an overload condition has been detected.

Because of the instability of the charging current and the voltage across C_7 and C_8 , the onset point of the current limiter is far less accurately defined than that of the voltage limiter discussed above. The charging current drops when the battery voltage rises, while the input voltage drops when the charging current rises. Fortunately, accuracy is not terribly important in this respect. The current limiter built around IC_2 really acts as a 'dead stop' in case a serious problem occurs, and is perfect for that function.

The opamps are powered by a supply which takes its input voltage from the charger's mains transformer. The 12-V supply is entirely conventional, being based on a three-pin fixed voltage regulator type 7812 and the usual decoupling capacitors.

Finally, the polarity of the connected battery is detected in the simplest possible way. If the battery is connected the wrong way around, diode D_7 conducts, and buzzer $Bz1$ sounds.

Construction

The upgrade circuit is best built on the printed circuit board shown in **Fig. 3**.

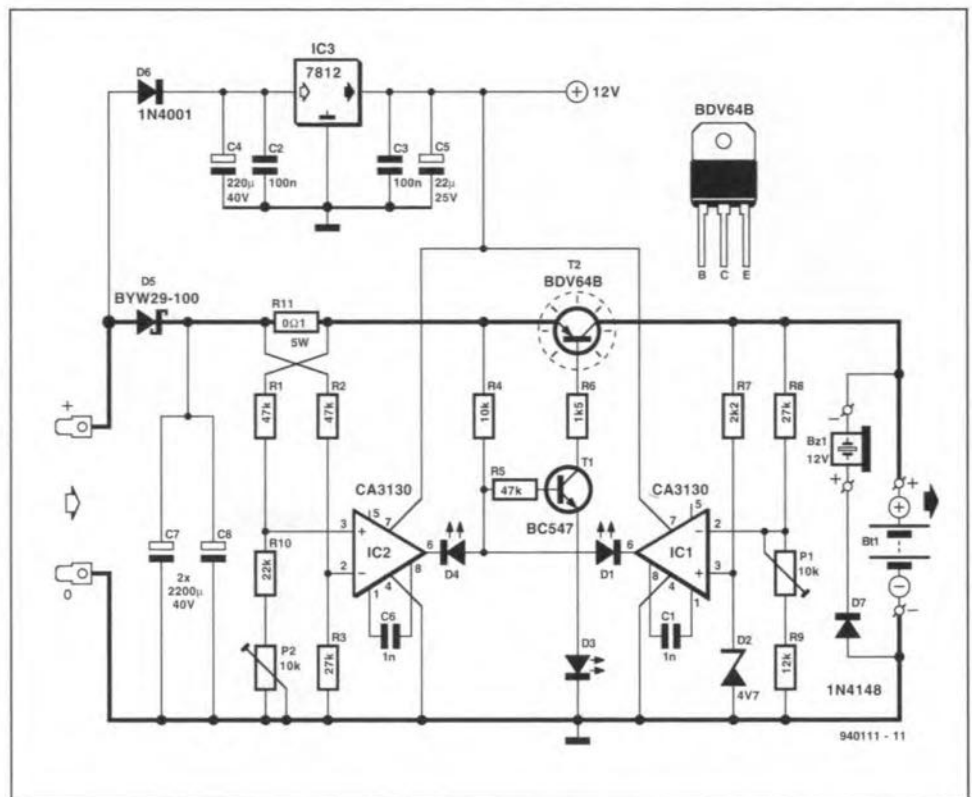


Fig. 2. The main components in the circuit are two comparators and a high-power darlington-type series transistor. Resistor R_{11} functions as a current sensor.

Construction should not present problems. Resistor R_{11} must be mounted a little above the board surface because it may run fairly warm. Similarly, transistor T_2 must be fitted with a heat-sink, or it may be secured against the inside of the charger enclosure with the aid of a good-quality electrical insulation set.

The extension circuit is simple to install in the battery charger. Disconnect the rectifier bridge outputs from the battery output wires. Connect the inputs (open arrows) of the extension board to the bridge rectifier outputs. Next, connect the outputs of the circuit (solid arrows) to the battery output wires. That is all. Use heavy-duty wire for the connections — a cable strength of 2.5 mm² or greater is recommended.

Adjustment

The circuit is adjusted as follows.

- (1) Connect an adjustable power supply instead of a battery. Shunt the power supply with a 27- Ω , 5-watt resistor.
- (2) Set the power supply to the voltage level at which the voltage limiter should act, for instance, 13.8 V.
- (3) Set P_1 for minimum resistance, and switch on the battery charger.
- (4) Adjust P_1 until LED D_1 just starts to light.

Next, proceed with the current limiter

adjustment. This requires an ammeter and a 'flat' battery or an adjustable high-power resistor. The resistor is more handy of the two, although it may be hard to find because of its ratings: adjustable between 2 Ω and about 5 Ω , and capable of dissipating up to 100 W.

- (5) Connect the load resistor to the battery terminals, and insert the ammeter in the circuit. Switch the ammeter to the 10-A range.
- (6) Switch on the battery charger, and adjust the power resistor for the desired maximum current, for example, 5 A.
- (7) Adjust P_2 until LED D_4 just starts to light. If the span of the preset is too small, resistor R_{10} may be made a little smaller.

Practical use

The circuit offers a reasonable degree of protection against misuse. It is, for instance, capable of withstanding reverse polarity at the input as well as the output. If D_3 lights, either the input voltage or the battery is connected the wrong way around. If D_3 lights and the buzzer sounds, the error is at the battery connections.

Finally, a word about the voltage limiter adjustment. Referring back to what has been said about the main characteristics of lead-acid batteries in the article 'Motive-battery charger'

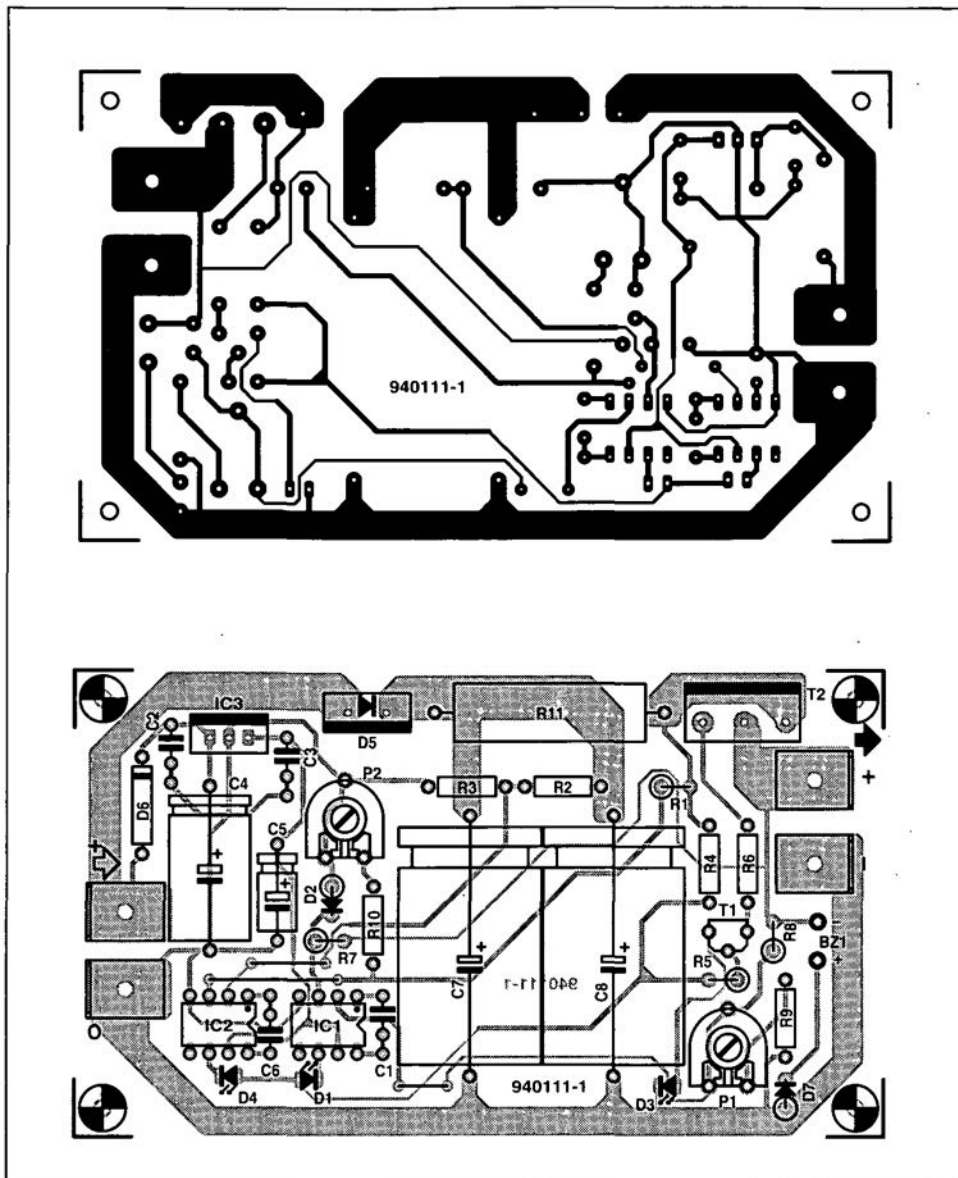


Fig. 3. Printed circuit board artwork (board available ready-made through the Readers Services).

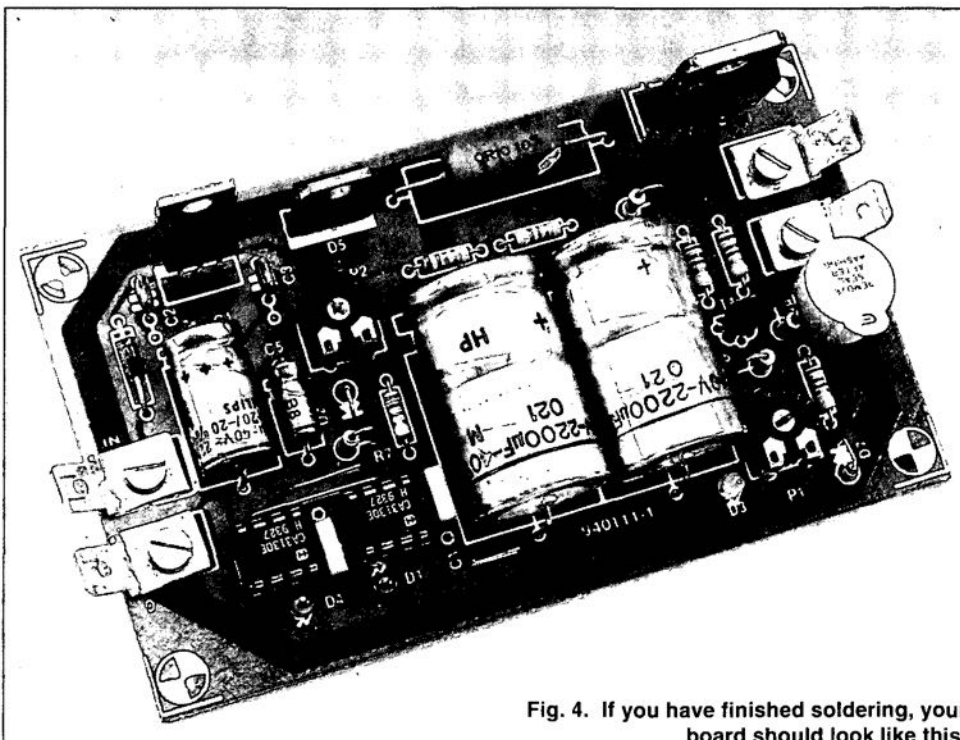


Fig. 4. If you have finished soldering, your board should look like this.

COMPONENTS LIST

Resistors:

$R_1; R_2; R_5 = 47k\Omega$
 $R_3; R_8 = 27k\Omega$
 $R_4 = 10k\Omega$
 $R_6 = 1k\Omega$
 $R_7 = 2k\Omega$
 $R_9 = 12k\Omega$
 $R_{10} = 22k\Omega$
 $R_{11} = 0.1\Omega$ 5W
 $P_1; P_2 = 10k\Omega$ preset H

Capacitors:

$C_1; C_6 = 1nF$
 $C_2; C_3 = 100nF$
 $C_4 = 220\mu F$ 40V
 $C_5 = 22\mu F$ 25V
 $C_7; C_8 = 2200\mu F$ 40V

Semiconductors:

$D_1; D_4 =$ low-current LED (red)
 $D_2 = 4.7V$ 0.4W zener diode
 $D_3 =$ LED, green
 $D_5 = BYW29-100$
 $D_6 = 1N4001$
 $D_7 = 1N4148$
 $T_1 = BC547$
 $T_2 = BDV64B$
 $IC_1; IC_2 = CA3130$
 $IC_3 = 7812$

Miscellaneous:

$BZ_1 =$ d.c. buzzer, 12V.
 Heat-sink for T_2 , e.g., Fischer type SK59, 7K/W.
 Printed circuit board, order code 940111-1 (see page 78).

(Ref. 1), a battery is normally 'fully charged' if the cell voltage is between 2.2 V and 2.3 V. The voltage level for trickle charging of lead-acid batteries is, therefore, normally set to 13.8 V. Also, as a rule of thumb, the amount of energy to be put into the battery is about 1.1 to 1.2 times the amount of energy drawn from it. For example, a completely discharged 40-Ah battery has to be charged 12 hours at a current of 4 A.

The maximum current that can be supplied by the present upgrade board is about 7 A. Larger currents will destroy diode D_5 because it has a maximum rating of 8 A. Transistor T_2 is capable of passing up to 12 A. If the circuit develops a malfunction, it is, therefore, advisable to check D_5 first.

(940111)

Reference:

1. Motive-battery charger, *Elektor Electronics* October 1994.

LETTERS

6-V lead-acid battery charger

Dear Editor—I am hoping you can help me with a seemingly simple problem.

My present Lambretta rectifier unit (6 V at 12 A) has packed up and I wish to replace it with a home-made battery charging unit. The power is supplied from a coil on the bike's magneto. As I have been unemployed for the past five years, I cannot afford Lambretta's extortionate price for a replacement unit, so I trust you can supply me with the circuit diagram of a suitable unit.

A. Appley, Bromley, Kent.

As luck would have it, we have just published a design that should meet your present needs exactly: '6 V motive-battery charger' (July/August 1995, p. 92).

[Editor]

Reception of Manx Radio

Dear Editor—For a couple of years now, I have been writing to different radio advertisers: what I would like to do is fit myself up with whatever equipment it takes to receive Manx Radio (1368 kHz). For some reason, I have never ever received any information on what I am asking for. May it is just simply impossible or nobody can explain it to me or they don't know how to do it themselves.

The reason I keep pursuing my quest is that I look at different electronics magazines and I see places like Slovenia, Liechtenstein, Turkey, and so on, being able to be reached by amateur radio. I put on my household radio, scan the waves and it is guaranteed that I find somebody from a foreign country speaking in a foreign language. Surely, the Isle of Man is not too far away.

If I am just plain stupid, then please, please, let somebody tell me or even take a little time to explain why these few (130) miles cannot be bridged.

R.J.R. Michelson, Melton Mowbray

The e.r.p. (effectively radiated power) of Manx Radio is only 2.5 kW; that, together with the hilly countryside between the isle and Melton Mowbray prevents good reception of the station. A directional antenna, such as described in 'Small loop antennas for MW, BCB, LF and VLF' by J. Carr in our June/July 1994 issues, may help you receive Manx Radio.

Suggestions and/or comments from other readers are welcome.

[Editor]

Bat detector

Dear Editor—The electret (condenser) microphone Type ME2500 (from MailTech), used in the 'Bat Detector' *EE* April 1995, p. 62) is NOTHING like the sketch on the circuit diagram..

[The letter continues with many notes and suggestions on the construction of the unit—copies of the complete letter can be obtained on request from our Editorial Office in Dorchester].

Bruce Williamson, Melton Mowbray

Unfortunately, you have misread both the circuit diagram and the parts list: the microphone around which the unit is designed and tested is an MCE2500 from Monacor (which is available from, among others, C-I Electronics at about £5). If you have trouble in obtaining this, please let us know.

None the less, thank you very much for your interesting and detailed letter.

[Editor]

Figuring it out

Over the past year, there has been correspondence between Mr Ritchie of Fraserburgh, Scotland, and Mr O. Bishop, author of the 20-part series 'Figuring it Out' which ended in our November 1994 issue. The correspondence was protracted owing to Mr Bishop's moving to New Zealand.

The main reason for the correspondence was Mr Ritchie's comment that the derivation of Equation 115 in Part 14 (March 1994) was flawed. Mr Bishop commented to this as follows: "In Part 14 there was an arithmetic error in deriving Eq. 112. The equation should have been $5000C + 50000Ct + 50000 = 400t$. Consequently, the values obtained by applying that equation were incorrect. Now, $C=8 \times 10^{-3}$, $D=-8 \times 10^{-4}$, and Eq. 115 should be $i=0.001913(e^{-10.02t}-e^{-4990t}) + t(8 \times 10^{-3}) - 8 \times 10^{-4}$. The graph of this equation has the same general features as that shown in Fig. 119, rising to about 1 mA as before, though rather faster, then falling slightly before it begins to rise again after about 90 ms. The text describing the graph and the conclusions to be drawn remain unaffected by this correction".

There remains a 'grey' area pertaining to (1) Eq. 112 in Part 14, which Mr Ritchie claims "is based on a fundamentally flawed concept (like Eq. 115)"; (2) Eq. 147 in Part 19, which Mr Ritchie claims "produces a result wherein the energy dissipated is greatly in excess of that stored in the source: a ridiculous situation which could imply that perpetual motion is not only possible, but can be achieved with an extraordinary degree of efficiency"; (3) Mr Ritchie's comment that "the answer given to question no. 2 in Part 20 is wrong and is subject to the same comment as (2) above. Mr Bishop has, however, agreed in principle that the published results quoted were in error and has advised of the correct solutions.

These comments are published here in the interests of other readers. The correspondence on this subject is now closed as far as this magazine is concerned. Any further comments will have to be directed

to the author.

[Editor]

Surround sound processor

I am contemplating the building of the surround-sound processor (*EE* February 1995), but I fear a possible problem with the linking of the processor to an existing sound system (TV or stereo).

The article states that the processor must be connected to the LINE OUT of the TV receiver. I am afraid of a possible snag here. The level of the LINE OUT or SCART output is fixed, since it pertains to a volume-independent signal of $1 V_{pp}$. After the processor has been set up, the sound level of the centre and surround loudspeakers will then also be fixed (independent of the volume setting on the TV). I fear that this will not lead to the pleasant listening we are promised.

What I would like to know, therefore, is: "Would it be possible to make use of the headphone or external speaker outputs? The centre and surround speakers will then follow the volume setting of the main speakers (in the TV). But, how will the surround processor react when the loudspeaker signal is clipped by the zener diodes in the input circuits?"

S. Paternotte

The design is based on a variable line level: the headphone output of a TV receiver is eminently suitable. However, a fixed level, such as that from a SCART socket, can be used if the main speakers are driven via a separate amplifier. The line signal is then fed to a line input on the amplifier.

The surround sound processor is fed from the variable output of the amplifier (or the headphone output of the TV).

The rating of the zener diodes (D_1-D_4) does not make clipping likely: the maximum drive voltage required by the output amplifiers is about 1 V, well below this rating.

[Editor]

Upgrade your car battery charger

The article on p. 34 in our February 1995 issue stated that the circuit can be set up with a variable load of 2–5 Ω , 100 W. This is, of course, a formidable load, which is quite expensive. It is considerably easier and cheaper to use a number of parallel-connected defect car headlight bulbs (normally, the dimmer filament of these bulbs goes, but the main beam filament remains intact). A flasher light bulb (21 W) and rear light bulb (5 W) may be used for fine adjustment.

FOCUS ON: COMPUTER-ASSISTED DESIGN (CAD) OF SCHEMATICS AND PRINTED CIRCUIT BOARDS

Computers have evolved rapidly over the past few years, and are now used for design work that was long thought to be possible by hand only. In modern CAD systems, for instance, computers have taken over from the traditional pen, paper and ruler. These tools are now completely replaced by advanced screen operations. In the field of electronics, too, many aspects of design have been taken over by the computer. The aim of this article is to show how an electronic circuit plus associated printed circuit board can be designed rapidly and efficiently with the aid of a computer.



By our design and editorial staff.

THE times when electronic circuits were designed with pen and paper on a drawing board are a few years behind us. Not only has the computer moved circuit drawing, copying, fault checking and editing to the desktop monitor, it has also greatly simplified and improved the design process. Furthermore, new possibilities have been added. It is now possible, for instance, to simulate and check the operation of an electronic circuit without soldering a single component. The thermal behaviour, too, of components is simple to predict, and 'hot spots',

which are potential sources of trouble, are simple to locate beforehand.

Most electronic designers have two main requirements as regards computer-aided design: (1) software to produce circuit schematics and (2) software to produce printed circuit board artwork. Both programs are usually supported by a library editor and a netlist converter. The former is used to edit existing component parameters stored in libraries, and to create new component libraries. The netlist converter is necessary whenever data has to be exchanged between a

schematic drawing program and a PCB design program from a different manufacturer. The netlist is a file which contains descriptions of all parts used, and the way they are interconnected. In case the two programs are related, i.e., produced by the same software house, problems with exchanging data via the netlist file are unlikely to occur.

The drawing board

The very first stage of each design process is drawing the circuit diagram. A number of programs are available for that purpose. These typically include a number of libraries which contain complete component families. The most obvious of these are passive components, transistors, analogue ICs, TTL, CMOS, etc., although microcontrollers, memories and even sensors may also be included in the more up-market programs. The description of each component in a library comprises its enclosure and the pin functions. In many combination products, this information is divided between two separate libraries: one for the circuit drawing program, and another for the PCB design program.

In the process of entering the circuit into the computer, the user picks the components he or she wishes to use from the different libraries. Next, the components are interconnected to create an electronic circuit. In some cases, it is possible to include the enclosure and pinout information in the circuit diagram already. That may be very useful because many logic integrated circuits, for instance, are now available in SMD (surface mount device) packages, in addition to the standard DIL case. The pin numbering may still be the same, however, and the choice of enclosure is not usually an issue until the board is designed. Consequently, many programs do not

allow you to make your choice until you have arrived at the PCB design phase.

Early warnings!

Design faults may already be detected while the circuit is being entered into the computer. For instance, the program will alert you to an integrated circuit whose supply pins are not connected, or ICs whose outputs are interconnected. The so-called error file produced by the program's ERC function (electrical rule checking) tells you if the circuit contains connections which are less usual. Suspicious, but electrically acceptable, links are retained, however, and the decision whether or not modifications are in order is left to the user.

Some programs have two error reporting levels. An 'error' indicates a gross mistake in the circuit, for instance, a short-circuit on the supply lines, or a signal which runs from a component output terminal directly to the ground line. A 'warning' is produced if the program has reasons to suspect that a certain configuration can not work. Error and warning reports enable you to debug a circuit in the early stages of design, which is sure to save time and money later.

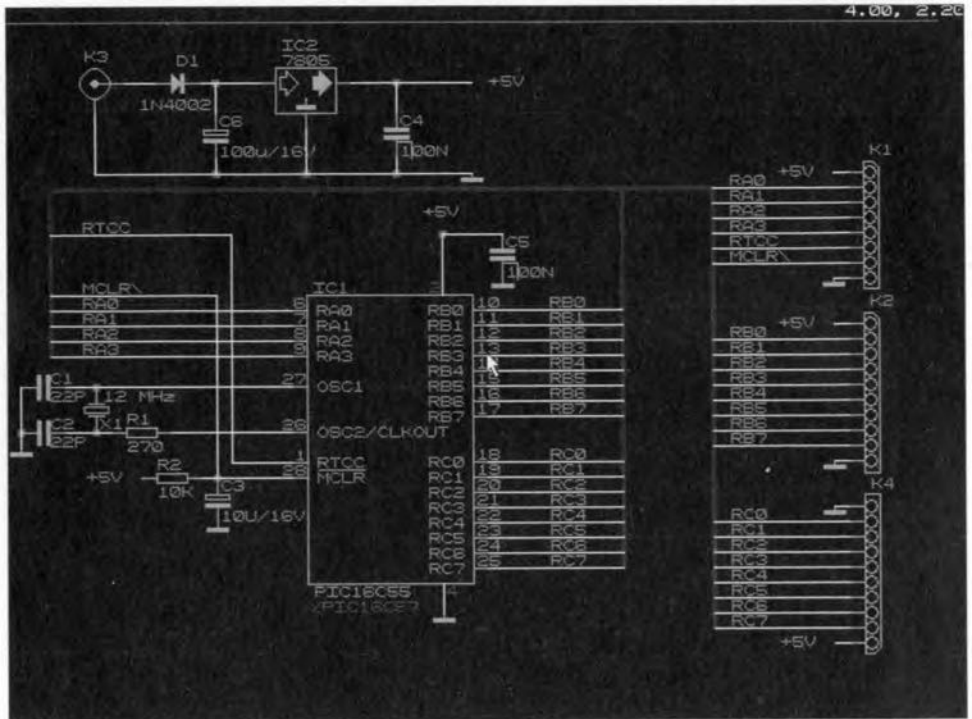


Fig. 1. A computer makes it possible to draw electronic circuit diagrams quickly and efficiently. Thanks to the netlist export option, other programs may use this circuit diagram also (screen snapshot of Orcad/SDT3).

Drawing bits and pieces

A useful feature of many circuit drawing programs is their ability to create, store and retrieve sub-circuits (also called modules) which allow circuits to be divided into segments. This function produces circuit diagrams which are legible and, therefore, understandable, despite being very complex. Moreover, modules may be copied and saved for use in other circuits, or run off on the printer on separate sheets. The use of labels and symbolic names for certain junctions in the circuit enable other designers (and yourself, after a couple of months...) to read the circuit diagram without problems.

There are also systems which enable signal groups (supply lines, address bus, databus, etc.) to be set off from the rest of the circuit. Furthermore, it is often possible to highlight the selected signal group (for example, a microprocessor's address or data bus) on the screen, giving you an immediate indication of the function of a particular link or group of links.

In a CAD environment, making alterations to a circuit is easy by first breaking existing links and then entering the necessary changes. This is in stark contrast with the traditional pen and paper design methods, which are really unsuitable for making large changes to an existing circuit.

Hard copy

For documentation purposes, it is essential that a circuit diagram can be moved from the screen to a printer. Any circuit

```
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(edifVersion 2 0 0)
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(comment " by Usarc, the Netherlands.")
(comment " (c) copyright 1992")
(comment "Input file created at 13 July 1994, 10:07:25")
)
)
(library AllComponents
(edifLevel 0)
(technology Unspecified)
(cell root
(view ADFS::IDEDisc4$.Work.Usarc.Man_cor.PCBs.Example3.Schema3
(viewType NETLIST)
(interface
)
(contents
(instance C1
(property DEVICE (string "C"))
(property PARTS (integer 1))
(property VALUE (string "10 nF"))
(property PACKAGE (string ""))
)
(instance D1
(property DEVICE (string "DIODE"))
(property PARTS (integer 1))
(property VALUE (string "1N4148"))
(property PACKAGE (string ""))
)
)
)
)
)
```

Fig. 2. This text file shows the structure of an EDIF file. EDIF allows programs from different manufacturers to communicate with each other.

drawing program should offer a wide range of drivers to support at least the most popular of today's bewildering range of printers. If the program runs under a graphics user interface, for instance, Windows, use is made of the printer drivers offered by the 'shell' program. The number of CAD software programs running under Windows is on the increase recently. The computing power of today's 486 and Pentium-based machines allows these complex programs to run smoothly on a Windows platform. Hard copy of the circuit diagram(s) and the text files which contain, among others, a list of all parts used, are invaluable for documentation purposes.

In many cases, the final aim is not to print the circuit diagram on paper, but to use it to produce a printed circuit board. That, obviously, requires a means of exporting the output data of the circuit drawing program to a PCB design program. The step from electrical design (circuit diagram) to physical design (copper tracks on a board) is made with the aid of a netlist.

Export/import: the netlist

As already hinted at, the netlist has a key function in each CAD environment. It is used to convey information between sub-programs in the CAD system. In practice, each CAD system has its own netlist format, which allows a quick exchange of data between sub-programs in the same design environment. The big disadvantage is that conveying the same information to a different hardware and/or software platform without corrupting the data is fairly difficult. Fortunately, over the past few years a couple of standard formats have evolved for netlists. The most important of these are **EDIF** (electronics Design Interchange Format) and **Spice**. The latter is of particular interest if you want to feed your schematic drawing program into an electronic simulation program. That is achieved by including, in the netlist file, information on the electrical behaviour of the relevant components.

As far as transferring information from a circuit drawing program to a PCB design program is concerned, EDIF is the obvious choice because all well-established programs support this format. It should be noted, however, that advanced options such as back-annotation (i.e., comparing the connections list produced by the circuit drawing program with the actual connections on the PCB, and vice versa) are not always possible when EDIF is used.

Spice and EDIF are 'all-ASCII' formats which can be read and modified by almost any word processor. As such, they have essential functions in documenting a project. **Figure 2** shows an extract from an EDIF listing.

Some of today's more advanced CAD

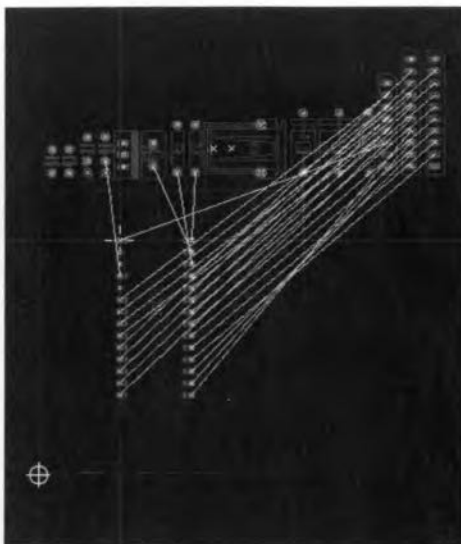


Fig. 3. After importing the netlist, all components are thrown haphazardly on the board. The result is called a rats nets (screen snapshot, zoomed in, program: Ultiboard).

packages also offer macro functions to generate the netlist. Such macros enable communication with almost any design system.

Printed circuit board design

Based on what sales people will tell you, you could be lead to believe that designing a printed circuit board with the aid of CAD software is a trifle. 'Well Sir, just start by selecting a standard PCB size

and the desired number of copper layers. Next, load the netlist produced by the drawing program, and away you go with the automatic component placer. Once that function is finished, the components are at the appropriate positions on the board, and the auto-router may be called to finish the job. All you have to do is wait until a perfect PCB layout appears on the screen. That gives you just enough time to switch on your laser printer and telephone around for the cheapest PCB manufacturer.'

Alas, things are a little more complicated in practice. Although many software suppliers boast about the power of their component placers and autorouters, few PCB designers will rely on these tools for the full 100 per cent. In many cases, the work is split between the computer and the designer. Supply tracks and 'critical' analogue networks are then positioned manually, and the rest of the work is left to the autorouter to sort out.

In practice, a PCB designer starts by selecting the board size, and then the number of layers. Once that is done, the screen displays an image which represents the empty board. Each layer usually has its own colour. The next step is to import the netlist produced by the circuit drawing program. The result is a rat's nest of components thrown on the board with a all interconnections tangled in a heap. **Figure 3** shows an example. At this stage, it is wise to check that the parts are in the right enclosures. In many cases, that is very simple because a particular component comes in one case only. The enclosures available for a certain component should be defined in the

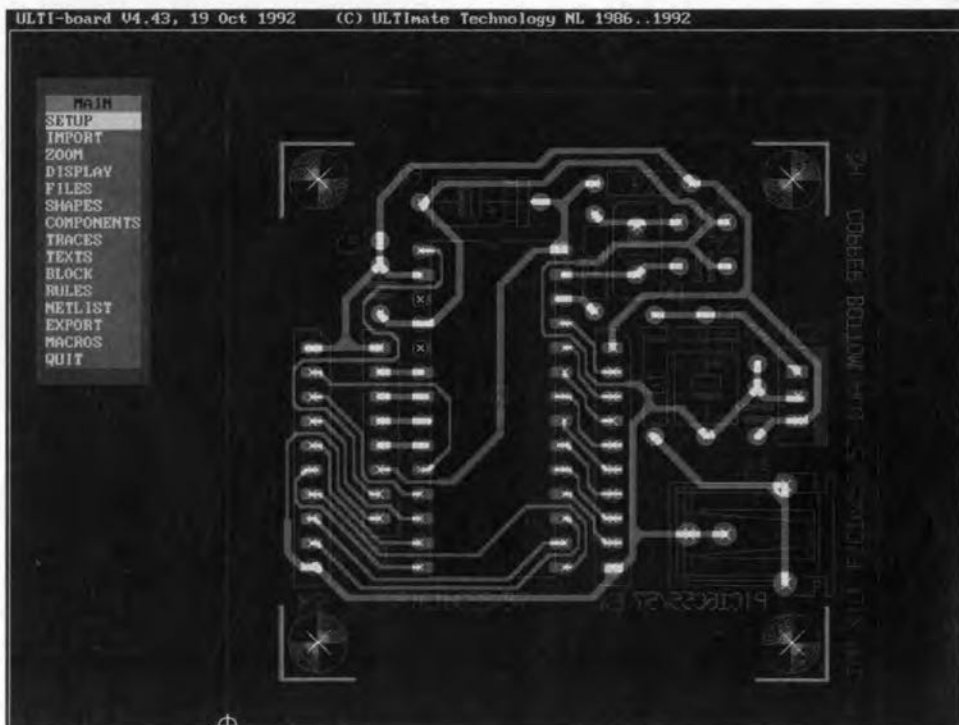


Fig. 4. Most programs allow a component to be picked up and moved to another location on the board (program: Ultiboard).

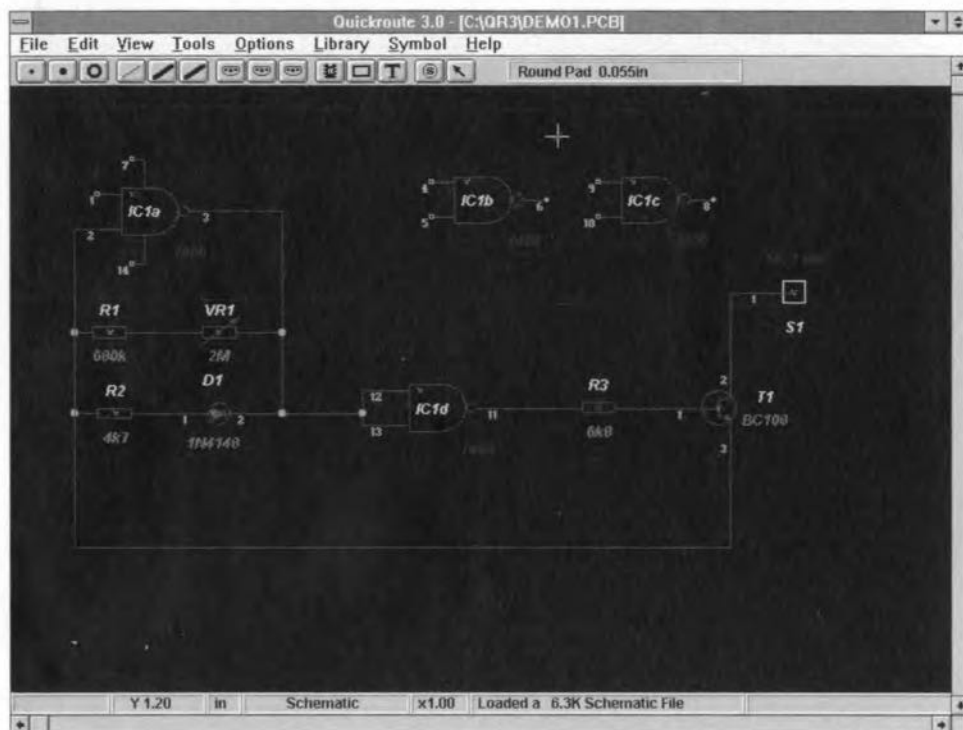
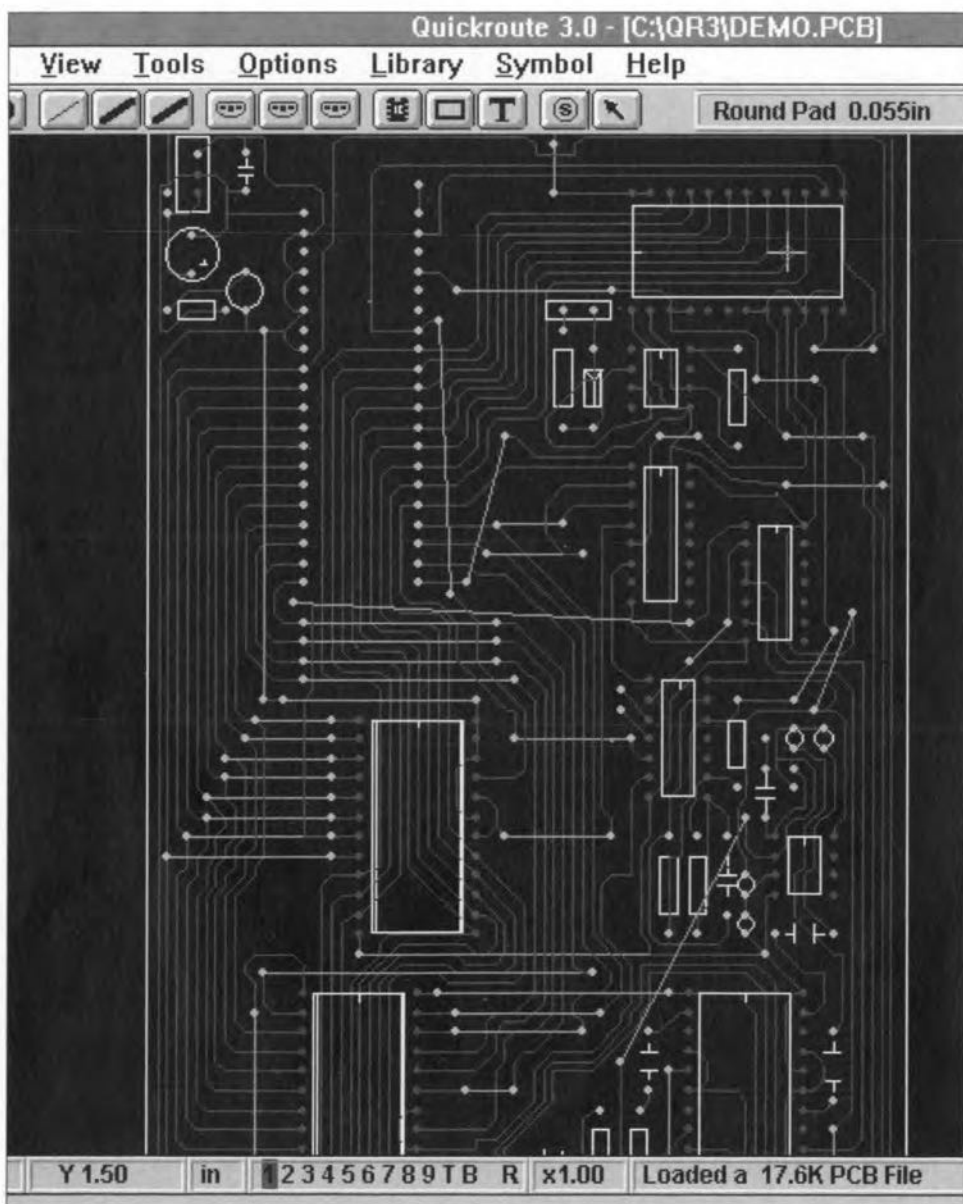


Fig. 5. Schematics drawing in the Windows era: Quickroute Pro+.



component library. The program will then automatically tell you the alternatives with each component.

Once the component enclosures have been decided on, components whose location can not be allowed to change, for instance, connectors, are 'fixed' on the board. Next, the automatic component placer may be called up. Depending on the conditions you set up for this utility, this utility is capable of establishing the optimum position of the components on the board. Although quite a few conditions and design rules may be defined for the component placer, most designers will prefer to do the component placement themselves. An interesting compromise between automatic and manual component placement is the ability of some programs to start by locking critical components at a certain position on the board. Next, the automatic placement tool is allowed to move the less critical parts across the circuit board. Alternatively, some programs allow the auto-locator to operate on a selected number of components only.

Rotating components, or swapping pins and gates with logic ICs, may help to simplify finding the best possible board layout. Some CAD programs enable you to define 'keep out' areas on the board, where no components or copper tracks are allowed. Such areas may be necessary to enable a hole to be drilled or fraised later. Alternatively, they may help to improve the screening between two sub-sections of the circuit. In most cases, the software is capable of managing keep-out areas quasi-automatically. The use of a grid, finally, makes for a neat component arrangement on the board.

Enter the autorouter

When, after careful editing, the best possible component locations have been established, the links between the components have to be turned into copper tracks. Like component placement, this so-called 'routing' may be done manually or automatically. The software indicates each track drawn by showing a thin line on the screen, or by highlighting the copper pads which are being interconnected. In this way, the user is able to find the optimum route for a track across the board, without running the risk of forgetting a connection. Should a particular connection turn out to run less favourably, it is often possible to relocate the routing, or undo it. By doing so, the

Fig. 6. Example of a PCB design produced with the aid of a CAD system (screen snapshot, zoomed in, of Quickroute 3.0 Pro+). Note that this particular program allows wire links to run diagonally across the board.

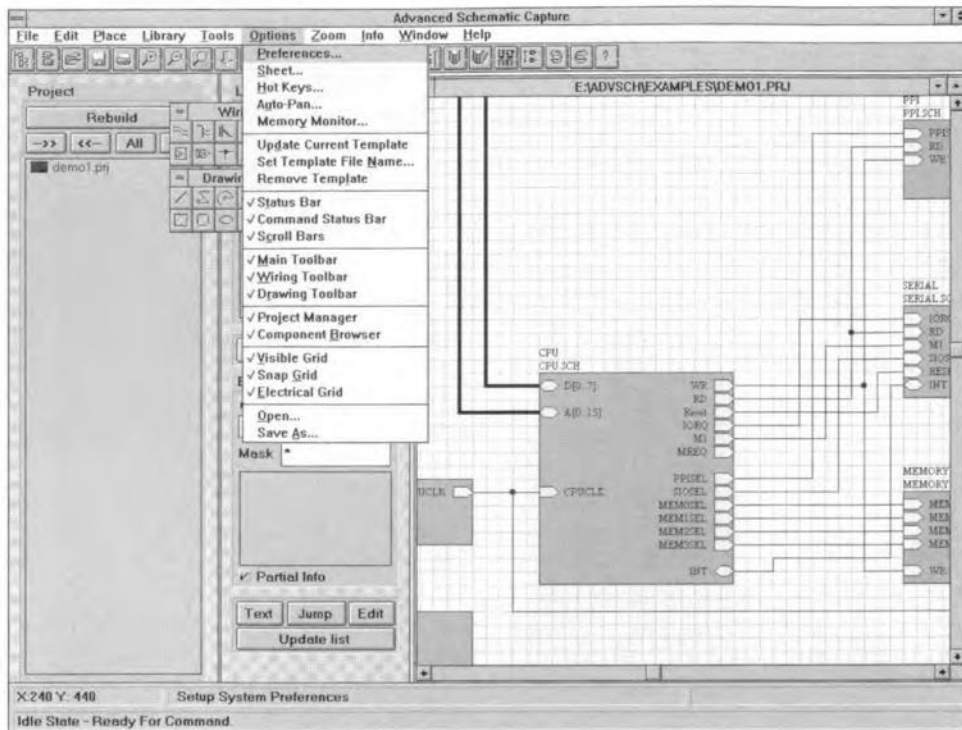


Fig. 7. Protel Advanced Schematic Capture in action.

relevant component may be repositioned on the board, or a different track route may be defined.

While the track pattern is being built, screening areas may be defined between tracks. With large copper areas, it is important that the program allows them to be given a raster to facilitate soldering (a small copper area is easier to heat than a large one). Screening between parallel running tracks considerably reduces cross-talk levels. To ensure that the PCB layout has a one-to-one correspondence with the circuit diagram, the PCB design program should produce a netlist also. The so-called **back annotation** utility of the CAD program then compares the PCB netlist with the circuit diagram netlist. If there are no differences, the PCB layout is a one-to-one electrical copy of the circuit diagram. The program will also check for short-circuits between tracks, or tracks which are too close to another. If the PCB is modified with respect to the circuit diagram (for instance, as a result of pin or gate swapping), that will be abundantly clear in this phase of the design process.

A feature called **forward annotation**, also referred to as **ECO** (engineer change order) appears to be a less well known than back annotation. Forward annotation makes it possible to import changes made with the aid of a circuit drawing program into an existing board layout. This is achieved by combining the netlist of the modifications with that of the printed circuit board. Unfortunately, because the ECO function is fairly difficult to implement, only a few high-end CAD packages actually support this useful function.

The final product

The last step in the design phase involves producing transparent films which can be used by the PCB manufacturer. Such films are usually produced with the aid of a file written in the Gerber format. Traditionally, this is an area dominated by plotters, in particular, Gerber photoplotters which are the *de facto* standard in the PCB production industry. These plotters use an x-y coordinates system and have a built-in library containing standard images of copper spots. These spots are on a transparent disc, and are transferred to the photosensitive layer with the aid of a flash light. The copper tracks consist of lines drawn between two coordinates.

Meanwhile, modernized versions of the Gerber photoplotter have arrived, which copy the track image into a memory, just like a laser printer. Next, the information is transferred onto film by an exposure operation.

Gerber files are accompanied by a document containing additional information on technical specs including the metric standard and the accuracy of the Gerber data. This information may be required by the PCB manufacturer to do his production equipment settings. Information representing the hole pattern (Excellon NC drill files) and the component mounting plan is supplied in separate files. Furthermore, a document is supplied which states the total number of holes to be drilled, and their sizes.

Finally, more up to date file formats such as Postscript are reported to gain rapid acceptance in the PCB production industry. (950001)

Addresses

UlitiCap & Ultiboard:

Ultimate Technology UK Ltd., 2 Bacchus House, Calleva Park, Aldermaston, Berkshire RG7 4QW. Tel. (01734) 812030, fax (01734) 815323.

PCB Designer (Windows 3.1):

Niche Software, 22 Tavistock Drive, Belmont, Hereford HR2 7XN. Tel. (0432) 355 414.

Easy-PC (Schematic and PCB CAD)

Number One Systems, Harding Way, St. Ives, Cambs PE17 4WR. Tel. (01480) 461778, fax (01480) 494042.

BoardCapture, BoardMaker, BoardRouter

Tsien (UK) Ltd., Aylesbury House, Wenny Road, Chatteris, Cambs PE16 6UT. Tel. (01354) 695959, fax (01354) 695957.

Orcad/SDT3

1049 S.W. Baseline St., Suite 500, Hillsboro, OR 97123, U.S.A. Tel. (+1) 503 640 5007.

QuickRoute

POWERware, 14 Ley lane, Marple Bridge, Stockport SK6 5DD. Tel./fax (061) 4497101.

Protel Design System for Windows

Protel Technology Inc., 4675 Stevens Creek Blvd, Suite 200, Santa Clara, CA 95051-6764, U.S.A. Tel. (+1) 408 243 8143, fax (+1) 408 243 8544.

Layo1

Baas Electronics bv, Rijksstraatweg 42, NL-3281-LW Numansdorp, Holland. Tel. (+31) 1865 4211, fax (+31) 1865 3480.

Programs for analogue simulation only:

Electronics Workbench

Robinson Marshall (Europe) PLC, Nadella Building, Progress Close, Leofric Business Park, Coventry, Warwickshire CV3 2TF. Tel. (0203) 233216, fax (0203) 233210.

SpiceAge for Windows

Those Engineers Ltd., 31 Birkbeck Road, London NW7 4BP. Tel. (0181) 9060155, fax (0181) 906 0969.

The Focus next month will be on CD-ROM production and standards

MOSFET LOGIC INVERTERS

By G. Kleine

WHENEVER you need a single inverter in a digital circuit, consider using a MOSFET, which is often cheaper and easier to fit on the board than a six-fold inverter 4049 IC of which five gates remain unused.

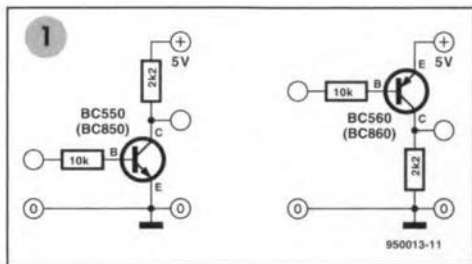
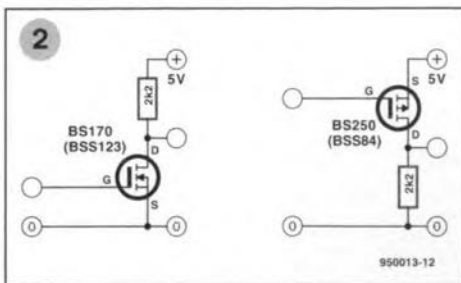


Figure 1 shows two logic inverters based on n-p-n and p-n-p bipolar transistors. The base circuit of both transistors contains a relatively high value resistor (for instance, 10 kΩ), which serves to limit the base current. At the output, a low-value resistor (here, 2.2 kΩ) is inserted in the collector line to drop the output voltage. That brings the parts count of a transistor-based logic inverter to a total of three.

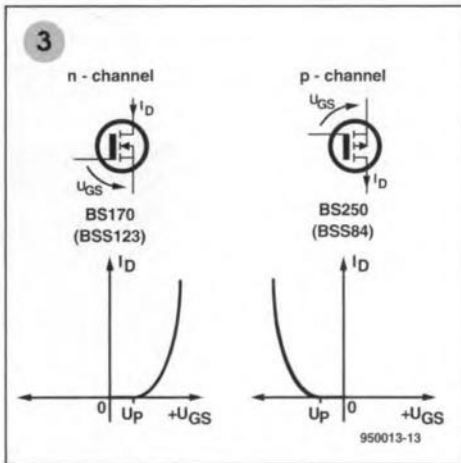
The above inverter circuits may be simplified by using MOSFETs (metal oxide semiconductor field effect transistor), which operate with zero-power drive signals. Since MOSFETs, unlike bipolar transistors, have a very high input impedance, they do not need a current limiting resistor at the gate. The inverter's component count is therefore reduced to two. Figure 2 shows schematics of two MOSFET inverters. The one to the left is based on an n-channel MOSFET (equivalent to an n-p-n transistor), and the one to



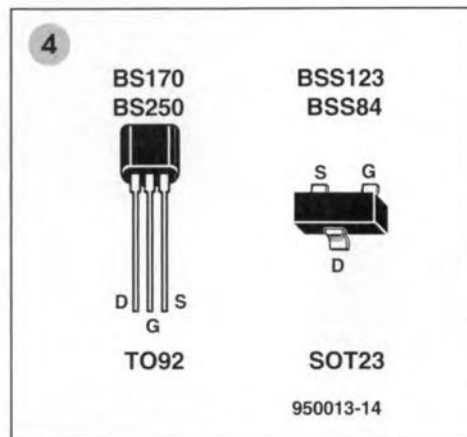
the right, on a p-channel MOSFET (equivalent to a p-n-p transistor). The MOSFETs listed in the drawing are typical examples of so-called enhancement (or 'normally off') types.

The MOSFET may be looked upon as a switchable resistor, which assumes a very high value at $U_{gs}=0$ V. Starting at a certain value of U_{gs} (the so-called pinch-off voltage, U_p), the drain-to-source junction resistance begins to drop rapidly (see Fig. 3).

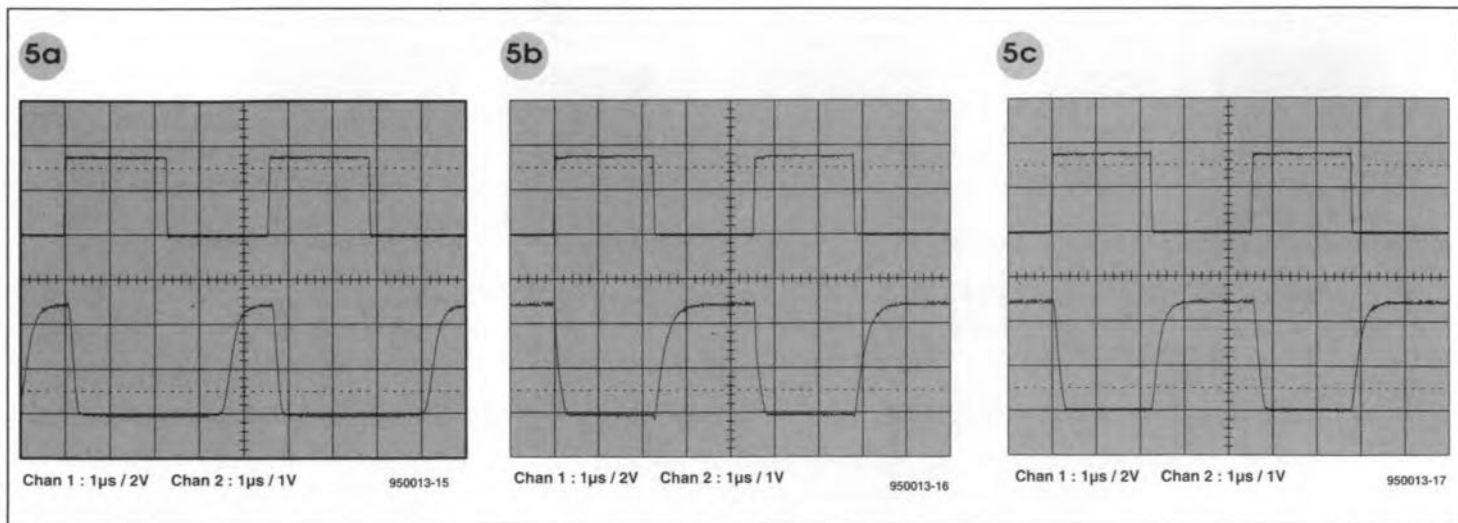
MOSFETs typically used for logic inverters are the BS170 (n-channel) and



BS250 (p-channel), which are supplied in TO92 packages. If you need SMD (surface mount device) versions, use the respective equivalents BSS123 and BSS84 which come in SOT23 cases. The pinning of the four devices is shown in Fig. 4. Whenever you handle MOSFETs, be sure to observe precautions against damage caused by static electricity.



The oscillograms in Fig. 5 clearly illustrate the superiority of MOSFETs over bipolar transistors when used in logic inverters. The bipolar type BC550 (Fig. 5a) responds slowly to the negative-going edge of the input signal (upper trace), causing a too short and badly defined inverted output signal. Although the response of a dedicated switching transistor type BSX21 (Fig. 5b) is a great improvement on the BC550, the best results are obviously obtained with a BS170 MOSFET (Fig. 5c) which ensures very fast response and crisp signal edges. (950013)



THE DIGITAL SOLUTION

Part 3 – Acquiring Data

By Owen Bishop

In this series we look closely at digital electronics, what it is, what it does, how it works, and its promise for the future.

Digital circuits operate on data: facts and numbers (which are a kind of fact). Unless a circuit 'knows' some data, there is nothing for it to work on; it is just a useless collection of wires and components. This month, we study the ways in which digital circuits can be supplied with data.

Switches

One of the simplest ways of supplying data to a digital circuit is to use a single-pole single-throw switch, although various types of switch can be used. In the circuits of Part 1 we suggested the use of a microswitch to inform a digital circuit whether a door is open or closed. Similarly, a push-button switch on the door informs a door-alert system (and the occupants of the house) that there is somebody waiting outside the door. A switch in the form of a pressure-pad may be used to inform a security system that there is an intruder in the room.

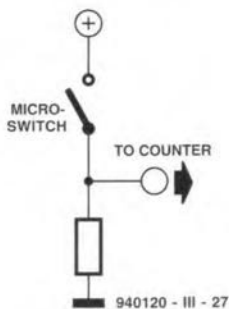


Fig. 17

Although an ordinary push-button may be adequate for inputting information to a door-alert system, there are circumstances in which this is too simple a solution. Take the example of the door and microswitch and suppose that, instead of simply lighting a lamp to show the state of the door, we want to know how many times the door has been opened. The switch is to be connected to a digital counter

circuit. There is more to be said about counters in a later issue but, for the moment, all we need to specify is that the counter state is to be increased each time its clock input detects a change of level from high to low. **Figure 17** is a circuit that provides a high output level when the switch (and door) is shut and a low level when the switch (and door) is open. Opening the door causes the level to change from high to low and advances the counter. Closing the door causes a change from low to high, but this has no effect on the counter.

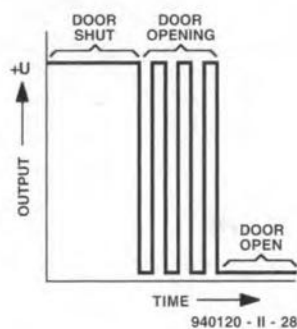


Fig. 18

One of the disadvantages of mechanical switches is that their contacts open and close several times when the switch is open and when it is closed. When the switch of Fig. 17 is opened, the output from the circuit may show several swings between +V and 0 V before it finally settles to 0 V (**Fig. 18**). It may take several milliseconds to do this and produce numerous short pulses. This is no problem when we are using a switch to control an indicator lamp for the eye can not detect the flickering of the lamp. But the digital

counter has a very short response time and is easily able to count all the pulses shown in Fig. 18. Counters work fast and detect every change of voltage. It appears to the counter that the door has been opened and closed three times before it is finally left open. The effect is known as *contact bounce* and is a source of error.

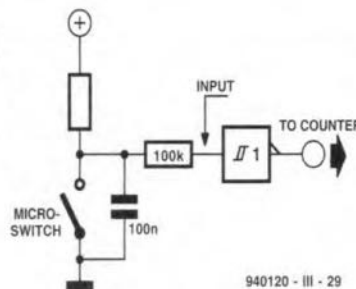


Fig. 19

The cure for contact bounce is *debouncing*. **Figure 19** shows one way of debouncing the switch of Fig. 17. The logic gate is a NOT gate, so the microswitch and resistor have been interchanged. An ordinary NOT gate can be used, but it is preferable to use one with a Schmitt trigger input as indi-

cated by the symbol in the box. When the door is opened, the switch opens and the voltage input to the gate rises. The gate output falls, which increases the counter state by one as before. The effect of the capacitor is to make the voltage level at the input of the gate change more gradually; it partially smoothes out the former discrete pulses (**Fig. 20**). The input voltage rises but, because of the Schmitt trigger input, there is no change in the state of the output until it rises *above* the *upper* threshold. When the voltage falls again, it has no effect on the output unless it falls *below* the *lower* threshold. The capacitor prevents the voltage changing to this extent, so there is only one change of state when the switch is opened, and only one opening of the door is registered. Similarly, there is only one change when the switch is closed. The circuit would work with an ordinary NOT gate, but the advantage of using a Schmitt trigger gate is that the thresholds are set further apart, so the debouncing is more effective. Debouncing complies with the general principle of digital circuitry that logic levels are to be high or low and that intermediate states are to be eliminated as far as possible.

The drawback of the circuit of Fig. 17 is that it relies on the capacitor to smooth over the irregularities of the operation of the switch. This intro-

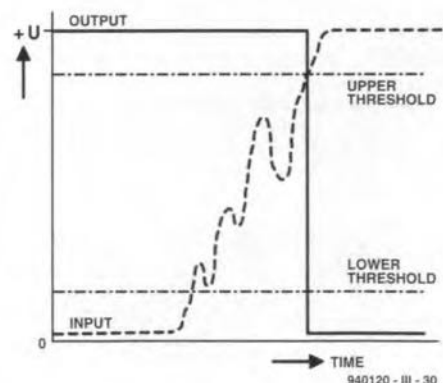
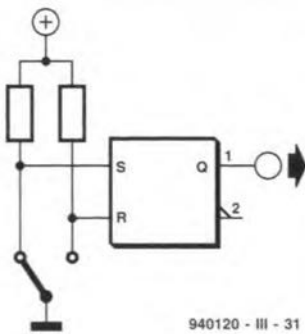


Fig. 20



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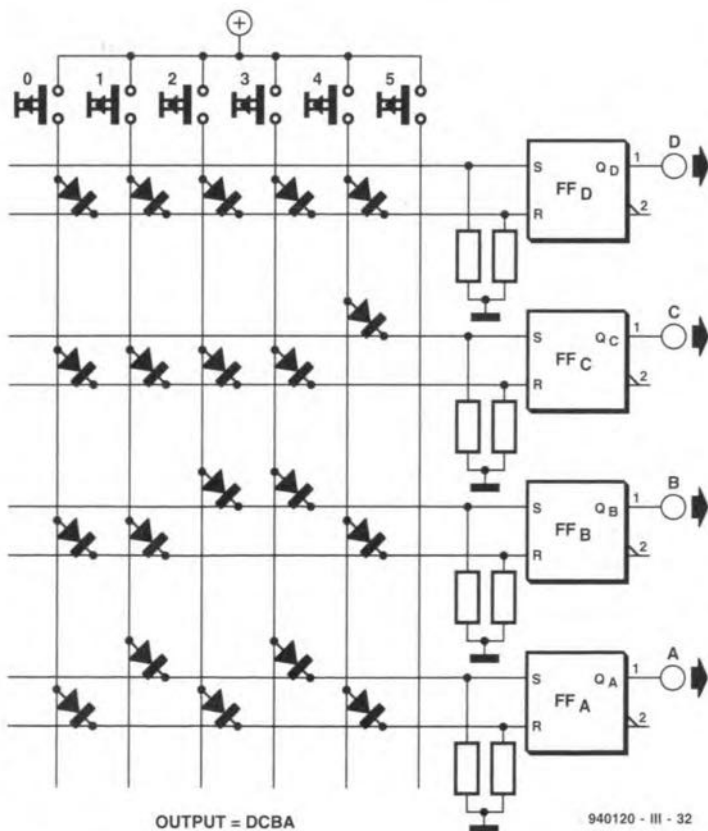
Fig. 21

duces a time factor, for there is a minimum time required for the capacitor to be either charged or discharged to allow the voltage level to change. The larger the value of the capacitor and of the resistors, the longer the time and the more efficiently the key is debounced. But this makes it impossible for the circuit to respond to genuine rapid changes in the state of the key. **Figure 21** shows an alternative debouncing circuit which is more complicated but allows for almost instant repetition. The heart of the circuit is a set-reset (R-S) bistable (US: flip-flop). We shall say more about bistables in a future issue, but for the present take a bistable to be a digital sub-

circuit with two inputs (S and R) and an output Q. When S is made high, the bistable is set and Q goes high. When R is made high, the bistable is reset and Q goes low. In this circuit the inputs are held high, except when the switch connects them to 0 V. In the state shown in Fig. 21, reset is held high so the bistable is in the reset state with output Q low. When the switch is moved, the S input immediately goes high and the bistable changes state to 'set' with Q high. This happens on the *first* occasion the contact is broken. It is a property of the bistable that, once it has been set, it can not be reset except by a low input to its reset terminal. Any subsequent makes and breaks at the set terminal have no effect.

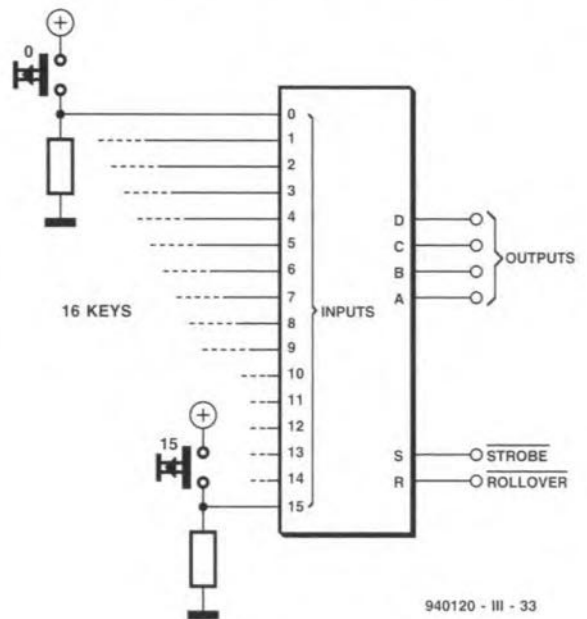
Keyboards

When the input to a digital circuit is by way of more than one key, the circuit is required to detect which key has been pressed. For example, consider the 6-pad key of **Fig. 22**. The keys are numbered 0 to 5. The output comes from a set of four R-S bistables, each of which provides one binary digit (bit) to make up the output. The keys are connected to the



940120 - III - 32

Fig. 22



940120 - III - 33

Fig. 23

anodes of a *diode matrix*. The set and reset inputs are connected to the cathodes. The connections are such that, when a key is pressed, certain bistables are set and certain others reset. The Q outputs take on the values of the appropriate binary number. For example, if key 5 is pressed, the set inputs of bistables A and C are made high and the reset inputs of bistables B and D are made low. The output from the bistable array is 0101, the equivalent of decimal 5. Actually, we need only three bistables to encode six keys. With the four bistables shown in Fig. 22, it is possible to encode a keyboard of up to 16 keys.

In Fig. 22 the keys are not debounced. Debouncing circuits can be added, but usually it is preferable, in devices that are complicated enough to require several keys, for the circuit to undertake the debouncing function automatically. The state of each key is monitored regularly, several times a second, and registered in the circuit. If the state of a key has changed since it was last monitored, it is checked again to see if it has settled to a new state. If so, the new state is registered. This is known as *software* debouncing and is commonly used in computers.

One snag with this type of keyboard is what to do when the operator presses two keys at the same time. This can easily happen with fast typing

since one key may not have been released before the next one is pressed. The solution to this is to use a *priority encoder*. This is a logic circuit that gives priority to one input, usually that of higher magnitude. Thus, if keys 3 and 5 are pressed at the same time, the output of the priority coder is 5.

Keyboard encoders are available as integrated circuits (ICs) containing all the logic necessary to produce a binary output related to the number of the key being pressed. The simplest version is a 16-to-4-line encoder (**Fig. 23**). This accepts inputs from up to 16 keys; one of the 16 input lines is made high when a key is pressed. The circuit produces an output on four lines; the output corresponds to one of the 4-bit binary numbers 0000 (=0₁₀) to 1111 (=15₁₀). As might be expected, a large number of logic gates is required to perform this operation, but there is plenty of room for these on an IC. To illustrate the principle, **Fig. 24** shows the logic of a 3-line to 2-line encoder. Pressing any one of the keys 1 to 3 automatically generates the binary numbers 01 to 11 on the output lines. No key is required for zero, since the resistors pull all inputs down to 0 V when no key is pressed. An encoder such as that in Fig. 23 has additional outputs for preventing errors. One of these is a *strobe* output, which is normally high but which goes low

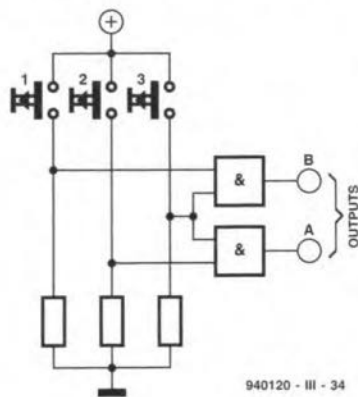


Fig. 24

when any key is pressed. This output is connected to a delay sub-circuit which prevents the output from the other lines passing to the remainder of the circuit until sufficient time has elapsed for the key state to become stabilized. This is a form of debouncing. There is also a rollover output which goes low when two or more keys are pressed at the same time, allowing the circuit to recognize and take steps to ignore the consequent decoding error.

The most complex keyboard encoders can accept inputs from the 80 or more keys of a computer keyboard, and include the circuitry for debouncing and for rollover avoidance. They may also include a memory so that the most recent keystrokes are stored if the operator occasionally types faster than the computer can respond.

Keyboard scanning

When a large number of keys has to be encoded, we do not provide each key with an individual input to the encoder. We resort to *keyboard scanning*. There is no dependence on specially wiring-up the keyboard with diodes or other devices. Scanning is another example of software taking over the functions of hardware. A typical remote control IC (based on Plessey's Type MV500) is shown in Fig. 25. It uses keyboard scanning for a keyboard of 32 keys (though not as many keys as this need actually be installed). The IC has three outputs which are current sources and eight inputs that are current sinks. The sources correspond to the rows of the keyboard and the sinks corre-

spond to the columns. Each source in turn produces a pulse, so scanning the rows one at a time. As each row is scanned, the sinks are monitored to see which one, if any, is receiving a pulse, so scanning that row. If a pulse is received by a sink, it indicates that the key being pressed connects that source to that sink. This identifies the number of the key being pressed. The column decides the two digits at the extreme right and the row decides the three digits at the extreme left. Thus, pressing the shaded key in the diagram gives the output 01101. The IC cycles rows and columns repeatedly, producing an appropriate output whenever a key depression is detected.

Pulse detection

A remote control transmitter, such as the one referred to above, produces an output of coded pulses depending on which control key is pressed. This output is transmitted to the controlled device, such as a TV set. The electrical pulses from the IC may be converted to pulses of infra-red (IR) light, or ultrasound, or sent as voltage levels on a wired connection. We shall have more to say about long-distance line transmission of digital signals in a later issue but, for the moment, let us look at some of the problems associated with the reception and recognition of digital signals from nearby source.

A digital signal does not necessarily consist of a pulse, as such. The essentials of a digital input are that there are two distinct levels and there is an almost instantaneous change of state from one level to the other. We have already described how pressing a key causes a change in voltage level from low to high. A thermistor circuit such as that in Fig. 26 has an output which is normally low but which goes high when the temperature (perhaps room temperature) rises above a preset level. This may provide one of several inputs to a digital logic system controlling central heating. Note the Schmitt trigger gate, which is intended to give a positive action to the circuit. It acts as an amplifier, for a very small change input voltage

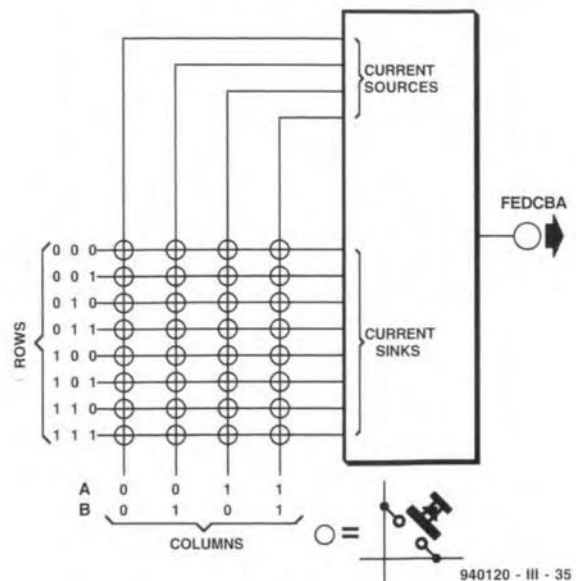


Fig. 25

around one of its thresholds produces a swing in output voltage from high to low, or low to high. The other aspect of the Schmitt trigger action is its *hysteresis*, described earlier. Once the temperature has exceeded a certain level, it needs to drop several degrees below that level before the output reverts to its original low-temperature state. The reverse applies as the temperature falls. This is the equivalent of debouncing a switch; it prevents the room heating from being switched on and off for very short periods when the temperature is hovering around the transition point. Looking at this from a different point of view, the trigger circuit, in conjunction with the fact that significant temperature changes are usually slow, acts as a *filter*. It ignores short-term variations in temperature, but responds to long-term changes. Similar circuits can be used to monitor other physical quantities such as light (photodiode),

mechanical strain (strain gauge), magnetic field (Hall-effect device), and vibration (piezoelectric crystal, microphone). In the case of a circuit designed for detecting light levels, we may need to include a high-pass filter to eliminate the effects of long-term lighting changes such as those brought about by weather conditions or the time of day. Yet, the circuit responds to the rapid changes of level produced by arriving pulses. The high-pass filter may need a cut-off frequency as low as 20Hz so as to eliminate the effects of mains-frequency interference, either electromagnetic effects or, in the case of light sensors, the fluctuations of room lighting, particularly where fluorescent tubes are installed.

Summarizing the foregoing, a typical circuit has a sensor, an amplifier and a device to sharpen the response. A Schmitt trigger gate is only one way of processing the signal from the sensor. Many other designs of circuit are deployed, using comparators or amplifiers with special characteristics. The amplifiers may also incorporate a filter of some kind. Finally, an input circuit needs an interface so that signal levels within the detector circuit may be converted to those of the logic system to which it is connected.

A typical infrared detector circuit is shown in Fig. 27. It could be used for detecting the pulses transmitted from a TV

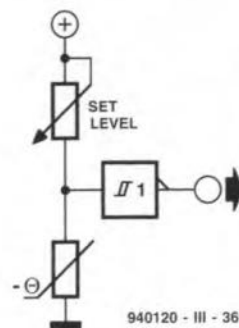


Fig. 26

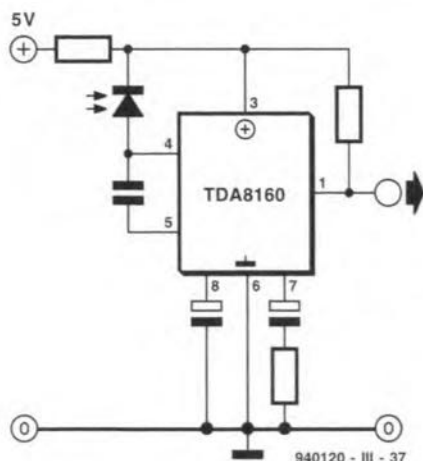


Fig. 27

remote controller (Fig. 25). The sensor is a reverse-biased IR photodiode. The diode element is enclosed in a plastic package which permits only IR light to enter. A small reverse current passes through the diode; this is very small in the absence of IR light and increases when a pulse arrives. It flows to the IC where it is amplified and causes the output to switch between low and high logic levels. In the case of remote control, the signal is a series of pulses. The pulses are all of the same width, so that it is only necessary for the circuit to detect the *arrival* of a pulse, not its exact duration. The circuit has to detect only a *sudden increase* in IR level against the continuously changing background levels and interference from other devices such as filament lamps and heaters. It is the *duration* of the interval between the arrival of one pulse and that of the next pulse that is used to code the control signal. This is known as *pulse position modulation* (PPM) and will be detailed in a later issue.

A similar circuit is used in a bar code reader. The source of light is a laser beam of red light, which is of high intensity and very narrow. The high-intensity spot of light is used to scan across the bars. Since it is laser light, which is monochromatic, there are no blurring effect owing to differential refraction in lenses and

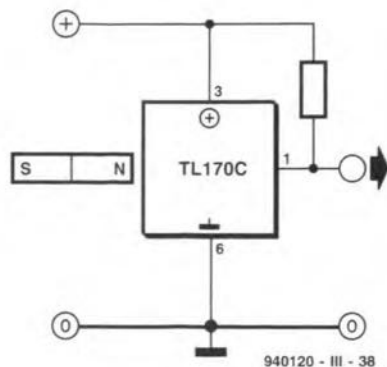


Fig. 28

mirror in the system. The bar code is read by swiping the code panel across the beam or by scanning a deflectable beam across the panel. The reflected light is monitored by a detector circuit. The bars and the gaps between them are of different widths. It does not matter whether the scanning is exactly perpendicular to the array of bars, nor is the exact speed of the scan important, for it is the relative lengths of the pulses and pulse intervals that are decoded.

Magnetic sensor

Figure 28 illustrates a sensor circuit for detecting the presence of a ferromagnetic object or a magnet. The IC includes a Hall-effect device and an amplifier which produces a binary output compatible with logic ICs. This sensor has many applications in the control of machines because it is able to detect when metal parts (or non-metal parts bearing a small magnet) are in a certain position. If a magnet is attached to rotary parts and the Hall-effect device is placed so that the magnet sweeps past it at each rotation, the number of pulses generated can be counted. A timing circuit counts the number of pulses within a set period of time and the circuit functions as a tachometer.

The output of a Hall-effect device swings sharply up or down when the magnetic field changes in a certain way. For example, IC Type TL170C is sensitive to field *direction*. It is switched on (output goes logic high) when the field strength exceeds 25 mT. To switch it off, the field must reverse to become -25 mT. By comparison, the TL172C is sensitive to field *strength*. It is turned on when the field strength exceeds 45 mT, and is turned off when the field strength falls below 22 mT. The action shows hysteresis, and is the same as that of a Schmitt trigger. One application of this is to make bounce-free keys. The base of the key contains a Hall-effect device and a small magnet is mounted in the key-top. When the key is pressed, the magnet is brought closer to the Hall-effect device, which is turned on. There is no making or breaking of contacts but just a single transition from low to high, ideal for input to a logic circuit.

Phase-locked loop

In many environments, there is the difficulty of sensing pulses against a noisy background. Take the detection of light pulses as an example. The noise may be of the random type, for example, flashes of light or interruptions of light caused by objects and people moving in the area surveyed by a light sensor. Or it may be by regular pulses generated by various sources such as a mains-powered lamp or a remote controller for some other digital

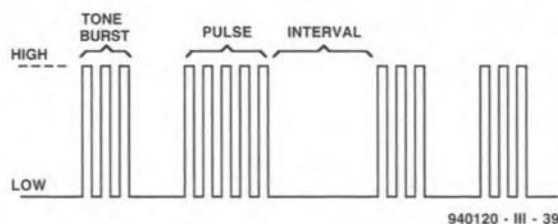


Fig. 29

circuit. It is usually easy to deal with the second type of noise, either by filtering as explained earlier or by operating different remote control circuits with different pulse timings so that each circuit recognizes only its own controller. Random noise is more difficult to anticipate and ignore. The solution is to contrast the randomness by the use of signals that have a high degree of regularity. Then the detecting circuit will be most easily able to distinguish between noise and signal, even if the amplitude of the noise is of the same order as that of the signal.

A very successful approach to this problem is to superimpose the signal (which is very regular in form) on to a *carrier* signal (which is even more regular). The highly regular modulated signal is more easily detected against random background. The carrier signal has a higher frequency than the digital signal and is 100% modulated by it to give a series of *tone bursts* instead of a series of pulses (Fig. 29). The detector circuit looks for the carrier signal and detects whether it is present (=pulse) or absent (=interval between pulses).

The carrier signal is detected by a phase-locked loop, a circuit that can be tuned to the carrier frequency. A block diagram of a circuit based on the Type 4046 phase-locked loop IC is shown in Fig. 30. The input to the circuit comes from the sensor (such as a photodiode or piezoelectric vibration sensor) and consists of a nominally square wave at the carrier frequency, modulated by the digital signal.

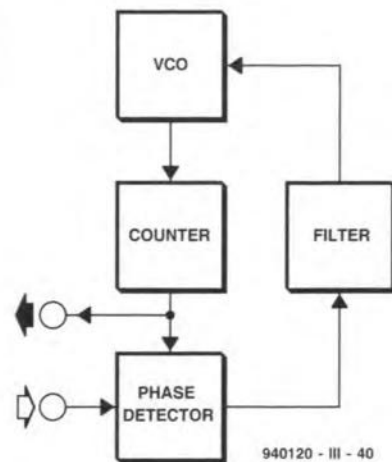


Fig. 30

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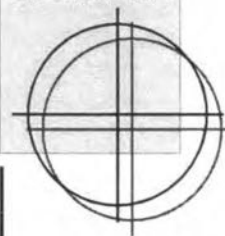
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The PLL has its own *local oscillator* generating a continuous square-wave signal. Its frequency is controlled by a voltage input, so it is a *voltage-controlled oscillator* (VCO). The frequency may be divided down by a counter, the degree of division depending upon the application. In some applications, there is no division, and we will assume this is the case in this description. At the phase detector stage, the incoming signal is compared with the signal from the VCO. In one form of PLL the phase detector consists simply of an XOR gate. If the incoming signal has exactly the same frequency and phase as the signal from the VCO, the output of the gate is continuously zero. But this is unlikely to be the case: the signals are more likely to be out of phase and possibly out of synchrony, too. The bigger the difference between the signals, the greater the average output voltage from the phase detector. This voltage is filtered and sent back around the loop to control the VCO. The result of this is that the frequency of the VCO is increased or decreased until it gradually latches on to the frequency of the incoming signal, and eventually runs in phase with it. Random noise on this signal may cause instantaneous changes in the output from the phase detector, but these are filtered out by being averaged

over several cycles. Overall, the VCO is kept in step with the incoming signal. If the incoming frequency changes, the VCO tracks the change.

The centre frequency of the VCO is preset by a suitable choice of capacitor and resistor so that it equals the known frequency of the incoming signal (for example, from a remote controller with its carrier tuned to a set frequency). The VCO is thus able to home on and track the incoming signal rapidly, and usually to ignore signals from controllers operating on different carrier frequencies.

The incoming signal is usually distorted in shape with spikes on it owing to random noise in the environment, but the locally generated signal from the VCO is a crisp square wave of identical frequency. If the incoming signal fades for a few cycles, or is totally masked by an eruption of interference, the VCO continues to oscillate with relatively little change in frequency. It is the signal *from the VCO* which is sent to the digital circuit for analysis.

In the foregoing we have looked at some of the ways in which binary (on-off) information may be detected and fed to a digital circuit. Next month we discuss how analogue information is processed to prepare it for digital analysis.

Test yourself 3

Design a keyboard encoder for a 6-key board, the output to indicate the key number from 0 to 5.

Answers to

Test Yourself 2

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PARAMETERS OF MMIC WIDEBAND RF AMPLIFIERS

Microwave monolithic integrated circuits (MMICs) are now firmly established components in wideband RF amplifiers. These devices offer excellent matching, high gain and a fabulous bandwidth at very low cost. This article provides an introductory overview of MMICs, and discusses their basic characteristics.

By G. Kleine

MMICs are drop-in amplifiers which can be used up to very high frequencies. Some versions packed in ceramic enclosures operate up to 30 GHz and higher, while low-cost variants in plastic cases can be used up to about 2 GHz. Since the introduction of MMICs about seven years ago (Ref. 1), the same technology has also produced one-chip mixers and oscillators for SHF applications. Furthermore, electronic switches and attenuation pads are now available as MMICs, which use Gallium-Arsenide (GaAs) technology for the most part.

MMIC basic circuits

An MMIC requires an absolute minimum of external parts to come to life. Figure 1 shows the three supply options for these devices, which are often referred to as gain blocks by their manufacturers. The configuration in Fig. 1a is generally recommended for use with a positive supply voltage, U_B . All you have to do is calculate the value of resistor R as a function of the MMIC operating voltage, U_d , and the operating current, I_d :

$$R = (U_B - U_d) / I_d$$

To cope with all thermal instability and individual device tolerances, the supply voltage, U_B should be at least 2 V higher than the typical operating voltage, U_d . If that is not possible, the circuit of Fig. 1c should be used. This will be reverted to below. The value of the choke is uncritical. The function of the choke is to decouple the supply resistor, R , from the RF signal at the MMIC output. The choke may be omitted if the value of R is large with respect to the output impedance (which is usually 50 Ω). In practice, the choke is not used when $R > 500 \Omega$.

The basic circuit for negative supply voltages is shown in Fig. 1b. Here, the MMIC output is tied to ground (d.c.-wise, that is) via the choke, so that the ground terminals of the MMICs are at $-U_d$. These two terminals are decoupled for RF signals by two capacitors. In some cases, a number of capacitors with different values must be connected in parallel to prevent resonance effects. Series resistor R is connected between the MMIC's ground terminals and $-U_B$. Its value is calculated as with the circuit in Fig. 1a. The observations as regards the choke are the same as for the positive supply variety. The choke may not be omitted, however, when a negative supply is used.

When the supply voltage varies by a couple of volts, or when it is less than 2 V above the MMIC operating voltage, an active supply as shown in Fig. 1c may be used. The p-n-p transistor forms a constant current source together with resistor R_E and the voltage divider at the base. The MMIC operating current, I_d , equals U/R_E . The level of U (see Fig. 1c) is determined by the voltage divider, and is about 0.7 V lower than the transistor's base voltage. A silicon diode, D , is added as a thermal compensation for the transistor's b-e junction. When U is of the order of a couple of volts, the diode may be omitted. As with the two previous supply options, the value of the choke is uncritical.

Matching

The input and output matching characteristics of MMICs are usually expressed in a VSWR (voltage standing wave ratio) value or a reflection damping value (in dB). The VSWR should be as close as possible to 1 (for instance, 1.5), while the reflection damping should be as high as possible (for in-

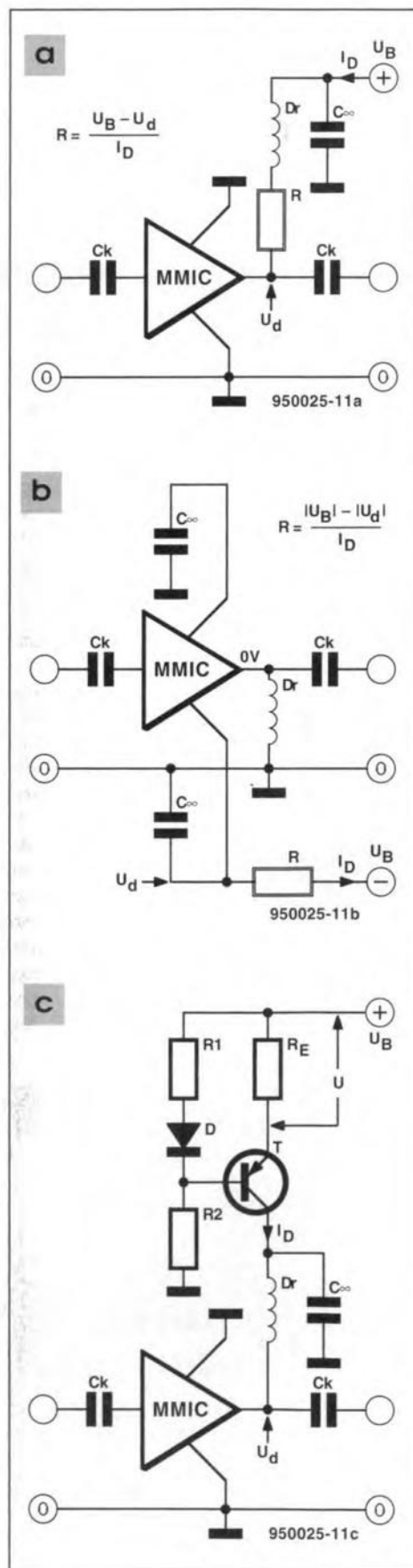


Fig. 1. Power supply options for MMIC RF amplifiers.

stance, 15 dB). These two values indicate the amount of power reflected by the MMIC input as a result of an impedance mismatch. The same goes for the MMIC output. For cable TV networks, the reflection damping should be at least 20 dB, which equals a VSWR of 1.2.

Although MMICs are simple to use as gain blocks, special attention should be given to the geometry of their input and output lines if you want to ensure that they are properly matched. As discussed in Ref. 2, 50- Ω stripline techniques should be applied in all cases where the input and output connection are not very short. The matching properties are also affected by the way the MMIC's ground terminals are connected. These should be soldered flush on the ground plane.

1-dB compression point

All amplifiers may be driven to a certain maximum as regards their output signal level. The absolute maximum signal level that can be achieved is, obviously, determined by the supply voltage. Before that level is reached, however, distortion will occur which makes the amplifier useless at output signal levels way below that of the supply voltage.

From a certain drive level onwards, saturation will occur in any amplifier, when the output voltage will not rise in proportion with the input voltage any more. Consequently, the amplifier's large-signal gain is lower than the small-signal gain. When the input level is increased beyond the saturation level, the output level remains virtually constant. The saturation effects then give rise to harmonics and distortion, the negative effects of which will be reverted to below.

The 1-dB compression point (P_{1dB}) is the output level at which the theoretically constant gain has dropped by 1 dB. **Figure 2** shows an example. The 1-dB compression point is found where the output level deviates 1 dB from the (theoretically) straight line. The actual value of P_{1dB} is about 13.7 dBm.

Intermodulation products and 3rd order intercept point

Distortion occurs in any amplifier, particularly at high drive levels, and is first noticed from the presence of harmonics. As illustrated in **Fig. 3**, an amplifier driven with two frequencies, f_1 and f_2 , produces its first harmonics at $2f_1$ and $2f_2$. The harmonics have a lower level than the wanted signals. The levels of the higher harmonics, $3f$, $4f$, etc. drop rapidly with increasing frequency, and need not be taken into

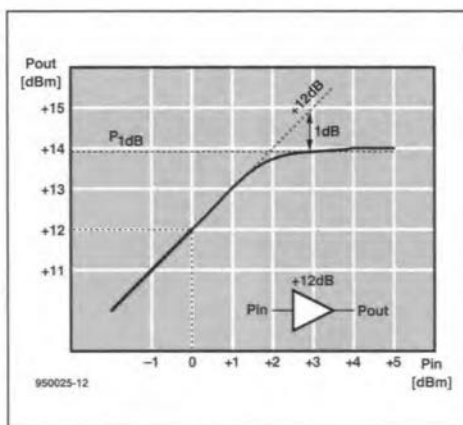


Fig. 2. Graphic representation of the 1-dB compression point.

account. The ratios of the harmonics levels allow you to estimate the degree of distortion which occurs in the MMIC amplifier. The presence of strong odd-numbered harmonics ($3f$, $5f$, etc.) indicate that a sine-wave input signal is being distorted into a rectangular shaped signal. Time to reduce the input level!

The two-tone input signal of **Fig. 3** also produces intermodulation products, which are weaker than the harmonics. Intermodulation also occurs at relatively high drive levels, and is caused by non-linear behaviour of the RF amplifier. The IM products are classified according to their 'order', a number obtained from the multiples of the basic frequencies present in the IM signal. In the output spectrum, frequency lines caused by $(n \cdot f_1 \pm m \cdot f_2)$ are referred to as the $(m+n)$ -order IM product. In **Fig. 3**, the second-order IM product, $f_1 + f_2$, appears between the first two harmonics.

Harmonics and second-order intermodulation products rarely cause problems in narrow-band RF amplifiers, such as intermediate frequency

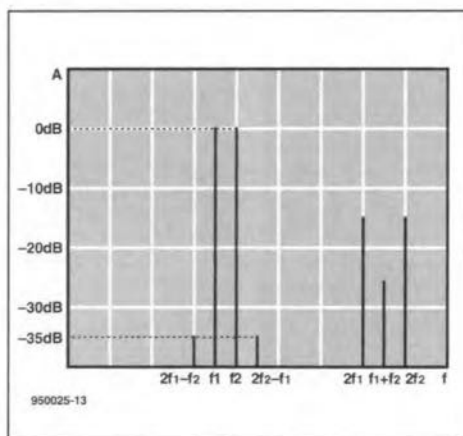


Fig. 3. Intermodulation products caused by non-linear amplification.

(IF) amplifiers in radios and TV sets. In wideband amplifiers, however, these spurious signals are far more troublesome. Third-order IM products in particular need to be kept as small as possible because they fall within the same frequency range as the wanted signal(s). The third-order IM products are components $2f_1 - 2f_2$ and $2f_2 - 2f_1$, which are very close to the two-tone components f_1 and f_2 (**Fig. 3**). Complex signals, such as an amplitude-modulated TV signal with a sound subcarrier, consist of a large number of individual components. Because of the amplitude modulation, the differences between the levels of the wanted signals and those of the IM products must be sufficiently high. The term used to express this parameter is 'intermodulation distance'. In **Fig. 3**, it has a value of 35 dB. In cable TV networks, the IM distance should be at least 70 dB for all amplifiers.

Because the effects discussed so far are dependent on the degree to which the amplifier is driven, the design of an amplifier forces you to select a device which guarantees the desired third-order intermodulation distance at the required output level.

In order to obtain a generally valid parameter to describe the performance of an RF amplifier in this respect, it is necessary to gather the different drive levels and the respective intermodulation distance values into one specific quantity. This is aided by the following rule of thumb which applies to the drive range below the 1-dB compression point: if the wanted signal rises by 1 dB, the levels of the third-order intermodulation products rise by 3 dB. When both the level of the wanted signal and that of the third-order IM product are entered into a graph like the one in **Fig. 4** (large drive signal range assumed), you get two straight lines with different rates of rise. The one to the left is the gain curve already shown in **Fig. 2**, which starts to move into the horizontal saturation line at the 1-dB compression point. The curve to the right represents the level of the third-order IM products. The quality parameter mentioned earlier is found by extending both lines. The theoretical output level at which the wanted signal and the third-order IM products have the same level is found where the lines cross. This is called the third-order intercept point, or IP_3 . In the example of **Fig. 4**, the IP_3 level is about 15.5 dBm.

Although an intercept point may also be defined for the second-order intermodulation products, it is rarely used because these products fall outside the relevant channel bandwidth.

When the intercept point is stated as referring to the input, the output intercept point may be obtained by sim-

Type	Frequency range	Gain	P_{1dB}	IP_3	U_d	I_d	Manufacturer
MAR-1	DC - 1 GHz	16 dB	+1.5 dBm	+14 dBm	5.0 V	17 mA	MiniCircuitsLabs
MAR-7	DC - 2 GHz	12 dB	+5.5 dBm	+19 dBm	4.0 V	22 mA	MiniCircuitsLabs
MAR-3	DC - 2 GHz	12 dB	+12.0 dBm	+23 dBm	5.0 V	35 mA	MiniCircuitsLabs
MSA 0104	DC-0.8 GHz	17 dB	+1.5 dBm	+14 dBm	5.0 V	17 mA	HP (Avantek)
MSA 0286	DC-2.5 GHz	12 dB	+4.5 dBm	+17 dBm	5.0 V	25 mA	HP (Avantek)
MSA 0404	DC-2.5 GHz	8 dB	+11.5 dBm	+24 dBm	5.3 V	50 mA	HP (Avantek)
MSA 0886	DC - 3 GHz	25 dB	+12.5 dBm	+27 dBm	7.8 V	36 mA	HP (Avantek)
MSA 0986	0.1 - 3 GHz	7 dB	+10.5 dBm	+26 dBm	7.8 V	35 mA	HP (Avantek)
MSA 1105	0.05-1.3 GHz	12 dB	+17.5 dBm	+30 dBm	5.5 V	60 mA	HP (Avantek)
AM-184	10-2000 MHz	20 dB	+12.0 dBm	+22 dBm	15 V	60 mA	M/A-COM
AM-185	10-2000 MHz	19 dB	+15.0 dBm	+28 dBm	15 V	90 mA	M/A-COM
NE 5200	DC-1.2 GHz	7 dB	-1.7 dBm	+5 dBm	5.0 V	10 mA	Philips
NE 5205	DC-600 MHz	20 dB	+4.0 dBm	+17 dBm	6.0 V	24 mA	Philips
CA 2820	1 - 520 MHz	30 dB	+26.5 dBm	+37 dBm	24 V	330 mA	Motorola
CA 5800	10-1000 MHz	15 dB	+30.0 dBm	+40 dBm	28 V	400 mA	Motorola

Table 1. Technical data on generally used MMICs from different manufacturers.

ple addition of the nominal gain of the device in dB. For example, with reference to Fig. 4, the third-order input intercept point is 3 dBm, and the gain is 12 dB. It is safe to assume that the output intercept point then lies at about 15 dBm.

The advantage of estimating an amplifier's performance for a particular application with the aid of the IP_3 level is that this figure allows you to calculate the desired operating conditions in a simple way. The assumption for this method is the (theoretical) fact that the third-order IM products have the same level as the wanted signal if the output-level equals IP_3 . For example, when the wanted signal is 10 dB lower than the IP_3 level, the levels of the third-order IM products have dropped by 30 dB. Consequently, the third-order IM distance becomes 20 dB. Similarly, keeping the wanted signal 20 dB lower than IP_3 results in an IM distance of 40 dB. This method enables both the required IP_3 for a certain output level as well as the expected IM distance at a given IP_3 level to be determined with quite acceptable accuracy.

Practical use: today's MMICs

To help you understand and use the values and parameters mentioned in the datasheets, **Table 1** shows the main technical characteristics of today's most popular MMICs. Originally designed by Avantek, MMICs are now available from a number of manufacturers. Especially the

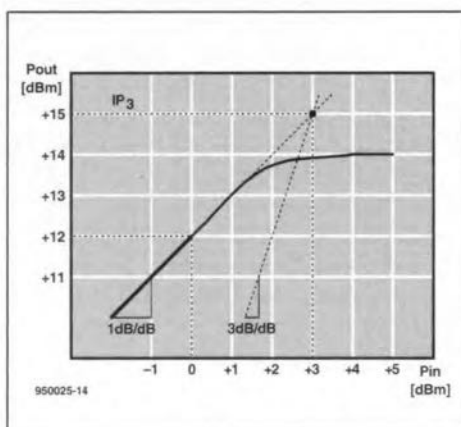


Fig. 4. Graphic representation of the third-order intercept point.

MSA devices from Avantek (now Hewlett Packard) have found wide acceptance with RF designers and radio amateurs. Not surprisingly, a number of second sources have emerged for these popular devices.

The table clearly indicates that low distortion can be achieved at the cost of (relatively) high current consumption only. Conversely, all low-current MMICs have relatively low IP_3 values.

The table also lists the main specs of two hybrid amplifier modules from Motorola, which are used in cable TV master amplifiers with a capacity of 30 to 40 AM TV channels. These specs are included as a reference to compare with those of MMICs. Clearly, the hybrids achieve sufficient linearity at

high output levels only at high supply voltage levels and high current.

(950025)

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1. MMICs revolutionize wideband RF amplifier design, *Elektor Electronics* January 1988
2. Using the MAR-x series of MMICs, *Elektor Electronics* October 1992.

OPERATIONAL AMPLIFIERS REVISITED

By J. Markus

The operational amplifier (often abbreviated to op amp) is an extremely stable, usually direct-coupled, linear amplifier originally developed for performing mathematical operations. Nowadays, it is widely used in computers, although it is not always realized that this is but one of its many applications. It comes in many shapes with varying specific parameter: one, two or even four in one enclosure.

An op amp is basically a differential amplifier typified by two complementary inputs: an inverting one (-) and a non-inverting one (+). It tends to hold its inputs at the same potential, and when a difference between the two occurs, it produces an output that tends to nullify that difference. Its amplification is determined by feeding back part of its output signal to its inverting input.

Use as inverting amplifier

Figure 1 shows how an op amp may be used to form an inverting amplifier. The input signal is applied to the **inverting** input via R_1 . The + input is connected to the reference voltage via R_3 . The reference voltage is usually equal to half the supply voltage. If the supply voltage is symmetrical, the reference potential is zero. This is why in many op amp circuits this point is at 0 V.

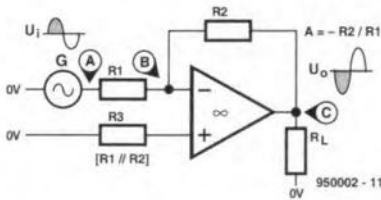


Fig. 1.

Feedback in Fig. 1 is effected via R_2 . The amplification, α , is calculated from

$$\alpha = -R_2/R_1.$$

The relationship between input and output is shown by the characteristics in Fig. 2. Points A, B and C on the x-axis correspond to those indicated in Fig. 1.

Since the level of the potential at the -input is always identical to, and is determined by, that at the + input, no voltage variations will be discerned at the - input of an inverting amplifier. This is also evident from the characteristics in Fig. 2, which show that both input and output voltage vary, but the potential at B remains constant.

The characteristics also show at a glance that they pertain to an inverting

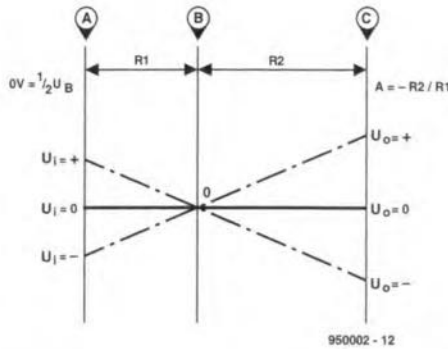


Fig. 2.

amplifier, because as soon as a line connecting input and output passes through B, the polarity reverses.

Furthermore, they show how the amplification setting works: the ratio of sections A-B and B-C corresponds to that of the values of R_1 and R_2 . (A line drawn from A to C through 0 shows that C is further from 0 than A. In other words, the larger B-C, that is R_2 , relative to A-B, that is, R_1 , the higher the output voltage).

Use as non-inverting amplifier

The circuit in Fig. 3 is identical to that in Fig. 1, but the input signal is applied to its + input. This arrangement has far-reaching effects on the characteristics shown in Fig. 4. A, the point of origin in Fig. 2, has become a pivot, while the new point of origin is somewhere between A and C. Because

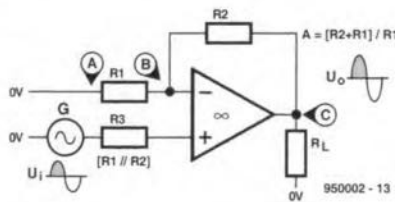


Fig. 3.

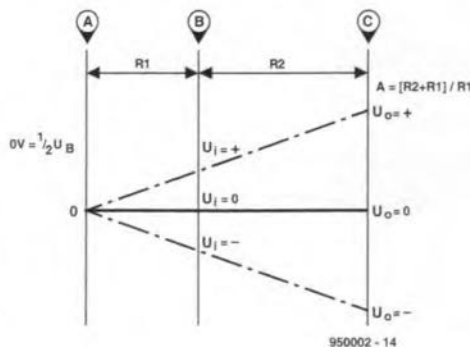


Fig. 4.

of amplification, the swing of C relative to 0 is larger than that of B, but both move in the same direction. This means that a non-inverting amplifier does not cause polarity reversal, so that input voltage and output voltage have the same polarity.

The amplification, α , is

$$\alpha = (R_1 + R_2)/R_1.$$

This shows that if the values of the resistors are the same as those in Fig. 1, the amplification will be greater.

Use as voltage follower

The circuit in Fig. 5 is not an amplifier in the true sense of the word, but a voltage follower. In this, the output is connected directly to the inverting input. This means that the potential at the output is identical to that at the - input; whence the name voltage follower. This circuit is comparable to that of an emitter follower.

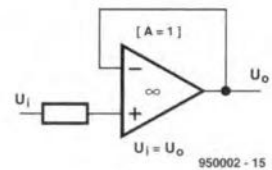


Fig. 5.

Load presented by an op amp

The op amp is no exception to the rule that each and every circuit presents a load to the preceding circuit or signal source. In the case of an op amp, this load depends on the configuration of the op amp.

In Fig. 1, generator G is loaded by the series network of R_1 , R_2 and R_L (the load resistance) to 0 V—see Fig. 6a. Since the input resistance of the op amp is high compared with the values of R_1 , R_2 and R_L , it hardly affects the value of the network. This is also true of R_L , since its value is invariably much lower than that of R_2 . It might, therefore, be thought that the input resistance is determined by R_1 and R_2 . In reality, this is not so, because B is at 0 V (called **virtual earth**). The circuit may thus be simplified as shown in Fig. 6b. It

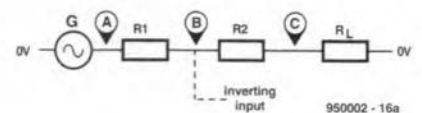


Fig. 6a.

is evident that the input resistance is determined almost exclusively by R_1 .

The matter is even simpler in the case of a non-inverting amplifier: in Fig. 3, the input signal is loaded by the series network of R_3 and the (very high) input resistance of the op amp. It is evident that the total resistance of this network is very high

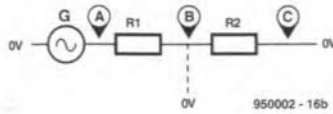


Fig. 6b.

(in excess of 1 M Ω , often as high as 10 M Ω).

As far as the input impedance or amplification of a non-inverting amplifier circuit is concerned, the value of R_3 does not seem to matter much. In practice, however, it does, because op amps are not as ideal as we would like them to be. In fact, they cause small errors which are minimal, however, when the value of R_3 is equal to that of the parallel connection of R_1 and R_2 —see Fig. 7.

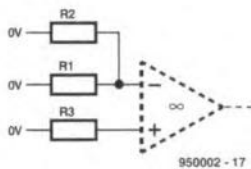


Fig. 7.

Note that, seen from the signal source, R_1 and R_2 are in series, but seen from B this is not so. Since, invariably, the internal resistance of the signal source is negligible relative to R_1 , the 'free' ends of these resistors, seen from B, are at 0 V, that is, they are in parallel as drawn in Fig. 7. To obtain symmetrical operation, the value of R_3 will thus have to be equal to that of the parallel combination.

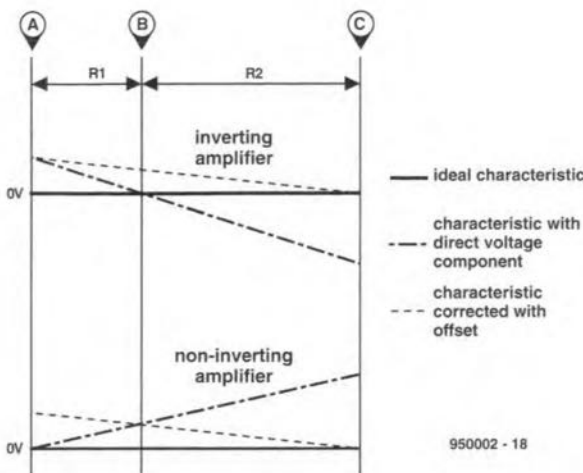


Fig. 8.

Offset

So far we have assumed that the 0-axis of the input signal is at the same level as the 0 V line of the op amp. This is not always so, however: for example, if the input signal has a direct voltage component. The operation of the op amp is then as illustrated in Fig. 8. This shows that the output (C) is no longer at 0 V, but at a different level. The result of this is that symmetry is lost and that maximum amplification can no longer be attained. This is because the voltage swing at one end is much smaller than that at the other end. If the amplification is arranged at maximum notwithstanding, the negative part of the output of an inverting amplifier will be distorted, because the signal can not exceed the lower limit of the negative supply line. This difficulty is avoided by correcting the position of the 0-axis of the input signal in such a way that it is at the same level again as the 0-axis of the op amp. This is done by superimposing it on to a direct voltage, called the offset voltage. The level of this voltage is determined empirically with a preset in the circuit.

This in itself raises a further difficulty: the resistance of the preset affects the input resistance of the op amp and this in turn affects the amplification and the symmetry. The only way to obviate this difficulty is to use a preset with an internal resistance of 0 Ω , which can be done only by adding a voltage follower to it—see Fig. 5. This has the effect of combining a very high input impedance with a very low (nearly 0 Ω) output impedance. For this reason, the voltage follower is sometimes called impedance transformer. It is frequently used with signal sources that must not, or hardly, be

loaded by the stage to which it is connected.

In Fig. 8, the voltage characteristics are given relative to the zero line of the op amp. When this line is 'clean', the characteristics are horizontal. When the input signal has a positive direct-voltage component, the output voltage of an inverting amplifier will be negative. In the case of a non-inverting amplifier, the output voltage will be at the same side of the 0-line as the undesired direct-voltage component. Both examples in Fig. 8 assume a positive direct-voltage component; if the component is negative, the characteristics are simply turned around.

It is, of course, possible to use an offset voltage if for some reason it is required that the average output voltage is not on the 0-line. This is achieved by applying the input signal to the amplifier input and adjusting the relevant preset until the output voltage has the required deviation. Note that it is almost impossible to do this accurately without an oscilloscope.

Finally

When experimenting with op amps on the basis of the foregoing, do consult the relevant data sheet(s). Also, note that not every op amp is suitable for use as a voltage follower: some may show a tendency to oscillate. Types like the 741, the 324 (quad), the TL0821 (single) and the TL084 (quad) are eminently suitable. Types like the LM3900 should definitely not be used, since these have current inputs that are quite different from those of most op amps. [950002]



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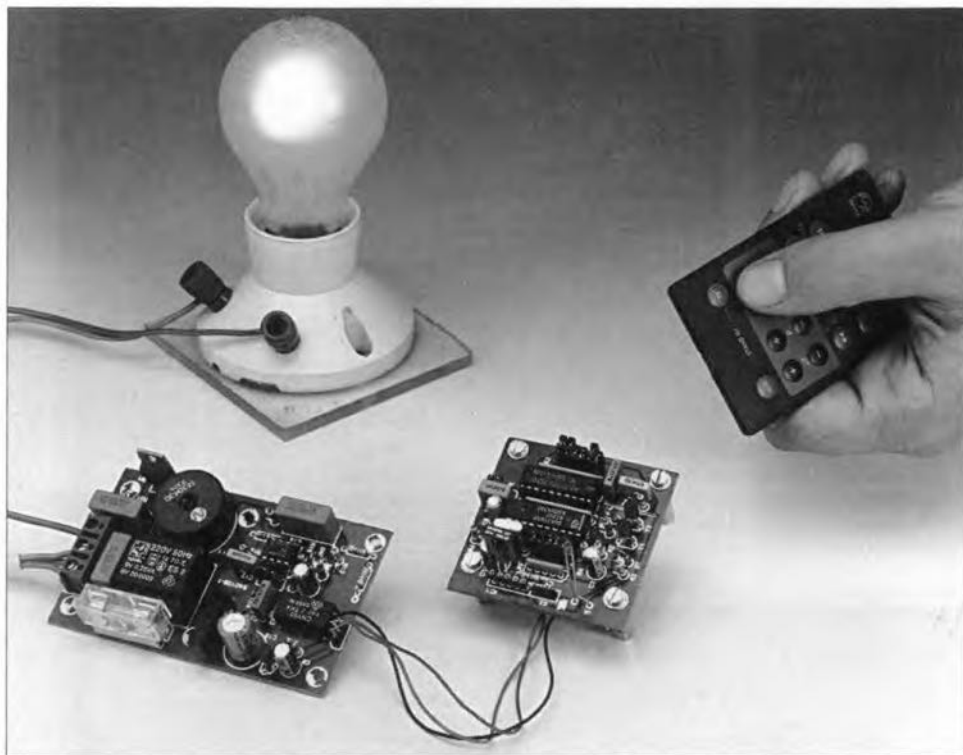
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INFRARED CONTROLLED DIMMER

These days it is perfectly normal for complex functions of TV and audio equipment to be controlled from the couch or armchair. Unfortunately, that luxury is not extended to lighting, although dimmers may be available. Time to do a little combinatorial thinking. The dimmer circuit discussed here responds to commands from the infrared remote control supplied with, say, your TV set.



Design by U. Reiser

REMOTE control is commonplace these days, with telephone answering machines, garage doors and central locking systems for cars responding to infrared remote controls small enough to fit in your pocket. Although infrared remote control transmitters and receivers have been the subject of a number of previous articles in this magazine, none so far was specifically geared to lights on/off and intensity control. That deficiency is made good by the present design.

The circuit discussed here is a combination of (1) a sensitive infrared receiver responding to signals from RC5 compatible remote controls and (2) a dimmer for ordinary light bulbs as well as halogen lamps. The two units may be fitted into a single case and installed near, for instance, a table lamp. The receiver is easily programmed to respond to one particular button on the remote control. This button may be one for a rarely used function on the

relevant audio/visual equipment. If a number of IR controlled dimmers are used, it is, however, worthwhile to use a remote control reserved for that purpose only.

Two sub-circuits

The schematic in **Fig. 1** clearly shows the two sub-circuits that make up the infrared controlled dimmer. The infrared receiver is shown to the left of the dashed line, and the dimmer circuit, to the right. Since the two are linked via an optoisolator, it is possible to locate the receiver at some distance from the dimmer, without running into problems as regards electrical safety. The two sub-circuits are then connected via a short cable. Obviously, the receiver must be able to 'see' the transmitter, hence the relocation option.

As far as the receiver circuit is concerned, since this is based on an ear-

lier design (Ref. 1), its operation will not be explained in great detail here. However, for those who have not seen the earlier article, a brief description is given.

The infrared signal receiver used is a type IS1U60 from Sharp. Received infrared signals are first amplified in a low-noise input stage and then fed through a 38-kHz bandfilter which serves to suppress interference. Next come a limiter and a demodulator. The demodulated signal is available at pin 1 of IC₁, and is fed to the decoder. The IS1U60 may be replaced by similar, but not pin-compatible, devices like the SFH505A or SFH506-36 from Siemens. Although these have different pinnings, they can all be connected to the board without problems.

The decoder is the familiar SAA3049 from Philips Semiconductors. This IC is capable of storing and analysing signals supplied by the infrared receiver. The RC5 codes contain information on the system address and the command, which are transmitted in succession. The SAA3049 is programmed to operate in one of two modes. Here, the 'single-system mode' is used. This is achieved by tying the \overline{CA} input/output, pin 19, to the positive supply voltage via resistor R₅. In this mode, the decoder only supplies commands via its outputs if the received system address matches the one programmed on pins $\overline{A0-A4}$. In this way, it is possible to define the type of transmitter the decoder will respond to. The code which belongs to the button pressed on the remote control appears on outputs $\overline{A-F}$.

A jumper, JP₁, is available to enable you to select between RECS80 (pulse position modulation) and RC5 (biphase modulation). Normally, RC5 will be used, which is selected with the jumper connected to ground.

The clock frequency is obtained from a 4-MHz quartz crystal, X₁, which operates in conjunction with C₃, C₄ and R₄. The combination C₂-R₃ provides a reset signal at pin 14 when the circuit is switched on. The supply voltage is decoupled by R₂, C₅ and C₆. IC₁ has its own decoupling network, R₁-C₁. Five 10-kΩ resistors contained in two SIL arrays, R₉-R₁₀, ensure that address inputs $\overline{A0-A4}$ are logic high if the relevant jumpers are not fitted.

The received code is applied to the P inputs of comparator IC₃, which compares the applied levels with those at its Q inputs. A pin header and some jumpers allow you to program the code of the button to which the system is to

respond. Output $P=Q$ of IC₃ goes low if the received code matches the programmed code.

The circuit around T₁ and T₂ has been added as an extra protection against noise, and to detect the reception of a new command. The \overline{CA} pin of IC₂ supplies a rectangular signal when a system address is detected. This signal is low for 15 ms, and high for 105 ms. Because of network R₈-C₇, T₂ functions as a rectifier, and keeps its collector terminal low as long as IC₂ supplies a rectangular wave at pin 19. As soon as this signal disappears, IC₃ is disabled.

When pin 19 of IC₃ goes low, both LED D₂ and the LED in the optoisolator light. An optoisolator is used to guarantee complete electrical isolation between the IR receiver/decoder and the lamp dimmer, which is connected directly to the mains. Furthermore, the receiver/decoder is accommodated on a separate printed circuit board, so that it need not be co-housed with the dimmer circuit.

The SLB0587 from Siemens arranges everything to do with phase angle control. This IC is specially designed to dim mains-operated (inductive) loads. Its internal block schematic is given in Fig. 2. In addition to the logic which supplies the trigger pulses, the IC also contains a number of protection sub-circuits. For instance, it checks whether the 'on' time of the triac does not become too long, depending on the set phase angle. The IC also checks whether the triac has actually been switched on after a trigger pulse. If not, a new trigger pulse is applied after 1 ms. After 15 trigger faults, the triac is switched off. A soft-start circuit is also provided to reduce current surges when the load is switched on. This helps to increase the life span of the lamp, and is particularly important with halogen lamps. The SLB0587 is also capable of detecting whether the mains voltage has disappeared, when more than three successive periods do not arrive. If the mains is restored within a second, the IC does a soft-start, and automatically recalls the previously set lamp intensity. If the mains remains absent longer than one second, or the supply voltage drops below 3.6 V, the triac is disconnected.

Switching, reducing and increasing the brightness of the load are all controlled by applying a logic level to pin 6. The exact action depends on the logic level applied to pin 2, as will be discussed further on. Since the IC offers a fixed phase angle range of 45° to 152°, it is a simple matter to derive the 5 V supply voltage from the mains. The voltage across the triac will always be sufficient, even when the load is fully dimmed. The combination D₄-C₁₄-R₂₀

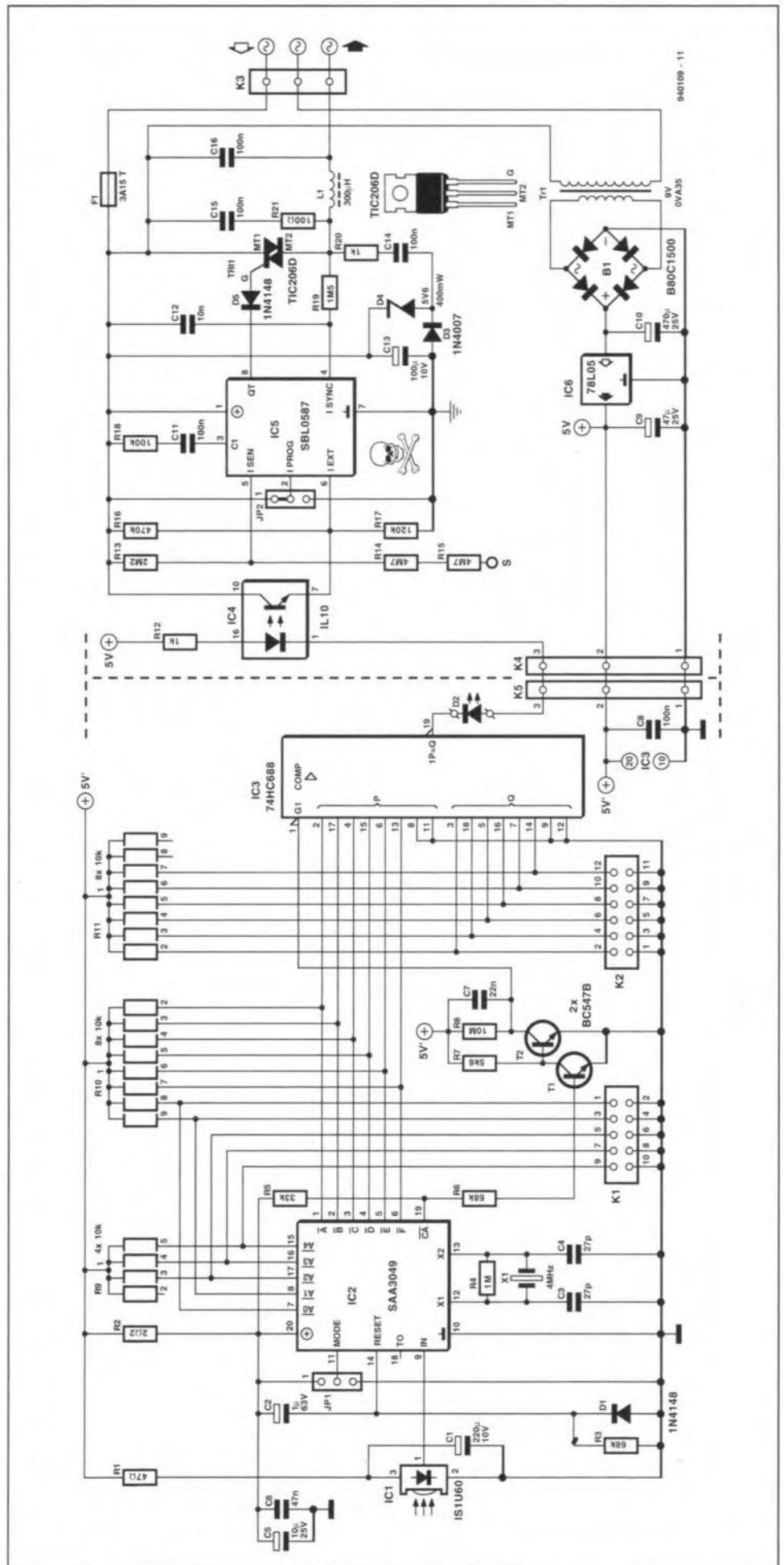


Fig. 1. The circuit diagram of the infra-red remote controlled dimmer consists of two parts: the left-hand side shows a sensitive infra-red receiver, and the right-hand side an intelligent dimmer circuit based on phase angle control.

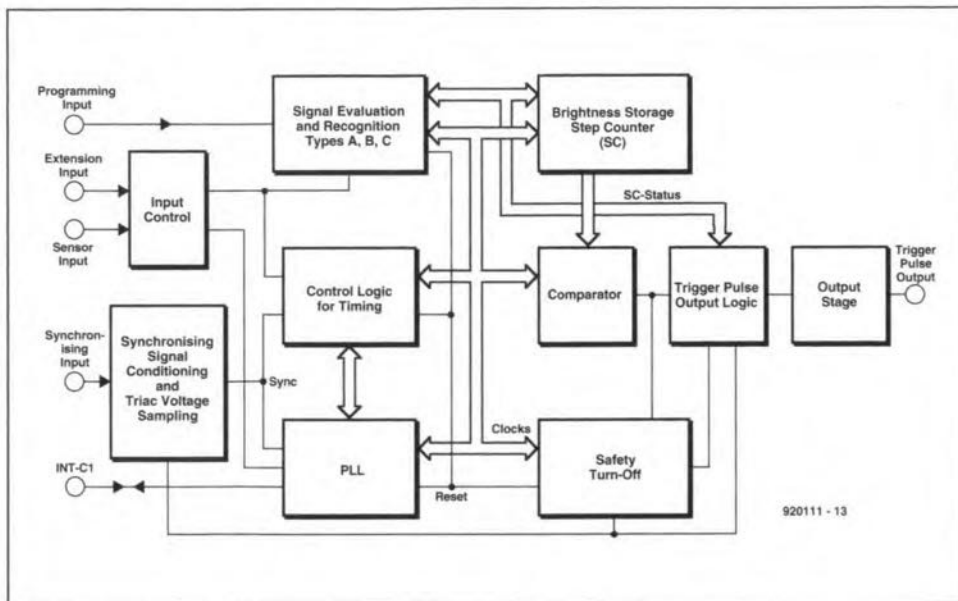


Fig. 2. Block diagram of the SLB0587 intelligent dimmer integrated circuit from Siemens.

derives a voltage of about 5 V from the mains, and is smoothed by C_5 . Diode D_3 chops off the negative half-periods. The current consumption of the SLB0587 is only 2 mA.

In addition to the external control input to which the phototransistor is connected (pin 6), IC₅ also has a sensor input which allows the lamp brightness to be controlled with the aid of a touch-key. This sensor, which takes the form of a metal plate together with two 4.7-M Ω series-connected resistors, functions only if the 'live' (L) wire is connected to fuse F_1 .

Of the other components around IC₅, R_{18} and C_{11} determine the response of the internal PLL. The status of the triac is monitored via R_{19} , which also serves to synchronize the PLL to the mains frequency. L_1 and C_{16} remove high-frequency components from the signal so that the mains lines remain reasonably clean, while network C_{15} - R_{21} limit fast voltage transients which would otherwise endanger the life of the triac. Finally, there is triac Tri_1 , a TIC206D, which switches the mains voltage on and off. Diode D_5 ensures that the gate of the triac is driven with negative pulses only by the SLB0587. Without a heat-sink, the triac is capable of controlling loads up to about 200 W. At higher powers (up to about 700 W) the device has to be fitted with a small heat-sink.

The control characteristic of the SLB0587 may be described as follows. If the touch-key or the button on the remote control is briefly operated (50-400 ms), the dimmer is switched on or off. Operating one of these controls longer than about 400 ms causes a dimming cycle to be started. The length of a complete cycle (for instance, from off to maximum bright-

ness) is about 7.6 s. The touch-key or remote control button is released when the desired lamp brightness is reached. Depending on the voltage at pin 2 (which can be defined with the aid of a jumper), there are three modes of operation:

- (1). Pin 2 connected to ground. When the dimmer is switched on, the lamp is powered at maximum brightness. Dimming starts at minimum brightness, and is then controlled up and down continuously. After releasing the button on the control, the dimming 'direction' is the same as with the previous dimming operation.
- (2). Pin 2 open-circuited. The IC memorizes the set brightness, which is called up automatically when the dimmer is switched on again. The dimming 'direction' is reversed each time the button is released.
- (3). Pin 2 connected to the supply voltage. As with mode (1), the dimmer switches to maximum brightness when it is powered up. As with mode (2), the dimming 'direction' is reversed each time the button is released.

In all three modes, a single button is, therefore, sufficient to dim a lamp as well as to switch it on and off.

Construction

The printed circuit board shown in Fig. 3 consists of two sections. The component allocation corresponds to the division indicated in the circuit diagram. After separating the two sections (with the aid of a jig-saw), you can start mounting the components. Some parts are mounted upright as in-

dicated on the component overlay. Do not forget the wire links on the smaller board, particularly those under IC₂. Also make sure that PCB terminal block K3 is not taller than Tr_1 and L_1 . For the rest, the construction is all pretty straightforward soldering work. Connector K₅ is a three-pin PCB header which is mounted upside down so that the long pins protrude from the underside of the board. As illustrated in Fig. 4, the exact connections of the IR sensor depends on the type used (Sharp or Siemens).

The enclosure is a type with a moulded mains plug at one side, and a mains socket at the other. The larger board is fitted on to the bottom plate of the case, in such a way that the optocoupler is above the mains plug. Do not secure the board yet, because the mains wiring still needs to be installed. The smaller board is then fitted on top of the optoisolator section of the larger board with the aid of two 2-cm long PCB mounting pillars. The boards are interconnected with three isolated wires with a length of about 5 cm. If the boards are in position, these wires cross straight from connector K₄ to K₅. Drill a small hole in the cover for indicator LED D_2 , and a larger hole to enable the lens of the IR sensor to 'see' the transmitted signal. Depending on the position of this hole, the sensor may have to be bent 90°.

If you want to fit the touch control as well, mount a decorative nail or a miniature wander ('banana') socket into the cover. The touch control is connected to terminal 'S' on the large board. If you want to play it absolutely safe as regards the mains voltage, connect resistor R_{15} directly to the sensor, and use a short length of insulated wire to connect through to R_{14} on the board. In the unfortunate event of the wire coming loose in the case and touching a part at mains potential, there is always R_{15} to protect you against the risk of an electrical shock.

Finally, install the mains wiring. The earth pin of the plug is connected directly to the earth pin of the socket. Next, the live and neutral pins are connected to the centre and outer pin of the PCB terminal block, at the side of the fuse. The remaining pin and the centre one are then connected to the live and neutral pins of the moulded socket. Once this wiring is fitted, the boards may be secured in the case.

The circuit is then nearly ready for use. All that remains to be done is to fit the jumpers and close the case. Also program the system address of the remote control you wish to use (K₁), and the button you wish to use (K₂). On K₁, an installed jumper represents a '0', while on K₂ it represents a '1'. Both patterns are set in binary coding. In most cases, a TV remote control will be

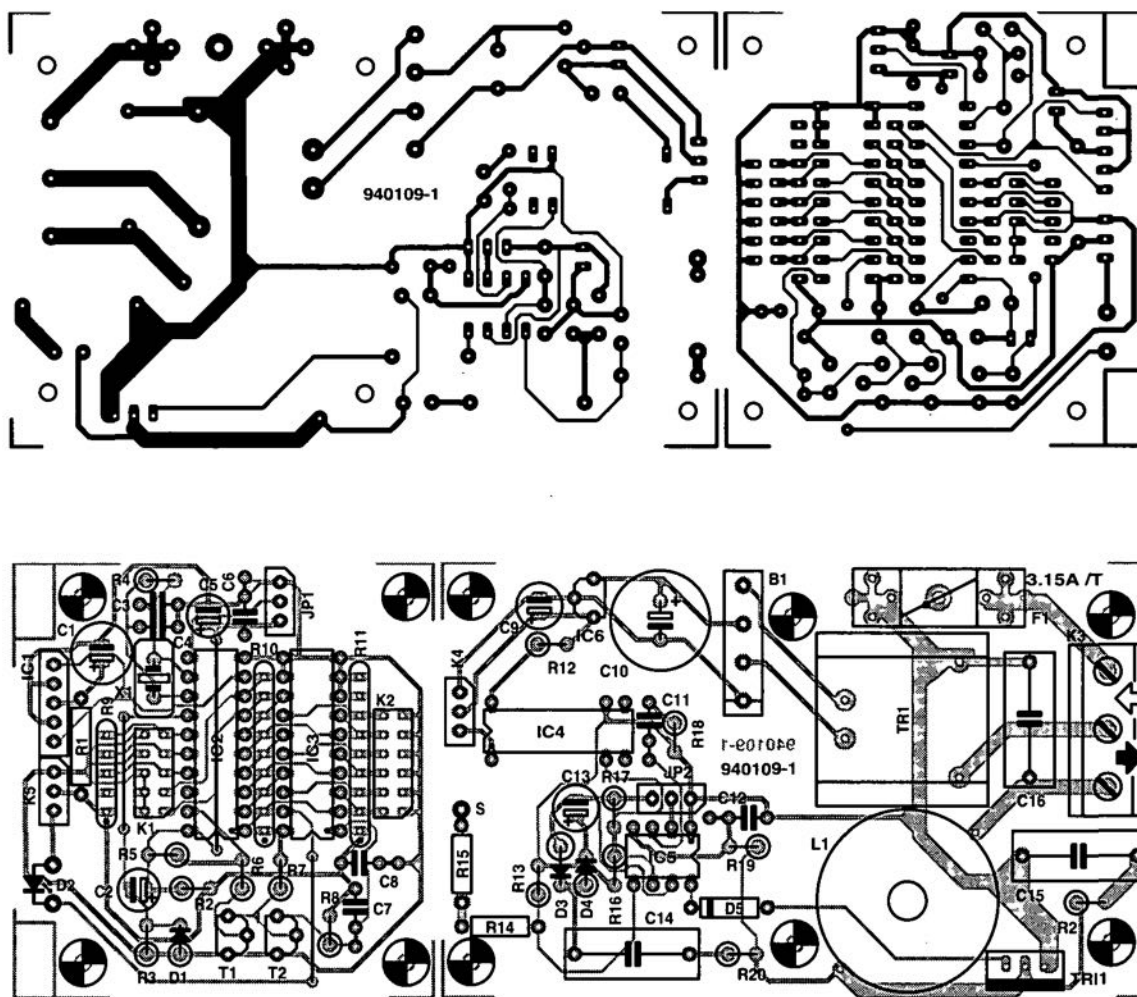


Fig. 3. The printed circuit board (available through the Readers Services) consists of two parts, which are separated by cutting.

COMPONENTS LIST

Resistors:

- R1 = 47 Ω
- R2 = 2Ω
- R3,R6 = 68kΩ
- R4 = 1MΩ
- R5 = 33kΩ
- R7 = 5kΩ
- R8 = 10MΩ
- R9 = 4x10kΩ -array SIL
- R10,R11 = 8x10kΩ array SIL
- R12,R20 = 1kΩ
- R13 = 2MΩ
- R14,R15 = 4MΩ
- R16 = 470kΩ
- R17 = 120kΩ
- R18 = 100kΩ
- R19 = 1MΩ
- R21 = 100Ω

Capacitors:

- C1 = 220μF 10V radial
- C2 = 1μF 63V radial
- C3,C4 = 27pF
- C5 = 10μF 25 V radial

- C6 = 47nF
- C7 = 22nF
- C8,C11 = 100nF
- C9 = 47μF 25V radial
- C10 = 470μF 25V radial
- C12 = 10nF
- C13 = 100μF 10V radial
- C14-C16 = 100nF 250 VAC (630 VDC)

Inductors:

- L1 = 300μH 3A

Semiconductors:

- D1,D5 = 1N4148
- D2 = low current LED (red)
- D3 = 1N4007
- D4 = 5.6 V 0.4 W zener diode
- B1 = B80C1500
- T1,T2 = BC547B
- Tri1 = TIC206D
- IC1 = IS1U60 (or SFH506-36, SFH505)
- IC2 = SAA3049 (Philips)
- IC3 = 74HC688
- IC4 = IL10 (or CNY65)

- IC5 = SLB0587 (Siemens)
- IC6 = 78L05

Miscellaneous:

- JP1,JP2 = 3-way pin header with jumper
- K1 = 10-way pin header with 5 jumpers
- K2 = 12-way pin header with 6 jumpers
- K3 = 3-way PCB terminal block, 7.5 mm raster
- K4,K5 = 3-way connector (SIL)
- X1 = 4 MHz crystal
- Tr1 = mains transformer, sec. 9 V/0.35 VA (e.g.. Hahn BV200009)
- F1 = fuse 3.15 AT + PCB mount holder 1 case (with moulded mains plug and socket)
- Printed circuit board 940109-1 (see page 78).

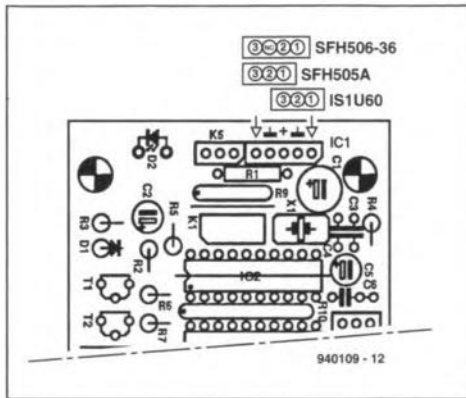


Fig. 4. The circuit is suitable for use with three different types of infrared receiver, two from Siemens (SFH types) and one from Sharp (IS1 type). These devices are connected as shown here.

used, whose system address is 0 (five jumpers installed on K₁). For instance, if you decide to use the 'mute' button to control the infrared dimmer, this corresponds to address 13. Consequently, jumpers have to be fitted on rows 1, 3 and 4 of connector K₂ (13= binary 8+4+1). The table opposite shows the button codes as standardized for RC5 (Philips/Sony) remote controls. Finally, a jumper is fitted in position JP₁ to select the type of infrared code used (RC5: jumper to ground).

(940109)

Reference:

1. General-purpose IR volume control, *Elektor Electronics* July/August 1994.

RC5 CODES, COMMANDS AND SYSTEM ADDRESSES

Address	System component
0	TV set 1
1	TV set 2
2	Teletext
5	video recorder 1
6	video recorder 2
8	Satellite TV receiver 1
10	Satellite TV receiver 2
12	Compact Disc/Video player
14	Photo CD player
16	Audio preamplifier 1
17	Radio receiver
18	Analogue cassette recorder
19	Audio preamplifier 2
20	Compact disc player
21	Audio rack or recording apparatus

Common commands for all addresses

Command	Description
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
16	volume +
17	volume -
18	brightness +
19	brightness -
22	bass +
23	bass -
24	treble +
25	treble -

26	balance right
27	balance left
63	system select
77	linear function incr.
78	linear function decr.
80	step up
81	step down
82	menu on
83	menu off
84	disp. A/V syst. status
85	step left
86	step right
87	acknowledge

Commands for TV 1 and TV2

Command	Description
10	1/2/3 digits 10
11	freq./prog./ch./11
12	standby
13	mute/de-mute
14	personal pref.
15	display
20	colour saturation +
21	colour saturation -
28	contrast +
29	contrast -
30	search +
31	tint/hue -
32	ch./prog. +
33	ch./prog. -
34	Altern./ch.
35	1/2 language
36	spatial stereo
37	stereo/mono
38	sleep timer
39	tint/hue +
40	RF switch
41	store/execute/vote
42	time
43	scan fwd./incred.
44	decrement
46	sec. con/menu
47	show clock
48	pause
49	erase/correct
50	rewind
51	go to
52	wind
53	play
54	stop
55	record
56	external 1
57	external 2
59	advance
60	TXT sub-mode/12
61	sys. standby
62	crispener
70	speech/music
79	sound scroll
104	PIP size
105	pic. scroll
106	act. on/off
107	red
108	green
109	yellow
110	cyan
111	index/white
112	next
113	previous
122	store open/close
126	movie expand
127	parental access

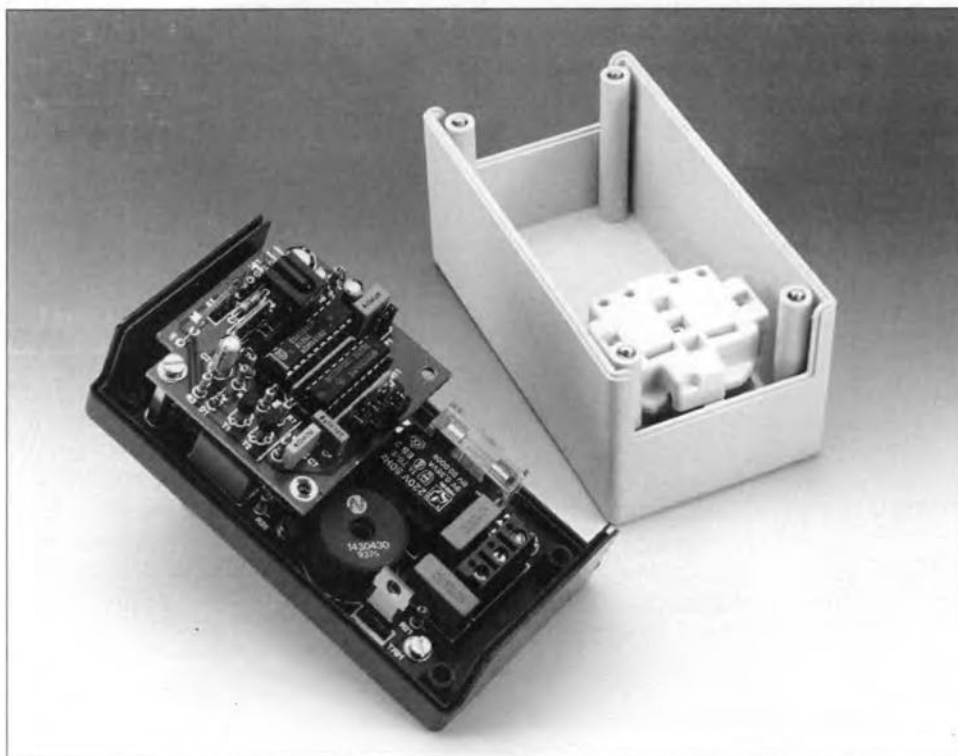


Fig. 5. Prototype just before final assembly. The rear side of the moulded mains socket in the fits in the free space above the dimmer board.

GOVERNOR FOR INDUCTION MOTORS

Design by H. Bonekamp

The induction motor may be regarded as practically a constant-speed machine: the difficulty of varying its speed economically constitutes one of its main disadvantages. This drawback is overcome by the circuit described here: it enables the speed to be lowered in small steps.

A.C. motors have the great advantages of being relatively inexpensive and very reliable. Induction motors in particular are very robust and therefore used in many domestic appliances such as washing machines, vacuum cleaners, water pumps, and others.

In an induction motor, the higher the speed of the rotor, the lower is the speed of the rotating field relative to the rotor winding and the smaller is the e.m.f. generated in the latter. Were the speed of the rotor to attain the synchronous value, the rotor conductors would be stationary relative to the rotating flux. There would then be no e.m.f. and no current in the rotor conductors and consequently no

torque on the rotor. Thus, the rotor could not continue rotating at synchronous speed. As the rotor speed falls more and more below the synchronous speed, the values of the rotor e.m.f. and current, and therefore of the torque, would continue to increase until the latter is equal to that required by the rotor losses and by any load there may be on the motor.

The speed of the rotor relative to that of the rotating flux is called the *slip*. For torques varying between zero and the full-load value, the slip is practically proportional to the torque. It is usual to express the slip either as a per-unit or fractional value or as a percentage of the synchronous speed:



$$\text{per-unit slip} = (n_1 - n_r) / n_1,$$

and

$$\text{percentage slip} = (n_1 - n_r) / n_1 \times 100,$$

where n_1 is the synchronous speed and

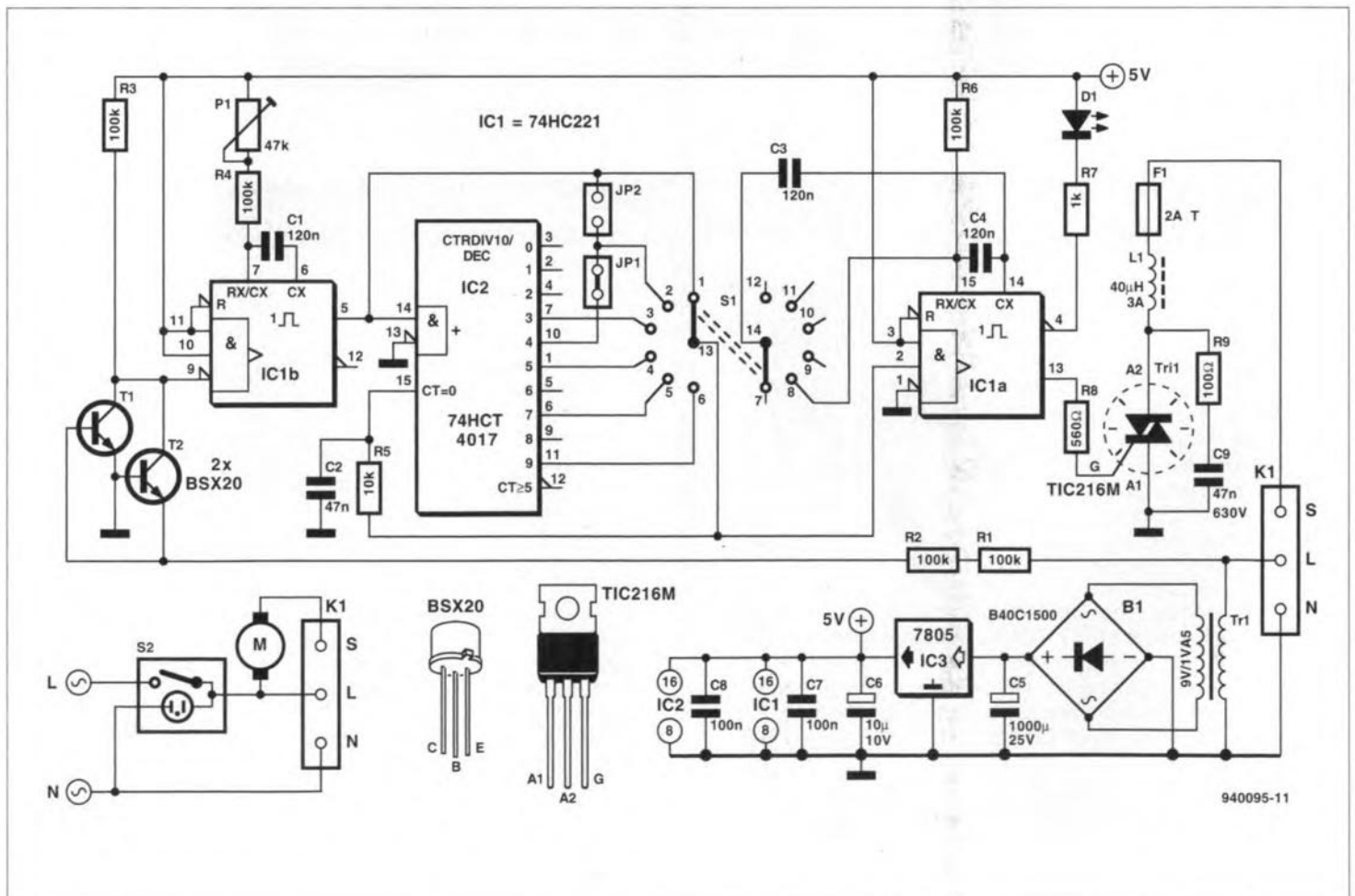
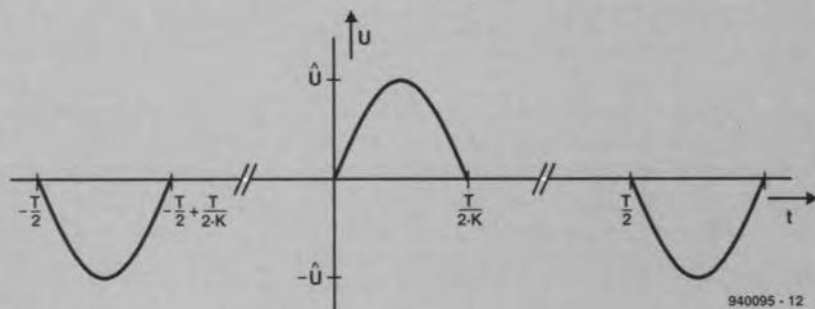


Fig. 1. Circuit diagram of the induction motor governor.

Frequency spectrum of signal with reduced frequency



The output signal of the governor can be dissected by Fourier analysis. In the following analysis the frequency-reduction factor is k (which in the present design may have a value of 3, 5, 7 or 9).

The signal is

$$u(t) = \sum_{n=0}^{\infty} \left\{ a_n \cos\left(\frac{2\pi}{T} nt\right) + b_n \sin\left(\frac{2\pi}{T} nt\right) \right\}$$

or

$$u(t) = \sum_{n=0}^{\infty} \left\{ a_n \cos\left(\frac{2\pi f_0}{k} nt\right) + b_n \sin\left(\frac{2\pi f_0}{k} nt\right) \right\}$$

where $f = f_0/k$ and $T = kT_0$.

Since the signal is shift-symmetrical, ($u(t) = -u(t-T)$), it consists of sinusoidal as well as cosinusoidal voltages. This symmetry makes the computation of the components much simpler, since integration over a half period is all that is needed. Since over a full period of the signal, as far as area is concerned, is the same above and below the x -axis, the direct voltage component is zero.

Components a_n and b_n are

$$a_n = \frac{4}{T} \int_0^{T/2k} U \sin\left(\frac{2\pi}{T} kt\right) \cos\left(\frac{2\pi}{T} nt\right) dt$$

$$b_n = \frac{4}{T} \int_0^{T/2k} U \sin\left(\frac{2\pi}{T} kt\right) \sin\left(\frac{2\pi}{T} nt\right) dt$$

From these expressions the spectrum of the signal reduced in frequency is calculated.

The **amplitude spectrum** is

$$c_n = \left| 4 \frac{U}{\pi} \cdot \frac{k}{k^2 - n^2} \cdot \cos\left(\frac{n}{2k} \pi\right) \right| \quad (n \gg k \text{ and } n = \text{odd})$$

or

$$c_n = U/k \quad (n = k \text{ and } n = \text{odd})$$

The **phase spectrum** is

$$\Phi_n = a \tan \left\{ \cot\left(\frac{n}{2k} \pi\right) \right\} \quad n = \text{odd}$$

As an illustration of the above (for those who do not like too many calculations), the amplitude of the computed frequency components for a reduction factor of 3 is shown in **Fig. 2**.

n_r is the rotor speed. Note that the synchronous speed = f/p , where f is the frequency of the applied voltage (mains) and p is the number of pairs of poles of the stator.

The value of the slip at full load varies from about 6% for small motors to about 2% for large machines. This shows that, as already stated, the induction motor is practically a constant-speed machine.

Governing the speed

Since the speed of the motor depends primarily on the frequency of the applied voltage (normally the mains voltage), it is readily governed by altering the frequency. This is not so simple, however, because the mains frequency is internationally agreed to be 50 Hz (Europe and most parts of the world, except the USA and Canada where it is 60 Hz). Before the upsurge of electronics, complex techniques (such as the Ward-Leonard circuit for 3-phase motors) were developed to govern the speed of a.c. motors. With the aid of electronics, however, it becomes far less complex. The present circuit enables the frequency to be lowered as desired by a factor $1/2, 1/3, 1/5, 1/7$ or $1/9$. Greater precision is not necessary since the speed varies in any case as a function of the load. The factor $1/2$ should be treated with some circumspection since during tests by the designer some motors did not respond well to this reduction.

The circuit diagram of the governor is shown in **Fig. 1**. The circuit uses standard, inexpensive components. The mains as well as the motor is connected to K_1 . The mains voltage is reduced by resistors R_1 and R_2 and then applied to transistors T_1 and T_2 . Transistor T_1 is on during the positive half period of this voltage and T_2 during the negative half. The instant at which the transistors begin to conduct determines the width of the pulse at pin 9 of IC_{1b}. This instant depends to a large extent on the values of R_1 and R_2 . In the

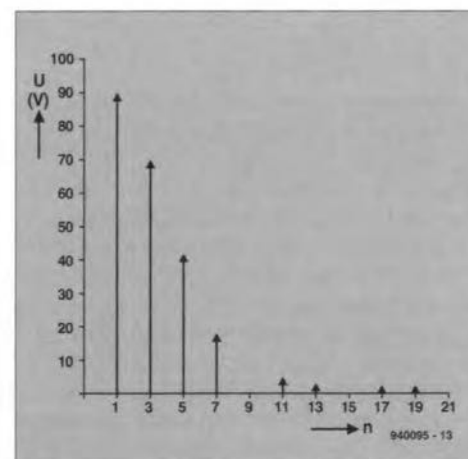


Fig. 2. Amplitude vs motor speed of the frequency components generated when the reduction factor is 3.

present design, these values are low, but the transistors are fast switching types. This results in narrow, positive pulses with steep edges that occur exactly at the zero crossing point.

These pulses, which are synchronous with the mains frequency, trigger monostable IC_{1b}. This is not retriggerable and its mono time is set to just below 10 ms with P₁. This arrangement ensures that spurious pulses can not, or hardly, enter the circuit. In fact, this can happen only when the monostable is inactive, which is when the mains is going through its zero crossing. An RC filter can not be used for the suppression of spurious pulses because this would create phase shifts that would be more troublesome than these pulses. As it is, the circuit provides clean trigger pulses at a frequency of 100 Hz at pin 5 of IC_{1b}.

The mains frequency can be made variable by a special arrangement, here provided by IC₂. In this arrangement, whole periods of the mains voltage are suppressed regularly. This results in a lower mains frequency – see the Fourier analysis in the box, on the previous page. In this box, the composition of the signal is derived for the reduction factors used with the exception of $1/2$. **Table 1** shows how the periods of the sine wave are suppressed. A + indicates that the positive half of a period is applied to the motor and a – that the negative half is applied to the motor; a 0 indicates that the motor is not connected to the mains.

Circuit IC₂ counts the incoming clock pulses. After a reset, output Q₀ is active, after one clock pulse, Q₁, and so on. Assume that rotary switch S₁ is in position 1. Every time a trigger pulse arrives, it is applied to the B input of IC_{1a} via S_{1a}. It also arrives at the reset input of IC₂ via delay network R₅-C₂. This delay is necessary to ensure that the signal is applied to the monostable during t_{hold}. This is actually of importance only when the rotary switch is in positions 2–6. At the instant that a pulse arrives at the B input of IC_{1a}, the monostable is triggered. Its Q output is then high for about 8 ms, which causes triac Tr₁ to conduct. At the same time D₁ lights. Because of the ignition pulse, the motor is connected to the mains for the instantaneous half period. Once the triac has fired, it remains on until the current through it drops below the hold level. In practice this means that, owing to the lagging current, the triac remains on for a short instant after the mains has gone through a zero crossing.

With S₁ in position 1, all trigger pulses are passed on, so that the triac is on permanently and the motor runs at maximum speed. Network R₉-L₁-C₉ suppresses any spurious pulses and prevents any likelihood of the triac going into spontaneous conduction.

When S₁ is in positions 3–6, the number of clock pulses, that is, half periods,

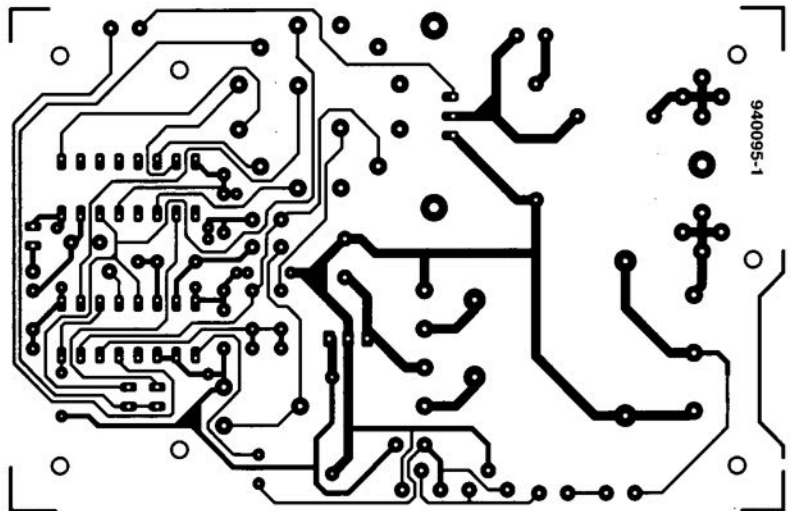
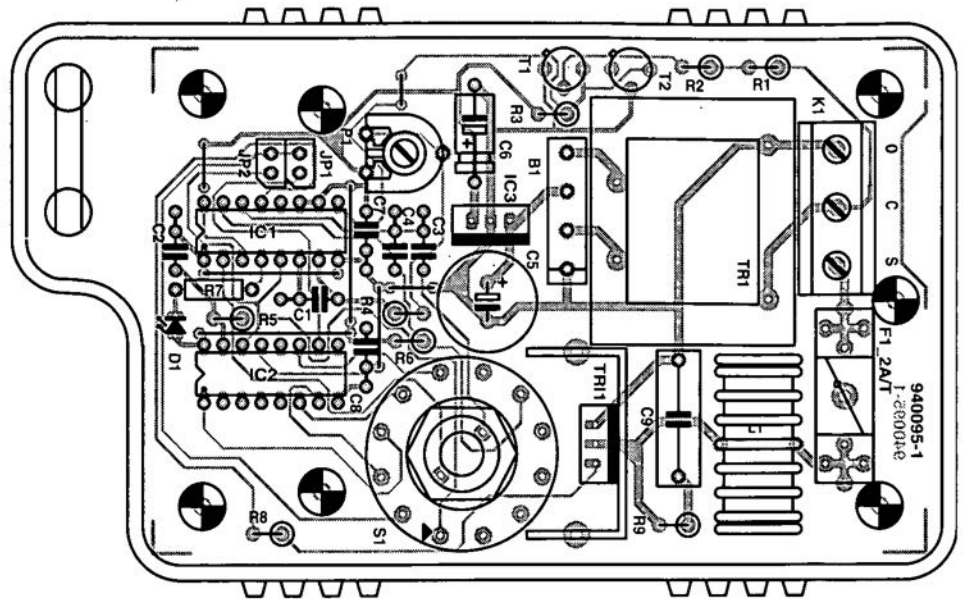


Fig. 3. Printed-circuit board for the induction motor governor.

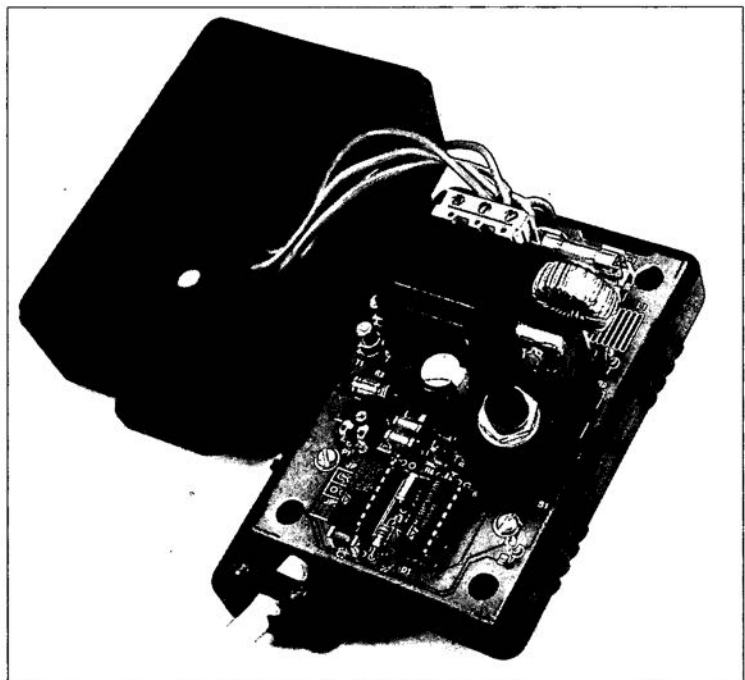


Fig. 4. Completed prototype of the governor.

that needs to be received before the triac begins to conduct, is 2, 4, 6 or 8 respectively. Position 2 of S_1 is a special one. Only in that position does the second wafer of the switch have a function. This consists of connecting C_3 and C_4 in parallel which results in a lengthening of the output pulse from 8 ms to 16 ms. In practice, this means that whole, alternate periods of the mains voltage are applied to the motor. During tests on prototypes, it was found that some motors do not function properly in this situation. Therefore, jumpers J_{p1} and J_{p2} have been provided to disable this setting of the switch. When J_{p2} is closed and J_{p1} open, and C_3 removed, positions 1 and 2 of S_1 are identical. The motor then runs at full speed.

Power for the circuit is provided by transformer Tr_1 , bridge rectifier B_1 and voltage regulator IC_3 . Note that the ground connections of the circuit must NOT be linked to mains earth, since they are connected to the Neutral line.

Construction

The circuit is intended to be built on the printed-circuit board shown in **Fig. 3**. Populating this is straightforward, but note that the triac must be fitted on a heat sink via a ceramic washer.

Since parts of the circuit are linked directly to the mains, the unit must be fitted in a synthetic fibre case (plastic, ABS). It is strongly recommended to connect the motor permanently to the governor (K_1). In many applications, this is in any case the most convenient. The photo of **Fig. 4** shows how this is all accomplished.

The red or brown wire of the mains lead must be connected to pin L(ive) and the blue or black wire to N(eutral). As stated before, the ground of the circuit must NOT be connected to mains earth (E). The motor must be connected between L and S(witched). A double-pole mains switch with integral neon indicator is recommended.

Do not connect the motor to the circuit before this has been set up correctly. This is to prevent direct current flowing through the motor, which does not do it any good.

Setting up the circuit is done with the aid of the LED on the board. Note that this diode MUST be fitted on the board and NOT on the enclosure, since it is connected to the mains and its coloured plastic lens does NOT provide sufficient protection.

Set S_1 to position 1 and turn P_1 from one end of its travel to the other. At some point, the LED will turn from flashing to lighting permanently. The preset should be set a little past that position. In switch positions 2-6 the LED will always flash, but at a rate that is different for each position.

Finally, connect the motor to the circuit and close the case.

There is a very small risk that the motor you are using is not suitable for use with the present governor. This manifests itself by the motor getting very hot. This is caused by the core becoming saturated, which results in very high currents. It is not possible to say beforehand whether a motor is suitable or not, but, as already stated, the risk of it happening is very small, indeed.

Parts list

Resistors:

R_1 - R_4 = 100 k Ω
 R_5 = 10 k Ω
 R_7 = 1 k Ω
 R_8 = 560 Ω
 R_9 = 100 Ω
 P_1 = 47 k Ω preset

Capacitors:

C_1 , C_3 , C_4 = 120 nF
 C_2 = 47 nF
 C_5 = 1000 μ F, 25 V, radial
 C_6 = 10 μ F, 10 V
 C_7 , C_8 = 100 nF
 C_9 = 47 nF, 630 V

Inductors:

L_1 = 40 μ H, 3 A

Semiconductors:

D_1 = LED, high efficiency
 B_1 = B40C1500 bridge rectifier
 T_1 , T_2 = BSX20
 Tri_1 = TIC216M

Integrated circuits:

IC_1 = 74HC221
 IC_2 = 74HC4017
 IC_3 = 7805

Miscellaneous:

J_{p1} , J_{p2} = jumper (wire bridge)
 K_1 = 3-way terminal strip, pitch 7.5 mm
 S_1 = 2-pole, 6-way rotary switch
 S_2 = single-pole, single-throw switch with integral neon lamp
 Tr_1 = mains transformer with 9 V, 1.5 A secondary, e.g. Velleman 1090018M (from Maplin)
 F_1 = fuse holder for PCB mounting with 2 A slow fuse
 1 off heat sink for Tri_1 20 K W⁻¹
 1 off non-metal enclosure 75×126×53 mm (3×5×2¹/₁₆ in)
 PCB Order no. 940095-1

[940095]

t/n	1	1/2	1/3	1/5	1/7	1/9
0	+	+	+	+	+	+
1	-	-	0	0	0	0
2	+	0	0	0	0	0
3	-	0	-	0	0	0
4	+	+	0	0	0	0
5	-	-	0	-	0	0
6	+	0	+	0	0	0
7	-	0	0	0	-	0
8	+	+	0	0	0	0
9	-	-	-	0	0	-
0	+	0	0	+	0	0
1	-	0	0	0	0	0
2	+	+	+	0	0	0
3	-	-	0	0	0	0
4	+	0	0	0	+	0
5	-	0	-	-	0	0
6	+	+	0	0	0	0
7	-	-	0	0	0	0
8	+	0	+	0	0	+
9	-	0	0	0	0	0

Table 1. Illustrating how the half sinusoidal periods are switched as a function of the delay.